# AQUATIC RESOURCES OF THE LOWER AMERICAN RIVER: BASELINE REPORT

**DRAFT**

PREPARED FOR:

**Lower American River Fisheries And Instream Habitat (FISH) Working Group**

PREPARED BY:

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# PREFACE

The *Aquatic Resources of the Lower American River: Baseline Report* (*Baseline Report)* provides a foundation upon which to build the initial *Fisheries and Aquatic Habitat Management and Restoration Plan for the Lower American River* (the "FISH Plan"). The FISH Plan, as has been discussed previously, will serve as both: (a) the Aquatic Habitat Management Element of the *River Corridor Management Plan for the Lower American River* (expected out in summer 2001); and (b) the Habitat Management Element (HME) of the Water Forum Agreement.

Draft sections of the *Baseline Report,* provided herein, have been developed for review by the Lower American River Fisheries and Instream Habitat (FISH) Working Group, and the FISH Working Group's Technical Subcommittee. The enclosed document summaries and presents key data/information regarding the aquatic resources and associated habitats of the lower American River, and provides essential background information necessary to support development of the FISH Plan, including specific restoration and management actions.

Draft sections of the *Baseline Report* have been reviewed by the FISH Working Group and the FISH Working Group's Technical Subcommittee. Additional analyses have been suggested by the Technical Subcommittee in order to enhance the overall informational value of the document. At this time, a number of supplementary analyses are still being conducted to accommodate these suggestions. This work includes several evaluations to better ascertain the relationships between physical habitat parameters and biological indices related to lifestage history and in-river production of fall-run chinook salmon and steelhead in the lower American River. Results of these analyses will be reflected in revisions in a subsequent draft of the report. The entire *Baseline Report*, when complete, will include a summary of findings for each resource, a discussion of data limitations, and recommendations for directed research.

Your comments and input on this current version of the draft *Baseline Report* are sought at this time. Please submit comments to Susan Davidson, Water Forum, no later than **March 30, 2001**.

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# 1.0 INTRODUCTION

A comprehensive, broadly supported river corridor management plan is being sought for the lower American River. Such a plan is needed by numerous interests including CALFED, the Sacramento Area Water Forum (Water Forum), Sacramento Area Flood Control Agency (SAFCA), the Lower American River Task Force (LAR Task Force), and the Sacramento County Department of Regional Parks, Recreation, and Open Space.

In January 2000, CALFED provided partial funding to create a multi-agency river corridor management plan for the lower American River that would incorporate CALFED objectives for ecosystem restoration along the lower American River (CALFED Bay-Delta Restoration Project 99-B157). Additional funding was provided by the sponsoring agencies responsible for development of the River Corridor Management Plan (RCMP) including SAFCA and the Sacramento City-County Office of Metropolitan Water Planning (CCOMWP).

The proposed RCMP will create the necessary planning framework and consensus building process by which ecosystem restoration along the lower American River can be achieved, within the context of the river's multiple use functions. Specifically, the development of the RCMP for the lower American River has two main objectives: (1) to establish scientific consensus among biologists, resource managers, and other technical experts concerning the resources of the lower American River ecosystem and the priorities for restoration and recovery actions; and (2) to provide an integrated planning framework to identify, prioritize, define and implement restoration actions in the lower American River.

The RCMP is to be based on information and recommendations made from four working groups of the LAR Task Force including the Fisheries and Aquatic Habitat Working Group (FISH Group), the Floodway Management Working Group (FMWG), the Bank Protection Working Group (BPWG), and the Recreation Management Working Group. Coordination also is occurring with the [Folsom] Reservoir Operations Working Group (ROWG) through overlapping membership. The RCMP will have three major components: (1) the Fisheries and Aquatic Habitat Element; (2) the Floodway Management Element; and (3) the Recreation Management Element. It will build upon several efforts to manage the river for multiple beneficial uses, including those undertaken by the California Department of Fish & Game (CDFG), the Water Forum, the LAR Task Force, and previous LAR Technical Committee Workshops. The FISH Group is developing the Fisheries and Aquatic Habitat Element. The Floodway Management Element is being prepared and managed jointly by the FMWG and BPWG, while the Recreation Management Element is being developed by the Recreational Management Working Group.

The charge of the FISH Group is: (1) to develop an initial fisheries and aquatic habitat management and restoration plan for the lower American River (the FISH Plan), which will serve as the Fisheries and Aquatic Habitat Element of the RCMP and the Habitat Management Program of the Water Forum Agreement; and (2) to provide strategic advice to proponents of lower American River fish and aquatic habitat management and restoration projects who seek "early start" status for their individual projects.

The FISH Plan will focus on five fish species of priority management concern including fall-run chinook salmon, steelhead, splittail, American shad, and striped bass. Special emphasis will be placed upon the first three of these species to facilitate compliance with applicable laws, particularly, the federal Endangered Species Act (ESA) and the California Endangered Species Act (CESA), and to be consistent with state and federal restoration plans. This focus is consistent with: (1) CALFED's 1999 *Ecosystem Restoration Program Plan* (ERPP); (2) U.S. Fish & Wildlife Service's (USFWS) 1997 Draft *Anadromous Fish Restoration Program*, which identifies specific actions on the lower American River to protect anadromous salmonids; (3) CDFG's 1996 *Steelhead Restoration and Management Plan for California*, which identifies specific actions on the lower American River to protect steelhead; and (4) CDFG's *Restoring Central Valley Streams, A Plan for Action* (1993), which identifies specific actions on the lower American River to protect salmonids. Improvement of habitat conditions for these species of priority management concern will likely protect or enhance conditions for other fish resources, including native resident species.

A key component in the development of the FISH Plan is the collation and distillation of all information/data for the lower American River associated with the five priority species. While the primary focus of the FISH Plan is on the fish species noted above, consideration of the various natural physical attributes, habitat elements, environmental stressors, and operational management protocols active in the lower American River also is essential in the development of any long-term restoration effort for the lower American River.

Before the FISH Plan can be developed, an assessment of the baseline conditions in the river must be made. To this end, the FISH Group has commissioned the preparation of a *Baseline Report*, which summarizes and presents available data/information about the current health of the aquatic resources and associated habitats of the lower American River. It will provide the baseline against which the effectiveness of any future restoration efforts may be measured and evaluated. The *Baseline Report* is intended to assist the FISH Group in its planning efforts for the FISH Plan. The *Baseline Report* will subsequently be summarized and disseminated to the public as a *State-of-the-River Report*.

The FISH Plan will identify ecosystem needs and stressors for the priority species and aquatic habitats of the lower American River. It also will identify and help select actions (e.g., new management actions, modifications of existing practices, restoration projects, research projects, and mitigation/conservation measures) for implementation through an Implementation Plan. The Implementation Plan will establish a timeline for restoration and management actions, identify lead agency roles and responsibilities, and identify technical assistance needed to develop, update, administer, implement, and monitor results of the FISH Plan.

A key component of the FISH Plan will be the Ecological and Biological Monitoring and Adaptive Management Plan, which will identify monitoring goals, objectives, and performance standards with which to measure the attainment of each objective. It will develop a method of measuring performance standards and identify detailed protocols for ongoing monitoring, interpreting the results of the monitoring exercise, and adjusting the applied management and restoration actions accordingly. The monitoring and adaptive management plan will contain guidelines for making adjustments as information and priorities change with respect to monitoring targets, funding priorities, and restoration techniques.

## 1.1. BACKGROUND

In December 1999, CALFED approved funding for 31 restoration projects in the Bay-Delta estuary and its watershed under the Federal Bay-Delta Act and California Proposition 204. Projects were selected from a pool of 226 proposals submitted to CALFED in April 1999. The lower American River RCMP development project was among those approved and funded.

The CALFED Bay-Delta Program is a cooperative effort among state and federal agencies and California's environmental, urban, and agricultural communities. It was initiated in 1995 to develop a long-term strategy to restore environmental health and resolve water management problems in the Bay-Delta, and its watersheds.

The lower American River and its watershed have been recognized as important components in the pursuit of CALFED's vision and objectives for ecosystem restoration. Based on the core involvement of local, State, and federal agencies, as well as business and community groups, this comprehensive RCMP will serve as the planning framework that will allow local entities to coordinate their management activities related to the lower American River and to assist CALFED in evaluating appropriate lower American River restoration actions.

Several projects are being developed for early implementation as one part of the overall RCMP. These projects include improved management of the coldwater pool in Folsom Reservoir, a new minimum flow release schedule for the lower American River, and enhanced floodplain habitat and increased SRA along specific sections of the lower river associated with flood control activities.

The RCMP will result in the following desired outcomes:

1. Improved coordination and assistance through support from multi-faceted participation including community organizations, public trust resource managers, local businesses, and local, state, and federal agencies.
2. Development of monitoring protocols and the application of adaptive management principles.
3. Improved river stewardship with improved riparian and aquatic habitat conditions, as well as improved flood management characteristics.

As an element of the RCMP, the FISH Plan will identify and prioritize opportunities for improving the health of the lower American River fish and aquatic habitats, including both new initiatives and modifications to existing management practices. It also will identify key data gaps and research efforts needed to address these gaps. An important FISH Plan component will be assessing its effectiveness through monitoring, data interpretation, and adaptive adjustments to restoration actions, as needed.

The FISH Plan will continue to be refined and upgraded over the years, as additional data regarding the health of the lower American River becomes available. In addition to serving as the aquatic habitat management element of the RCMP, the FISH Plan also is intended to serve as the Habitat Management Plan (HMP) for the lower American River as required under the Water Forum Agreement, consistent with the mitigation described and certified in the Water Forum

Agreement Environmental Impact Report and associated Mitigation, Monitoring, and Reporting Program (MMRP). Once the FISH Group has approved the FISH Plan, it will be submitted to the LAR Task Force for consideration and incorporation into the over-all RCMP.

## 1.2. PURPOSE AND INTENDED USES OF THE BASELINE REPORT

The *Baseline Report* is intended to provide the essential background information for the lower American River, necessary to support development of the FISH Plan and its specific project prescriptions to effect long-term restoration of the river and its habitats.

### 1.2.1. SCOPE OF THE BASELINE REPORT

This *Baseline Report* documents available information/data regarding the health and status of the aquatic resources and habitat of the lower American River. It serves as the baseline upon which to measure the effectiveness and long-term efficacy of any future restoration efforts as developed through the FISH Plan. This report includes published and unpublished documents on the fisheries and aquatic habitats of the lower American River.

Establishing the baseline condition requires a synthesis of work previously conducted by CDFG, USFWS, United States Bureau of Reclamation (USBR), University of California at Davis (UCD), SAFCA, CCOMWP, and the Water Forum. Particular emphasis has been placed on the numerous monitoring studies and reports prepared by CDFG.

This report presents information including historical review and discussions of the current status of the aquatic resources of the lower American River. Key resources or components of the lower American River include fish, instream habitats, riparian habitats, water quality, hydrology, and fluvial geomorphology (see Section 1.2.2, Ecosystem Processes Approach, below).

### 1.2.2. ECOSYSTEM PROCESSES APPROACH AND FISH LIFESTAGE LINKAGES

From an ecosystem perspective, the lower American River is not unlike other diverse riverine ecosystems in that the important stressors to ecosystem health include streamflow, water temperature, sediment supply, and floodplain and stream channel processes. The hydrology of the watershed, coupled with the morphometric response of the channel through numerous influences (both man-made and natural), have helped evolve the lower American River corridor into what it is today. The health of the riverine ecosystem, therefore, cannot be adequately assessed without due consideration to river hydrology, water quality, riparian ecology, and in-river geomorphological features and causal processes, as well as the existing fish resources.

In April 1997, the lower American River Technical Team identified and ranked the priority stressors for specific species including chinook salmon, steelhead, splittail, and striped bass. Stressors and rankings also were developed for lower American River habitats including shaded riverine aquatic habitat (SRA) and seasonal wetland and associated aquatic habitat. The stressors included water temperature, flow, spawning habitat, rearing habitat, water quality, water diversions, migration barriers, fish harvest practices, predation, flood control, and channel morphology. Key stressors identified included high water temperature, inadequate flow, inadequate rearing habitat in the floodplain/littoral zone and wetland sloughs, offsetting hatchery practices, and the adverse effect of Nimbus and Folsom dams.

This *Baseline Report* presents and discusses detailed information with respect to the fish resources of the lower American River. Long-term recovery and the maintenance of viable populations of the priority fish species require that a thorough evaluation of the known stressors and interrelationships to each critical lifestage be conducted.

## 1.3. RELATED/ONGOING INITIATIVES

The lower American River is a much-studied system, with the initial fish and related physical environment studies dating back to the early 1900s. Numerous project-level investigations and system-wide efforts have focused on the lower American River and its watershed. These investigations have been conducted for flood control (i.e., levee improvements), flood control operations (i.e., Folsom Dam flood control procedures), new surface water diversions, parkway plans, water management plans, and new facilities infrastructure projects (e.g., water treatment plant expansions, intake improvements, pumping facilities, etc.). Several projects and programs have ongoing or potential implications for the manner in which the lower American River is managed, the most relevant of which are described below.

### 1.3.1. CALFED ECOLOGICAL RESTORATION PROGRAM PLAN

Under CALFED's ERPP, the vision for the lower American River Ecological Management Unit focuses on restoring important fish, wildlife, and plant communities to a condition in which the status of specific resources is no longer considered to be of concern within the unit. Restoration efforts should emphasize benefits to naturally-spawning chinook salmon and steelhead populations, which co-exist with non-native American shad, striped bass, and hatchery stocks of chinook salmon and steelhead.

CALFED recognizes that several diverse actions could be implemented over a broad scale to restore and maintain sustainable, naturally spawning stocks of chinook salmon and steelhead in the lower American River, including improving seasonal flow and water temperature regimes, in-channel and riparian habitats, fishery regulations, and hatchery operations.

From an ecological perspective, the ERPP also has identified visions for several key processes in the lower American River including:

1) maintenance of streamflows in creeks to support riparian habitat and associated species;
2) re-distributing and/or supplementing gravel to continually replenish the supply of gravel needed by chinook salmon and steelhead for spawning habitat;
3) preserving natural floodplain processes by allowing winter-spring flows to overflow into riparian and wetland habitats; and
4) providing cooler spring through fall water temperatures by protecting and enhancing streamflow, enhancing riparian vegetation along creeks, reducing warmwater discharges to creeks, and reducing diversions from creeks.

From a habitat restoration perspective, the ERPP has identified several additional visions for protection and/or enhancement of seasonal wetlands, riparian and riverine aquatic habitat, freshwater fish habitat, and essential fish habitat. These visions, together with the CALFED ERPP visions for reducing known ecosystem stressors and addressing the needs of individual species (see above), is consistent with the overall intent of the RCMP and FISH Plan.

### 1.3.2. CVPIA AFRP

Section 3406(b)(1) of the Central Valley Project Improvement Act (CVPIA) of 1992 requires the Secretary of the Department of the Interior to …"*develop within three years of enactment and implement a program which makes all reasonable efforts to ensure that, by the year 2002, natural production of anadromous fish in Central Valley rivers and streams will be sustainable, on a long-term basis, at levels not less than twice the average levels attained during the period of 1967 to 1991…*".

Further, Section 3406(b)(1)(A) requires that the program…"*give first priority to measures which protect and restore natural channel and riparian habitat values through habitat restoration actions, modifications to Central Valley Project operations, and implementation of the supporting measures mandated by this subsection…"*. Moreover, this section requires that the program *"...shall be reviewed and updated every five years; and shall describe how the Secretary intends to operate the Central Valley Project to meet the fish, wildlife, and habitat restoration goals and requirements set forth in this title and other project purposes*."

The USFWS and USBR are jointly implementing the CVPIA, including Section 3406(b)(1), through development of an Anadromous Fish Restoration Program (AFRP) to address the needs of those species identified for restoration actions in the CVPIA. A total of 172 actions has been identified to meet the intent of the CVPIA, 103 of which are assumed to have a high potential for implementation in the near future. For the American River, 10 actions have been identified, with five having a high potential for near-term implementation.

For the American River, the AFRP identified the development of a riparian corridor management plan to improve and protect riparian habitat and instream cover as one potential action. Other actions include, but are not limited to, developing and implementing a river regulation plan that meets specific flow objectives, reducing and controlling flow fluctuations to avoid and minimize adverse effects on juvenile salmonids, and replenishment of spawning gravels and restoring existing spawning grounds. Each of these recommended restoration actions is consistent with the goals and intent of the RCMP and FISH Plan.

### 1.3.3. WATER FORUM AGREEMENT - HABITAT MANAGEMENT ELEMENT (HME)

The Habitat Management Element (HME) for the lower American River, combined with other elements of the Water Forum Agreement, fulfills one of the Water Forum's two coequal objectives: to preserve the fishery, wildlife, recreational, and aesthetic values of the lower American River. The HME contains five programmatic components that together address river flow, water temperature, physical habitat, and recreation issues for the lower American River. These programmatic components include the lower American River Habitat Management Plan

(HMP), Habitat Projects that Benefit the lower American River Ecosystem, Monitoring and Evaluation, Project-Specific Mitigation, and lower American River Recreation.

The HMP includes descriptions of reasonable and feasible projects that could be implemented to avoid and/or offset potential impacts to the lower American River fish and riparian resources due to the increased surface water diversions defined under the Water Forum Agreement. The HMP will identify and define the following:

1) performance standards to be used as indicators of the health of the lower American River;
2) conceptual (e.g., mitigation banking or other) and technical framework for the HMP;
3) schedule and technical assistance required for development, implementation, and monitoring of the HMP;
4) the manner with which the HMP will be coordinated with other programs, plans, initiatives, and/or mandates that affect the lower American River ecosystem;
5) logistics and responsibilities associated with administering the HMP;
6) implementation priorities, strategies, and schedules for the proposed projects;
7) lead organizations for implementation of each project;
8) the manner with which the HMP could serve as the framework for addressing ESA requirements; and
9) cost sharing obligations and specific funding commitments.

The FISH Plan will serve as the HMP for the lower American River as required under the Water Forum Agreement, consistent with the mitigation described and certified in the Water Forum Agreement Environmental Impact Report and associated MMRP. The Water Forum Agreement indicated that the HMP would be completed and adopted within 12 months of the signing of the Water Forum Agreement (April 2001).

### 1.3.4. EDF V. EBMUD

The Environmental Defense Fund (EDF) et al. vs. East Bay Municipal Utility District (EBMUD) litigation addressing the ability of EBMUD to divert from the lower American River at the Folsom South Canal concluded in 1989, but Judge Richard Hodge retained jurisdiction through the Alameda County Superior Court. One of the findings of Judge Hodge's decision ("Hodge Decision") addressed the concept of scientific uncertainty in the body of evidence, which the Judge had to review in rendering his decision. In retaining jurisdiction, the Alameda County Superior Court established a technical advisory committee and Special Water Master. The court directed that studies be conducted to reduce the level of scientific uncertainty regarding anadromous salmonid resources in the lower American River, and their environmental requirements. Studies recently completed emanating from this effort include water temperature monitoring (1991-1997), fish resources monitoring (1992-1997), Phase I gear evaluation studies, fish physiology studies (1992), chinook salmon spawning gravel evaluation (1997), aerial redd surveys (ongoing), and flow fluctuation criteria development (ongoing).

The intent of the Hodge Decision is consistent with the goals and objectives of the RCMP and FISH Plan in assessing the current health of this ecosystem and identifying areas where existing information requires augmentation.

### 1.3.5. LOWER AMERICAN RIVER OPERATIONS WORKING GROUP

An operational working group has been established for the lower American River known variously as the lower American River Operations Group (AROG), or [Folsom] Reservoir Operations Working Group (ROWG). This group includes representatives from the USBR, USFWS, NMFS, CDFG, SAFCA, Water Forum, City of Sacramento, County of Sacramento, Western Area Power Administration (WAPA), and the Save the American River Association. It generally convenes monthly with the purpose of providing input to the management of Folsom Reservoir for fish resources in the lower American River, within the confines of water availability and other operational considerations.

The USBR provides this group with data/information such as flows for the prior several months, reservoir storage, projected reservoir inflow, water temperature data, and projected outflows. The ROWG use these data and information to plan and develop the annual flow release schedule for Folsom Dam. This takes place on a monthly basis with the group adapting and refining the projected flow release schedule for the next month, and making necessary adjustments for the remainder of the year.

The ROWG not only provides input into the flow release schedule for Folsom Dam, but also into the adaptive management of the coldwater pool in Folsom Reservoir. The coldwater pool is influenced by numerous factors, not the least of which are inflow, inflow temperatures, diversions, storage, and the volume of cooler, hypolimnetic waters in the reservoir. Water temperatures in the lower American River also are influenced by these factors, as well as by decisions about which elevation to draw water for release from Folsom Reservoir into the hatchery and down the lower American River. The ROWG provides regular input regarding how best to manipulate the shutters on the power penstocks at Folsom Dam to most effectively manage the coldwater pool reserves and provide maximal thermal benefit to downstream aquatic resources.

Operational management prescriptions identified and proposed during the development of the FISH Plan are likely to be reviewed and refined by the ROWG.

## 1.4. PROJECT LOCATION

The restoration and management efforts encompassed by the FISH Plan will take place within the boundaries of the lower American River corridor (and generally within the American River Parkway). Thus, FISH Plan actions will focus on the portion of the lower American River from Nimbus Dam down to its confluence with the Sacramento River. However, it is recognized that in formulating the goals, objectives, and actions necessary to implement the FISH Plan, the Fish Group may also consider out-of-boundary habitat influences, where they directly affect the fisheries, aquatic, or riparian habitats of the lower American River.

### 1.4.1. INFLUENCE OF FOLSOM DAM OPERATIONS

Historically, over 125 miles of riverine habitat were available for anadromous fish in the American River system. In 1955, with the closure of Nimbus Dam, upstream access to anadromous fish was permanently blocked, and all anadromous fish are now restricted to the lower 23 miles of the American River extending from Nimbus Dam down to the mouth of the American River at its confluence with the Sacramento River.

Since the construction of Folsom Dam and Reservoir, the USBR has made releases from the dam legally constrained by the instream flow requirements of State Water Resources Control Board (SWRCB) Decision 893. This decision allows flows in the river during dry years to be as low as 250 cfs at the mouth, with a minimum of 500 cfs maintained between September 15 and December 31. The USBR, however, makes every attempt to release flows higher than this minimum. Subsequent SWRCB decisions (D-1400), USBR operational interpretations of those decisions (i.e., "modified" D-1400), and CVPIA initiatives (AFRP flow objectives and management of 3406(b)(2) water) have resulted in variations in flow releases. Flow releases also have been implemented in consideration of water temperature objectives consistent with ESA consultations between USBR and NMFS.

This *Baseline Report*, through its discussion of the operational management practices of Folsom Dam and Reservoir, and integration of the dam and reservoir within the larger CVP/SWP operations, provides a thorough review of existing practices, their effects on the riverine ecosystem, and proposed changes that may assist in reducing the adverse effects of the key stressors (i.e., flows and water temperatures) affecting lower American River resources.

## 1.5. CONTEXT WITHIN MULTI-PURPOSE INTEGRATED PLAN

The aim is to produce a comprehensive, broadly supported river corridor management plan for the lower American River consistent with the goals and objectives of CALFED's ERPP, SAFCA's flood protection goals, the American River Parkway Plan, the Water Forum HMP, as well as the previously mentioned state and federal planning efforts. The FISH Plan represents one of the three primary elements of this multiple function, river corridor management plan.

### 1.5.1. LOWER AMERICAN RIVER TASK FORCE

One of the goals of the LAR Task Force is to guide the preparation of a multi-objective management plan for the lower American River. Its role in this process is supported by its major objective of helping to identify opportunities for improving existing flood control facilities and management strategies along the lower American River, while protecting and enhancing existing environmental and recreational resources within the American River Parkway. Thus, the LAR Task Force, consistent with its 1994 mission statement, will review and provide recommendations throughout the development of the RCMP and its associated component elements, including the FISH Plan.

### 1.5.2. FLOODWAY MANAGEMENT ELEMENT

The Floodway Management Element of the RCMP will have three key components. The Vegetation Resource Management Program and the Facilities Redesign and Relocation Program are being developed by the Floodway Management Working Group. The Anticipatory Erosion Control Program is being developed by the Bank Protection Working Group. The Floodway Management Working Group and Bank Protection Working Group are collectively expected to identify the terrestrial habitat restoration needs and priorities of the lower American River.

The Vegetation Resources Management Program is intended to represent a master plan for riparian and terrestrial habitats that preserves flood conveyance capacity and accommodates necessary maintenance activities consistent with locally adopted recreation and open space goals for the American River Parkway. The Facilities Redesign and Relocation Program is intended to reduce the impacts of infrastructure maintenance on floodplain habitats, reduce the risk of structural damage due to flooding, and improve flood conveyance capacity of the lower American River.

The primary goal of the Bank Protection Working Group is to produce a bank protection plan that addresses potentially critical sites, while minimizing impacts to the environment by incorporating environmental features. As a secondary objective, the Bank Protection Working Group will address the management of other, less-critical sites that nevertheless are potential flood control or mitigation sites.

### 1.5.3. RECREATION MANAGEMENT ELEMENT

The Recreation Management element of the RCMP will focus on recreational use of the American River Parkway. It will identify improvements necessary to increase public access to the Parkway and enhance the recreational experience of Parkway users, while protecting the wildlife and habitat values within the Parkway. Further, this element will provide guidance regarding preserving, protecting, and restoring existing Parkway facilities, enhancing and promoting educational and interpretive activities in the Parkway, and providing for improved public safety and security within and adjacent to the Parkway.

### 1.5.4. FUTURE FISH PLAN IMPLEMENTATION

The FISH Plan component will represent scientific consensus among biologists, resource managers, and other technical experts concerning the critical needs of the aquatic species in the lower American River and priorities for restoration and recovery actions. It will identify ecosystem needs and stressors for the priority fish species and habitats of the lower American River, identify actions (e.g., new management actions, modifications of existing practices, restoration projects, research projects, and mitigation/conservation measures) for implementation, and establish a monitoring program. As noted previously, in order to effectively implement the FISH Plan on a long-term basis, adaptive management must be established as the principle process for iterative change. The FISH Plan's Ecological and Biological Monitoring and Adaptive Management Plan will incorporate appropriate metrics, monitoring protocols, and updated population census techniques. Assuming requested funding is received, this monitoring plan will be carried out over an initial three-year period. It is anticipated that CDFG personnel will be responsible for the monitoring effort, consistent with their mandate for monitoring fish population trends in the lower American River. Enhanced monitoring efforts are proposed to systematically measure the responsiveness of the priority fish populations to the early start projects under contemplation by the RCMP (through the FISH Plan).

Several projects have been developed and others are in various stages of development as part of the FISH Plan implementation process. These projects would generally be aimed at improving management of the coldwater pool in Folsom Reservoir, establishing a new minimum flow release pattern for the lower American River, enhancing floodplain habitat in the lower three miles of the river, and increasing the extent of shaded riverine aquatic habitat along the river's shorelines.

# 2.0 FISH RESOURCES

## 2.1. Historic Overview

The American River watershed has a long history of development and alteration of fish habitat and fish resources. A comprehensive overview of development in the watershed and the fish resources of the American River was provided by Gerstung (1971). Yoshiyama et al. (1996) further reviewed the historical distribution of anadromous salmonids in the Central Valley Drainage of California, including the American River. This *Baseline Report* presents a concise summary of development in the American River watershed and its historic fish resources, including excerpts taken directly from Gerstung (1971) and Yoshiyama et al. (1996). More detailed and extensive discussions can be found in these two references.

### 2.1.1. AMERICAN RIVER WATERSHED

The American River watershed is comprised of approximately 1,875 square miles (**Figure 2-1**). The watershed ranges in elevation from over 10,000 feet in the Central Sierra Nevada range, to 23 feet at the confluence of the lower American and Sacramento rivers. Most of the drainage is located in Placer and El Dorado counties. Annual runoff averages 2.7 million acre-feet.

The Middle Fork of the American River extends into the Crystal Range of the Sierra Nevada, and contributes approximately 40 percent of the total flow of the river. The North Fork is the smallest of the upper forks, contributing about 20 percent of the flow (WEF 1988). The North Fork and Middle Fork join upstream of Folsom Reservoir near the City of Auburn, whereas the South Fork joins the river at Folsom Reservoir.

### 2.1.2. ANADROMOUS SALMONID RUN COMPOSITION AND GEOGRAPHIC DISTRIBUTION

Anadromous salmonids which utilized the historically available habitat included spring-run and fall-run chinook salmon, and summer-run, fall-run and winter-run steelhead (Gerstung 1971). The chinook salmon that migrated into the upper reaches of the American River watershed were undoubtedly spring-run, whereas fall-run chinook salmon traditionally spawned in the lower reaches of the forks and in the mainstem American River. It has been estimated that the American River historically may have supported runs exceeding 100,000 chinook salmon annually, prior to habitat degradation from mining and creation of migration barriers from dam construction (Sumner and Smith 1940).

Composition of the anadromous salmonid runs in the American River has changed over time due to habitat degradation and elimination. By 1955, spring-run chinook salmon and summer-run steelhead were extirpated from the American River, and only remnant fall and winter-run steelhead, and fall-run chinook salmon remained (Gerstung 1971).

**Figure 2-1 The American River Watershed, California.**

Historically, over 125 miles of riverine habitat were available for anadromous salmonids in the American River watershed. In the North Fork American River, the 60-ft. falls at Royal Gorge (elevation 4,000 ft.) may have been the uppermost extent of salmon, and most likely was the uppermost extent of steelhead (Yoshiyama et al. 1996).

In the Middle Fork American River, chinook salmon (particularly spring-run chinook salmon, which migrated upstream during spring high flow events) likely reached the confluence with the Rubicon River (elevation 1,640 ft.). Steelhead were able to transcend the lowermost portion of the Rubicon River, and the upstream extent probably was defined by a 15-ft. waterfall located about 4-5 miles from the mouth of the Rubicon River (Yoshiyama et al. 1996).

In the South Fork American River, large numbers of chinook salmon reportedly congregated at Salmon Falls, although the falls probably did not constitute a complete upstream migration barrier. A 30-ft. waterfall at Eagle Rock (elevation 4,600 ft.) most likely comprised the upstream extent of chinook salmon distribution (Yoshiyama et al. 1996).

## 2.1.3. HABITAT DEGRADATION AND ELIMINATION

### 2.1.3.1. HYDRAULIC MINING AND SILTATION

Between 1850 and 1885, hydraulic mining deposited large amounts of sediment in the American River (Yoshiyama et al. 1996). An estimated 257 million yards of gravel, silt and debris were washed into the river from hydraulic mining (Gilbert 1917 cited in Sumner and Smith 1940). The streambed became so heavily silted that salmon were nearly extirpated in the American River (Gerstung 1971).

### 2.1.3.2. MIGRATION BARRIER CONSTRUCTION

In 1895 Old Folsom Dam, a 68-ft. high power dam, was constructed about 27 miles upstream from the mouth of the American River and prevented anadromous salmonids from reaching the forks of the river. Although a fish ladder was built for Old Folsom Dam in 1919, an effective fish ladder was not built until 1931 (Sumner and Smith 1940; Gerstung 1971). Thus, anadromous salmonids were virtually restricted to the lower 27 miles of the American River from 1895 through 1931.

In 1899 the North Fork Ditch Company constructed a 16-ft. high dam on the North Fork American River near Auburn, located a few miles downstream of the confluence with the Middle Fork American River. Although a rock chute fishway was built for the dam in 1912 that may have allowed passage for steelhead, it did not provide effective passage for salmon (Sumner and Smith 1940; Gerstung 1971).

In 1939 the 140-ft. high North Fork Debris Dam was constructed on the North Fork American River about two miles upstream of the confluence with the Middle Fork American River. Anadromous salmonid passage facilities were not provided, and this impassable barrier eliminated anadromous salmonid access to the North Fork American River (Sumner and Smith 1940).

In 1950 the fish ladder at Old Folsom Dam was destroyed by flood flows (Gerstung 1971). Thus, anadromous salmonids again were prevented from reaching the forks of the American River, and were restricted to the lower 27 miles of the American River.

In 1955 Folsom and Nimbus dams were constructed on the mainstem American River approximately 28 miles and 23 miles, respectively, upstream from the confluence with the Sacramento River. Fish passage facilities were not built at Folsom or Nimbus dams. Thus, with the closure of Nimbus Dam, upstream access was blocked and all anadromous salmonids are now restricted to the lower 23 miles of the mainstem American River extending from Nimbus Dam downstream to the confluence with the Sacramento River. This 23-mile section of the mainstem river is now referred to as the lower American River.

### 2.1.4. INSTREAM FLOWS AND TEMPERATURES

Development of the American River watershed has modified the seasonal flow and temperature patterns that occur in the lower American River. In particular, operation of the Folsom-Nimbus project significantly altered downstream flow and temperature regimes. Also, operation of Sacramento Municipal Utility District's Upper American River Project (UARP) since 1962, as well as Placer County Water Agency's Middle Fork Project (MFP) since 1967, altered inflow patterns to Folsom Reservoir.

Changes in instream flows and temperatures are briefly mentioned in this section of the *Baseline Report* because, in addition to representing upstream barriers, resultant flow and temperature changes downstream of Nimbus Dam occurred concurrently with changes in run composition and abundance of anadromous salmonids in the American River. Discussion of historic conditions for this section of the *Baseline Report* includes the periods prior to completion of Folsom and Nimbus dams (1955), and after completion of the dams up to the more recent period beginning in 1967. For a more detailed discussion of hydrology and water temperatures of the American River, see Section 3.0 of this *Baseline Report*.

Completion and operation of Folsom and Nimbus dams resulted in higher flows during fall, significantly lower flows during winter and spring, and significantly higher flows during summer (**Figure 2-2**). This change in the seasonal flow patterns downstream of Nimbus Dam is reflective of changes in inflow to Folsom Reservoir since completion of the UARP and MFP in the upper watershed. Operation of these projects has generally resulted in reduced inflow to Folsom Reservoir from early winter through late spring, and increased inflow from summer through fall.

Seasonal water temperature regimes also have changed with development in the American River watershed, particularly with construction and operation of Folsom and Nimbus dams (**Figure 2-3**). Prior to the completion of Folsom and Nimbus dams in 1955, maximum water temperatures during summer frequently reached temperatures as high as 75°F to 80°F in the lower American River (Gerstung 1971). No temperature control mechanisms, in the form of variable elevation outlet structures, were included in the original construction of Folsom and Nimbus dams.

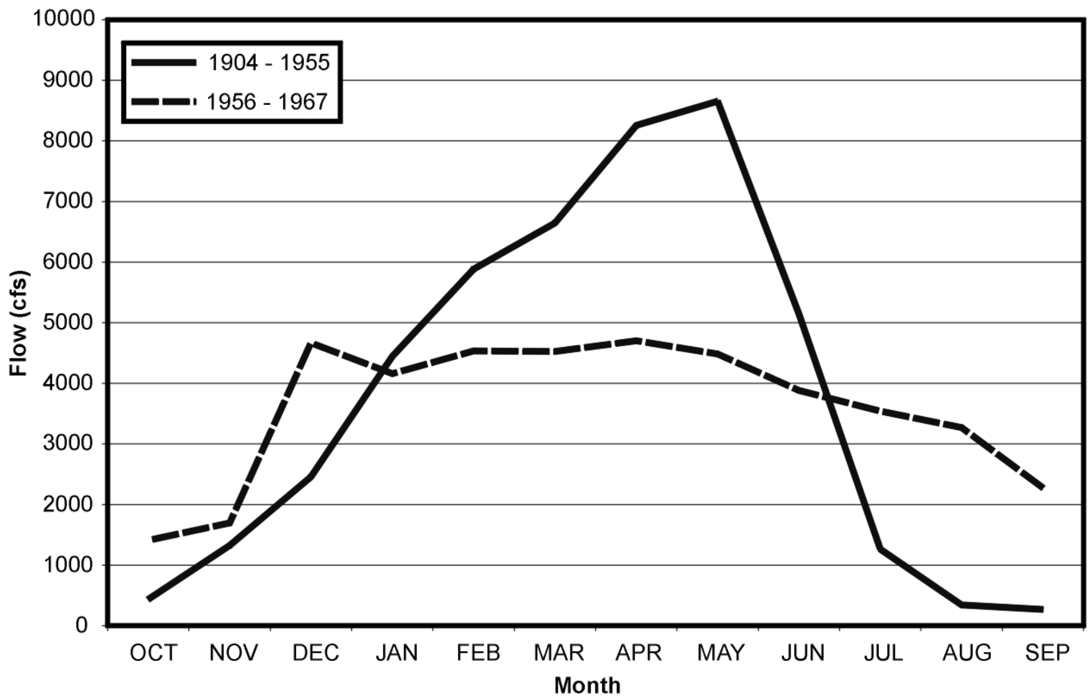


**Figure 2-2. Mean monthly flow of the lower American River at the Fair Oaks gage (1904-1955) and after (1956-1967) operation of Folsom and Nimbus dams (from Gerstung 1971).**

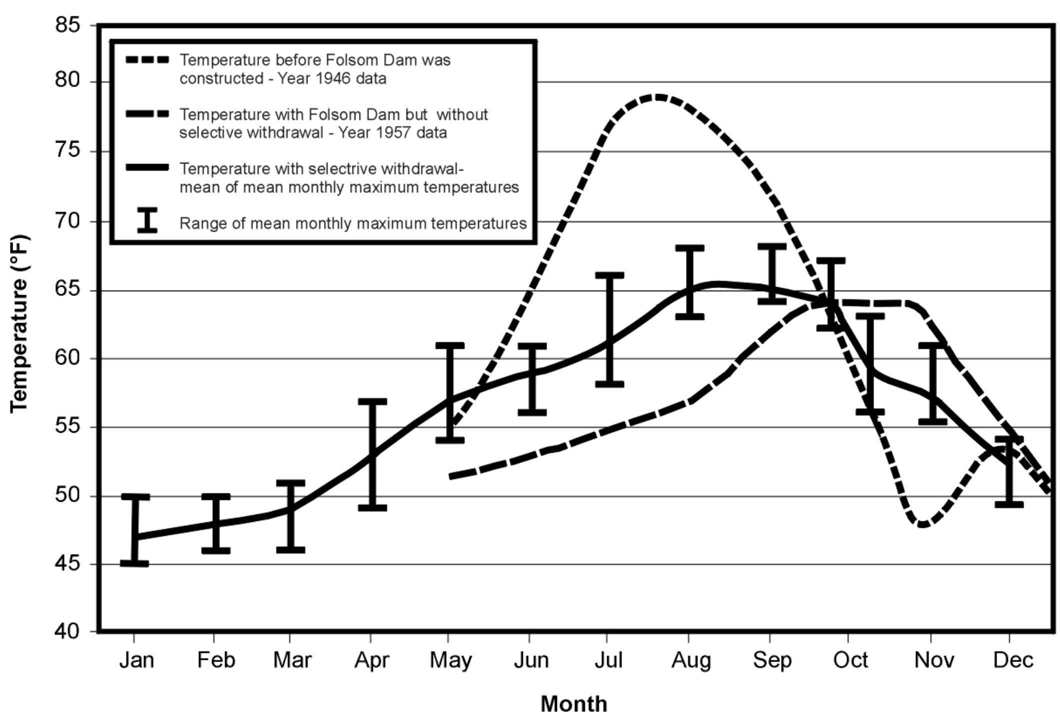


**Figure 2-3. Water temperatures recorded at the Fair Oaks gage on the lower American River prior to and after construction of Folsom and Nimbus dams (from Gerstung 1971).**

In the years immediately following construction of Folsom and Nimbus dams, lower water temperatures were provided downstream during the summer, but the cold water pool in Folsom Reservoir was usually completely depleted by early fall. Thus, elevated water temperatures generally occurred downstream at Nimbus Dam during the fall-run chinook salmon upstream migration and spawning period (September - November).

In 1962, vertical shutter mechanisms were installed at the penstock inlet ports at Folsom Dam. Relative to downstream water temperatures that occurred below Folsom and Nimbus dams prior to shutter installation, water temperatures increased during summer months. In addition, shutter operation provided a limited amount of cold water available on demand (Gerstung 1971), which could be provided, to some degree, during the early fall-run chinook salmon spawning season.

Elimination of access to upstream habitat, and relatively cool year-round water temperatures that historically occurred upstream of Folsom and Nimbus dams, undoubtedly resulted in extirpation of spring-run chinook salmon and summer-run steelhead from the American River.

### 2.1.5. CHINOOK SALMON

An overview of the historic abundance and distribution of chinook salmon in the American River was compiled by Gerstung (1971). The following discussion is taken directly from that report.

Annual salmon carcass surveys were conducted on the American River each fall beginning in 1944. Between 1944 and the construction of Folsom and Nimbus dams in 1955, an estimated average of about 26,500 chinook salmon spawned in the mainstem of the American River below the City of Folsom. During this 11-year period, estimated annual chinook salmon runs ranged from 12,000 to 38,652 (**Table 2-1**). Approximately 73 percent of the annual spawning run utilized gravels in the 5-mile stretch of the American River between the Old Folsom Dam and Nimbus Dam sites. The remaining fish spawned on mainstem riffles as far downstream as the H Street Bridge in Sacramento (Gerstung 1971).

**Table 2-1. Estimated annual runs of chinook salmon in the American River from 1944-1954 (from Gerstung 1971).**

| Year | Estimated Total Salmon Run | Estimated Spawners Below Nimbus Dam Site | Estimated Spawners Above Nimbus Dam Site |
|---|---|---|---|
| 1944 | 30,592 | 6,830 | 23,762 |
| 1945 | 38,652 | 13,841 | 24,815 |
| 1946 | 38,388 | 7,704 | 30,684 |
| 1947 | **No records** | | |
| 1948 | 15,000 | 2,940 | 12,060 |
| 1949 | 12,000 | 3,972 | 8,028 |
| 1950 | **No records** | | |
| 1951 | 22,000 | 8,316 | 13,684 |
| 1952 | 25,000 | 5,950 | 19,050 |
| 1953 | 28,000 | 6,000 | 22,000 |
| 1954 | 29,000 | 10,000 | 19,000 |
| 1944 – 1954 Average | 26,514 | 7,284 | 19,231 |
| Percent Distribution | | 27% | 73% |

After completion of Nimbus Dam in 1955, chinook salmon attempting to migrate upstream of Nimbus Dam were, instead, routed into the Nimbus Hatchery located immediately downstream of the new dam. Between 1955 and 1967, the number of salmon entering the Nimbus Hatchery averaged 10,789 annually and ranged from 875 to 29,166 per year. Over one-half of the chinook salmon entering the Nimbus Hatchery each year were believed to be fish produced by natural river spawning (Gerstung 1971).

### 2.1.6. STEELHEAD AND RESIDENT RAINBOW TROUT

An overview of the historic abundance and distribution of steelhead and resident rainbow trout in the American River also was compiled by Gerstung (1971). The following discussion is taken directly from that report.

Between 1944 and 1947, annual counts of summer-run steelhead passing through the fish ladder during May, June, and July at Old Folsom Dam (RM 27) ranged from 400 to 1,246 fish (Gerstung 1971). After 1950, when the fish ladder at Old Folsom Dam was destroyed by flood flows, summer-run steelhead perished in the warmwater in areas below Old Folsom Dam. By 1955, summer-run steelhead were completely extirpated and only remnant runs of fall- and winter-run steelhead persisted in the American River (Gerstung 1971).

From 1955 through 1959, an annual average of only 95 adult steelhead entered the Nimbus Hatchery (**Table 2-2**). In 1960, run size increased as a result of the change in hatchery procedures which included release of yearling steelhead into the lower American River, and importation of fall-run stock from the Sacramento River (Coleman Hatchery) and winter-run stock from the Eel River (Gerstung 1971). Thus, from 1960 through 1970, the number of adult steelhead annually entering the Nimbus Hatchery increased to an average of 1,170 fish, ranging from a low of 137 fish in 1962 to a high of 3,066 fish in 1969.

The numbers of adult steelhead annually entering the Nimbus Hatchery listed above do not include grilse, which are precocious males that return to the river but do not spawn. Gerstung (1971) speculated that up to 1970, the annual runs of steelhead grilse, which supported a popular sport fishery, were at least as numerous as the number of adults entering the Nimbus Hatchery. Gerstung (1971) further suggested that up to 1970, the total steelhead run including fish harvested by anglers and those entering the Nimbus Hatchery ranged from about 3,000 to 5,000 fish per year in the lower American River.

Gerstung (1971) reported that for the period extending from 1955-1970, steelhead began entering the Nimbus Hatchery during October and November, with peak migration generally occurring during February. He also reported that the early arrivals (i.e., October and November) were returned to the river until ripe, and egg taking began during January. Timing of steelhead returns to the lower American River apparently has changed from 1955-1970 to the present (2000), with fish arriving later in the year (e.g., beginning in December) which probably is reflective of the importation of winter-run Eel River stock (see section 2.2.3.1 of this *Baseline Report*).

**Table 2-2. Number of adult steelhead entering the Nimbus Hatchery and the number of juvenile steelhead released into the lower American River from 1955-1970 (from Gerstung 1971).**

| Year | Adult Steelhead Entering Hatchery | Released Yearlings | Released Fingerlings | Remarks |
|---|---|---|---|---|
| 1955-56 | 110 | None | None | Racks removed Dec. 22 |
| 1956-57 | 115 | None | 644,000 | Racks removed Feb. 26 |
| 1957-58 | 51 | 235,000 | 511,000 | Racks removed Feb. 12 |
| 1958-59 | 102 | 44,000 | 368,700 | |
| 1959-60 | 778 | None | 655,600 | |
| 1960-61 | 316 | 324,000 | 14,000 | |
| 1961-62 | 137 | None | 5,000 | Racks removed Feb. 12 |
| 1962-63 | 2,141 | 171,000 | 971,000 | Ladder removed on Jan. 30 |
| 1963-64 | 1,216 | 206,000 | 981,000 | Ladder closed until Dec. 31 |
| 1964-65 | 778 | 121,000 | 478,000 | Racks removed Dec. 22 |
| 1965-66 | 874 | 157,000 | 239,000 | |
| 1966-67 | 642 | 224,090 | 87,725 | |
| 1967-68 | 1,183 | 217,430 | 40,240 | |
| 1968-69 | 3,066 | 371,305 | 522,420 | |
| 1969-70 | 1,734 | 445,440 | 383,103 | |

### 2.1.7. OTHER FISH RESOURCES

Relatively little information is available specifically regarding historic fish resources other than anadromous salmonids in the American River. Gerstung (1971) provided a concise summary description which primarily focused on species composition and historic sport fishes in the lower American River. Historical information regarding non-anadromous fish resources in the lower American River, as available, is included in subsequent sections of this *Baseline Report*.

## 2.2. CURRENT STATUS

Numerous studies have been conducted on the lower American River over the past several years, many of which are indicated in **Figure 2-4**. In particular, more extensive, comprehensive studies have been conducted since 1990 to better describe the resources of the lower American River, aquatic habitats, ecosystem structure, and function and biotic interactions. Thus, for the purposes of this *Baseline Report*, current status is generally defined as the period extending from 1990 to 2000. Most studies have focussed on anadromous salmonids, particularly fall-run chinook salmon.

In recent years (1990 to 2000), water temperature data has been recorded at many locations along the lower American River, Lake Natoma, and Folsom Reservoir. Water temperature records, although extensive, were not continuous for most of the locations at which measurements were taken, which complicates the use of water temperature as an explanatory variable. However, from the existing temperature records, a mathematical water temperature model was developed to estimate water temperatures at locations along the lower American River between river miles 0.2 and 22.9. Model development and application is described in **Appendix A**.

**Figure 2-4. Overview of fish studies conducted on the lower American River.**

The fish resources of the lower American River have experienced significant changes over the years as a result of both natural and man-induced changes in population viability, habitat availability, and the hydrologic regime of the river. The wide diversity of indigenous aquatic habitats and historic flow regimes (including thermal conditions) has been significantly altered since the construction of Folsom Dam and Reservoir, and Nimbus Dam and Lake Natoma.

The lower American River currently provides a diversity of aquatic habitats, including shallow fast-water riffles, glides, runs, pools, and off-channel backwater habitats. The lower American River from Nimbus Dam (river mile [RM] 23) to approximately Goethe Park (RM 14) is primarily unrestricted by levees, but is bordered by some developed areas. This reach of the river is contained by natural bluffs and terraces cut into the side of the channel. The river reach downstream of Goethe Park, and extending to its confluence with the Sacramento River (RM 0), is bordered by levees. The construction of levees changed the channel geomorphology and has resulted in a reduction in river meanders and an increase in depth.

Although the lower American River is a regulated system, the factors that control habitat suitability and the health of the aquatic ecosystem can still be effectively managed. By managing the many interrelated elements that characterize a healthy riverine ecosystem, the habitat quality can be maintained in a healthy state. The information presented in this report is compiled from relevant studies conducted on the lower American River, for the purpose of providing a baseline condition view of the river.

At least 43 species of fish have been reported to occur in the lower American River system, including numerous resident native and introduced species, as well as several anadromous species (**Table 2-3**). Although each fish species fulfills an ecological role, several species are of primary management concern either as a result of their declining status or their importance to recreational and/or commercial fisheries. Species listed as "threatened" under the federal Endangered Species Act (ESA), occurring in the lower American River, include steelhead and Sacramento splittail. Current recreationally and/or commercially important anadromous species include fall-run chinook salmon, steelhead, striped bass, and American shad

Historically, the majority of anadromous salmonid spawning and rearing habitat within the American River was located in the watershed above Folsom Dam. The lower American River currently provides spawning and rearing habitat for fall-run chinook salmon and steelhead below Nimbus Dam. The majority of the steelhead run returning to the hatchery is of hatchery origin. The proportion of hatchery origin fish spawning in the river, however, remains uncertain.

In general, the primary factors potentially limiting fall-run chinook salmon and steelhead production within the lower American River are believed to be high water temperatures and inappropriate flow (including fluctuation) during portions of their freshwater residency in the river. High water temperatures during the fall can delay the onset of spawning by chinook salmon. In addition, river water temperatures can become unsuitably high for juvenile salmon rearing during spring and steelhead rearing during summer. Also, when flows are relatively low in October and November, fall-run chinook salmon redd superimposition tends to increase, thereby potentially limiting initial year-class strength.

**Table 2-3. List of fish species occurring in the lower American River.**

| Common Name | Scientific Name | Occurrence |
|---|---|---|
| **Anadromous Game Fish** | | |
| Chinook salmon | *Oncorhynchus tshawytscha* | Numerous in fall |
| Coho salmon | *Oncorhynchus kisutch* | Occasional |
| Pink salmon | *Oncorhynchus gorbuscha* | Rare |
| Chum salmon | *Oncorhynchus keta* | Rare |
| White sturgeon | *Acipenser transmontanus* | Uncommon |
| Striped bass[b] | *Morone saxatilis* | Numerous in summer |
| American shad [b] | *Alosa sapidissima* | Numerous in spring |
| Steelhead trout | *Oncorhynchus mykiss* | Numerous |
| **Coldwater Game Fish** | | |
| Kokanee [b] | *Oncorhynchus nerka* | Numerous above Nimbus |
| Rainbow trout | *Oncorhynchus mykiss* | Numerous |
| Brown trout [b] | *Salmo trutta* | Rare |
| **Warmwater Game Fish** | | |
| Largemouth bass [b] | *Micropterus salmonids* | Common in backwaters |
| Smallmouth bass [b] | *Micropterus dolomieui* | Common in backwaters |
| Green sunfish [b] | *Lepomis cyanellus* | Common in backwaters |
| Bluegill [b] | *Lepomis macrochirus* | Common in backwaters |
| Redear sunfish [b] | *Lepomis microlophus* | Few in backwaters |
| White crappie [b] | *Pomaxis annularis* | Few in backwaters |
| Sacramento perch | *Archoplites interruptus* | Rare |
| Channel catfish [b] | *Ictahurus punctatus* | Uncommon |
| White catfish [b] | *Ictahuruscatus* | Common in backwaters |
| Brown bullhead [b] | *Ictahurus nebulosus* | Few in backwaters |
| Black bullhead [b] | *Ictahurus melas* | Few in backwaters |
| **Nongame Fish** | | |
| Sacramento sucker | *Catostomus occidentalis* | Numerous |
| Carp [b] | *Cyprinus carpio* | Numerous |
| Goldfish [b] | *Carassius auratus* | Numerous |
| Sacramento blackfish | *Orthodon microlepidotus* | Uncommon |
| Hardhead | *Mylopharodon conocephalus* | Occasional |
| Sacramento hitch | *Lavinia exilicauda* | Occasional |
| Sacramento squawfish | *Prychocheilus grandis* | Numerous |
| Splittail | *Pogonichthys macrolepidotus* | Occasional |
| Mosquitofish [b] | *Gambusia affinis* | Numerous in backwaters |
| Tule perch | *Hysterocarpus traski* | Numerous |
| Riffle sculpin | *Cottus gulosus* | Numerous |
| Pacific lamprey | *Lampetra tridentata* | Common and anadromous |
| Threadfin shad [b] | *Dorosoma petenense* | Occasional |
| Golden shiner [b] | *Notemigonus crysoleucas* | Present above Nimbus |
| Fathead minnow [b] | *Pimephales promelas* | Present above Nimbus |
| Thicktail chub | *Gila crassicauda* | Extinct |
| Western roach | *Hesperoleucaus symmetricus* | Uncommon |
| Sacramento tui chub | *Gila bicolor* | Uncommon |
| Speckled dace | *Rhinichthys osculus sp.* | Uncommon |
| Mississippi silverside | *Menidia beryllina* | Occasional |
| Smelt | *Hypomesus sp.* | Occasional |

[a] Modified from Gerstung (1971)
[b] Introduced species

### 2.2.1. INSTREAM HABITATS

Stream habitat classification provides a necessary foundation between fish and abiotic (i.e., flow) conditions. Studies proposed to examine flow relationships in the lower American River including indices of fish abundance, and relationships between flow and habitat availability required development and implementation of a distinctive habitat classification system.

#### 2.2.1.1. HABITAT CLASSIFICATION

A geomorphically based habitat classification system was developed (Snider et al. 1992) to characterize aquatic habitat in the lower American River. In that study habitat definitions were based on channel morphology and general hydraulic criteria that distinguish areas, which exhibit similar hydraulic behavior. The primary challenges encountered while characterizing the river's large channel habitat were identifying and characterizing controls that would define relatively homogenous habitat units. The eventual classification system was developed combining information obtained from other stream habitat classification approaches (Rosgen 1985; Sullivan 1986; Bisson et al. 1982) and basic geomorphological principles (Leopold and Wolman 1957; Kondolf, pers. comm. 2000) with site specific information obtained from USGS quads and aerial photographic and ground surveys. This subchapter relies on the work of Snider et al. (1992) and, accordingly, incorporates text directly from that investigation.

Four levels of habitat classification were developed in the habitat characterization procedure. **Table 2-4** lists the classification levels and definitions used to characterize aquatic habitat in the lower American River, summarized below.

The broadest classification, *study reach*, described large-scale differences in channel character based on overall gradient, tidal influence, and general channel-bed substrate size. This classification level was used to identify large stretches of river with similar character. Using this method the river was divided into three geographic regions of study, called reaches, and are shown on **Figure 2-5**.

The second level of classification, *major channel features*, was assigned to major channel units within each reach. These units were based on the repeated sequence of aggraded areas that formed hydraulic controls (bar complexes) and intervening areas between the controls (flatwater areas). A third major channel feature unit within each study reach was identified as off-channel areas. Off-channel areas were secondary channels isolated from the main channel cross-section profile.

Various types of major channel features, c*hannel feature types,* were identified at the third level of classification within each reach. Five bar complex types, including island complex, lateral bar, transverse bar, channel-spanning bar, and mid-channel bar, were identified based on their position in the channel, elevation relative to water surface and presence of vegetation. Flatwater area types were identified as straight river sections (straight channel), river sections containing channel bends (channel bends), and river sections with split channels (split channel). Off-channel areas were identified as contiguous or non-contiguous with the main channel at an average flow of 1,000 cfs (from Nimbus Dam) in the lower American River.

**Table 2-4. Classification levels and definitions used to characterize aquatic habitat in the lower American River.**

| Classification Level | Definition |
|---|---|
| **Study Reaches** | |
| Reach One | Overall gradient 0.03% (average for study area is 0.06%); reach is tidally influenced; sand bed channel. |
| Reach Two | Overall gradient 0.05%; no tidal influence; primarily sand bed channel |
| Reach Three | Overall gradient 0.08%; no tidal influence; primarily gravel bed channel |
| **Major Channel Features** | |
| Bar Complex | River segment in which submerged and emergent bars are the primary channel morphological features |
| Flatwater | River segment in which primary channel is uniform, simple, and without gravel bars or channel |
| Off-channel | Area distinctly separate from main channel and lies outside the main channel cross-sectional profile |
| **Channel Feature Types** | |
| Island Complex | Located in main channel and surrounded by water; more built-up and stable than other bar types; generally supports established riparian vegetation |
| Mid-channel Bar | Located in main channel and surrounded by water; less built-up than island complex; usually lacks established riparian vegetation |
| Lateral Bar | Contiguous with one main channel bank, does not span channel; less built up than island complex; lacks established riparian vegetation |
| Channel-Spanning Bar | Spans entire channel at an approximate right angle |
| Transverse Bar | Spans entire channel at an approximate acute angle |
| Channel Bend | Main channel primarily curved |
| Straight Channel | Main channel primarily without curvature |
| Split Channel | Main channel split into tow or more channel |
| Contiguous | Off-channel area contiguous with main channel |
| Non-contiguous | Off-channel area not contiguous with main channel |
| **Habitat Units (relative to all channel feature components in the lower American River study area)** | |
| Riffle | Relative high gradient with substrate of large gravel and/or cobble; above average water velocities; below average depth; surface turbulence; channel controlled (i.e., no backwater influence) |
| Run | Moderate gradient with a substrate of small cobble and/or gravel; above average water velocities; average depth; low to moderate turbulence; channel controlled; generally associated with the downstream extent of riffles. |
| Glide | Relatively low gradient with substrate of small gravel and/or sand/silt; below average water velocities; below average depth; no turbulence; variable control; generally associated with the tails of pools and heads of riffles. |
| Pool | Relative low gradient with substrate of fine materials; below average water velocities; above average depth; tranquil; section controlled. |

The fourth level of classification was the *habitat unit,* which included riffle, run, glide and pool. Classification of habitat units was based on the channel gradient, substrate composition, and hydraulic characteristics. The habitat unit was associated with any combination of major channel feature and channel feature type, excluding contiguous and non-contiguous off-channels.

**Figure 2-5. Study reaches of the lower American River study area.**

### 2.2.1.2. HABITAT COMPOSITION AND DISTRIBUTION IN REACH 1

Reach 1 extends from the confluence of the American and Sacramento Rivers upstream a distance of approximately 4.9 miles to the Paradise Beach Recreation Area. Reach 1 was characterized by a very low gradient and was influenced by the effects of tidal fluctuation in the Sacramento River.

Reach 1 was composed almost entirely of long, uniform, flatwater stretches. Two bar complexes were located immediately downstream of bridge structures. The percent composition of each major channel feature within Reach 1 of the lower American River study area at a flow rate of 1,000 cfs is provided in **Table 2-5**.

**Table 2-5. Percent composition of major channel features within Reach 1 at 1,000 cfs.**

| Major Channel Feature | Area ($ft^2$) | Percent Composition | Number of major features |
|---|---|---|---|
| Bar complex | 996,934 | 11.0 | 2 |
| Flatwater | 8,071,667 | 89.0 | 3 |

The two mid-channel bar complexes were the only bar type complexes documented in Reach 1. The two bar complexes accounted for 11 percent of the major channel feature types in Reach 1. The remaining 89 percent of the reach was composed of channel bend and flatwater areas. The percent composition of channel features types within Reach 1 at a flow rate of 1,000 cfs is provided in **Table 2-6**.

**Table 2-6. Percent composition of major channel feature types within Reach 1 at 1,000 cfs.**

| Channel Feature Type | Area (ft2) | Percent Composition | Number of Channel Feature Types |
|---|---|---|---|
| Mid-Channel Bar | 996,934 | 11.0 | 2 |
| Channel Bend | 8,071,667 | 89.0 | 3 |

Reach 1 exhibited a general lack of habitat diversity as compared to the other two study reaches. Only glide and pool habitats were found in Reach 1. Pool habitats were found in the long uniform flatwater stretches, while the bar complexes, consisted entirely of glide and pool habitats. The percent composition of habitat units associated with major channel features within Reach 1 at a flow rate of 1,000 cfs is provided in **Table 2-7**.

**Table 2-7. Percent composition of habitat units associated with major channel features with Reach 1 at 1,000 cfs.**

| Major Channel Feature | Habitat Unit | Area ($ft^2$) | Percent Composition | Number of Habitat units |
|---|---|---|---|---|
| BC | Glide | 825,967 | 9.1 | 2 |
| BC | Pool | 170,967 | 1.9 | 1 |
| FW | Pool | 8,071,667 | 89.0 | 3 |

BC= Bar complex, FW= Flatwater

### 2.2.1.3. HABITAT COMPOSITION AND DISTRIBUTION IN REACH 2

Reach 2 extended upstream from the Paradise Beach Recreation Area a distance of approximately 6.7 miles to the Gristmill Dam Recreation Area. Like Reach 1, Reach 2 was characterized by predominately sand-bed channel, but was not subject to the influence of Sacramento River tidal activity.

Reach 2 contained only seven bar complexes. Flatwater areas with their associated glides and pools dominated Reach 2 accounting for 78.8 percent of the habitat area. Eight off-channel features were documented in Reach 2. Off-channels occurred most frequently around split channel complexes, with as many as four off-channels associated with a single major channel feature. The percent composition of major channel features within Reach 2 of the lower American River study area at a flow rate of 1,000 cfs is provided in **Table 2-8**.

**Table 2-8. Percent composition of major channel features within Reach 2 at 1,000 cfs.**

| Major Channel Feature | Area ($ft^2$) | Percent Composition | Number of major features |
|---|---|---|---|
| Bar complex | 1,772,134 | 13.3 | 7 |
| Flatwater | 10,541,901 | 78.8 | 7 |
| Off-Channel | 1,059,633 | 7.9 | 8 |

Specifically, Reach 2 contained various bar complexes including three mid-channel bars, two transverse bars, one Lateral bar and one Channel spanning bar. The percent composition of the channel features types within Reach 2 at a flow rate of 1,000 cfs is provided in **Table 2-9**.

**Table 2-9. Percent composition of channel features types within Reach 2 at 1,000 cfs.**

| Channel Feature Type | Area ($ft^2$) | Percent Composition | Number of Channel Feature Types |
|---|---|---|---|
| Mid-Channel Bar | 1,267,567 | 9.5 | 3 |
| Lateral Bar | 59,367 | 0.5 | 1 |
| Chan-Span. Bar | 199,034 | 1.5 | 1 |
| Transverse Bar | 246,166 | 1.8 | 2 |
| Channel Bend | 3,113,033 | 23.3 | 2 |
| Straight Channel | 3,280,467 | 24.5 | 5 |
| Split Channel | 4,148,401 | 31.0 | 3 |
| Contiguous | 765,966 | 5.7 | 6 |
| Non-Contiguous | 293,667 | 2.2 | 2 |

All four habitats (riffle, run, glide and pool) were represented in Reach 2. Flatwater areas associated with glides and pools accounted for the largest percentage of aquatic habitat in the reach. Flatwater glides accounted for 33 percent of the composition and flatwater pools 44.3 percent. The percent composition of habitat units associated with major channel features within Reach 2 at a flow rate of 1,000 cfs is present in **Table 2-10**.

**Table 2-10. Percent composition of habitat units associated with major channel features within Reach 2 at 1,000 cfs.**

| Major Channel Feature | Habitat Unit | Area ($ft^2$) | Percent Composition | Number of Habitat units |
|---|---|---|---|---|
| BC | Riffle | 544,034 | 4.1 | 13 |
| BC | Run | 683,800 | 5.1 | 7 |
| BC | Glide | 247,200 | 1.8 | 3 |
| BC | Pool | 297,100 | 2.2 | 3 |
| FW | Riffle | 71,601 | 0.5 | 3 |
| FW | Run | 134,467 | 1.0 | 2 |
| FW | Glide | 4,408,301 | 33.0 | 16 |
| FW | Pool | 5,927,532 | 44.3 | 11 |

BC= Bar complex, FW= Flatwater

### 2.2.1.4. Habitat Composition and Distribution in Reach 3

Reach 3 extended from the upstream terminus of Reach 2 at the Gristmill Dam Recreation Area to the Nimbus Hatchery weir, a distance of approximately 11.1 miles. Reach 3 was characterized by a relatively high gradient, gravel bed channel.

Flatwater areas were considerably less abundant in Reach 3 than the other two reaches, but still accounted for 60.1 percent of the major channel features within the reach. Reach 3 contained 15 bar complexes including the Goethe Park Bar. Reach 3 had five off-channels, with these major channel features occurring most frequently around split channel and island complexes. As many as four off-channels were associated with a single major channel feature. The percent composition of the major channel features within Reach 3 of the lower American River study area at a flow rate of 1,000 cfs is provided in **Table 2-11**.

**Table 2-11. Percent composition of channel features within Reach 3 at 1,000 cfs.**

| Major Channel Feature | Area ($ft^2$) | Percent Composition | Number of major features |
|---|---|---|---|
| Bar complex | 5,285,326 | 33.0 | 15 |
| Flatwater | 9,651,531 | 60.1 | 15 |
| Off-Channel | 1,109,167 | 6.9 | 5 |

Specifically, Reach 3 contained various bar complexes including three island complexes, seven mid-channel bars, one lateral bar, two channel spanning bars, two transverse bars, and the Goethe Park Bar. Reach 3 was the only reach to contain island complexes of which three were documented.

The "Goethe" channel feature was unique to this reach due to alteration of the channel resulting from past mining activity. Although evidence of past dredging occurred in other locations within Reaches 2 and 3, the Goethe Park bar complex was altered so severely that the channel did not conform to any standard feature type. The percent composition of the channel feature types within Reach 3 at a flow rate of 1,000 cfs is provided in **Table 2-12**.

All four habitats (riffle, run, glide and pool) were represented in Reach 3. In flatwater areas, pools were the most abundant habitat unit at 33 percent. Glides were the next most abundant at 25.6 percent and then run at 1.5 percent. Riffle habitats were not associated with flatwater areas in Reach 3. Bar complexes, including the unique bar complexes located near Goethe Park represented 33 percent of all major channel features in Reach 3. Bar complexes in Reach 3 were composed primarily of runs at 12.1 percent and riffles at 9 percent. Glide and pool habitats units within bar complexes represented 7.1 and 4.8 percent respectively. The percent composition of habitat units associated with major channel features within Reach 3 at a flow rate of 1,000 cfs is present in **Table 2-13**.

**Table 2-12. Percent composition of channel features types within Reach 3 at 1,000 cfs.**

| Channel Feature Type | Area ($ft^2$) | Percent Composition | Number of Channel Feature Types |
|---|---|---|---|
| Island | 1,348,830 | 8.4 | 3 |
| Mid-Channel Bar | 2,196,430 | 13.7 | 7 |
| Lateral Bar | 336,233 | 2.1 | 1 |
| Chan-Span. Bar | 256,134 | 1.6 | 2 |
| Transverse Bar | 593,467 | 3.7 | 2 |
| Goethe | 554,232 | 3.5 | 1 |
| Channel Bend | 810,000 | 5.0 | 3 |
| Straight Channel | 8,841,531 | 55.1 | 15 |
| Contiguous | 1,109,167 | 6.9 | 5 |

**Table 2-13. Percent composition of habitat units associated with major channel features within reach 3 at 1,000 cfs.**

| Major Channel Feature | Habitat Unit | Area ($ft^2$) | Percent Composition | Number of Habitat units |
|---|---|---|---|---|
| BC | Riffle | 1,445,500 | 9.0 | 40 |
| BC | Run | 1,942,399 | 12.1 | 24 |
| BC | Glide | 762,431 | 4.8 | 10 |
| BC | Pool | 1,134,996 | 7.1 | 12 |
| FW | Run | 246,666 | 1.5 | 2 |
| FW | Glide | 4,115,332 | 25.6 | 15 |
| FW | Pool | 5,289,533 | 33.0 | 14 |

BC= Bar complex, FW= Flatwater

### 2.2.1.5. REACH SUMMARIES

#### Reach 1

Reach 1 was characterized by a very low channel gradient and was influenced by the diurnal effects of tidal fluctuations in the Sacramento River. A general lack of habitat diversity was observed when compared to the other two study reaches. Reach 1 was composed almost entirely of long, uniform flatwater stretches of pool habitat. The two bar complexes, both consisting of glides and pools, were located immediately downstream of bridge structures. The two bar complexes only accounted for 11 percent of the major channel features area in Reach 1. The remaining 89 percent were composed of channel bend and flatwater areas.

#### Reach 2

Reach 2 was characterized by a predominately sand-bed channel, but was not subject to tidal activity of the Sacramento River. Flatwater areas dominated Reach 2, accounting for 78.8 percent of the major channel features. The most abundant habitats units were flatwater areas associated glides and pools which accounted for 33 percent and 44.3 percent of the aquatic habitat in the reach, respectively.

#### Reach 3

Reach 3 was characterized by a relatively high gradient, gravel-bed channel. Flatwater areas were considerably less abundant in Reach 3 than the other two reaches, but still accounted for 60.1 percent of the habitat within the reach. In the flatwater areas, pools were the most abundant habitat unit accounting for 33 percent of the habitat area, followed by glides at 25.6 percent, and runs at 1.5 percent. Riffle habitats were not associated with flatwater areas in Reach 3. Bar complexes, including the unique bar complexes located near Goethe Park, represent 33 percent of all habitat area in Reach 3.

### 2.2.2. FALL-RUN CHINOOK SALMON

Central Valley fall-run chinook salmon (*Onchorynchus tshawytscha*) is currently the largest run of chinook salmon in the Sacramento River system, and the primary run of chinook salmon utilizing the lower American River. Due to their numbers, fall-run chinook salmon continue to support commercial and recreational fisheries of significant economic importance. Central Valley fall-run chinook salmon were classified as a candidate species under the federal Endangered Species Act in November 1999.

Generally, adult chinook salmon migrate into the Sacramento River from the Pacific Ocean beginning in July, with migration peaking from mid-October through November. In addition to the lower American River, fall-run chinook salmon are known to spawn in numerous tributaries of the Sacramento River including the lower Yuba River, Feather River, and other tributaries to the upper Sacramento River.

A generalized depiction of the temporal occurrence of the various lifestages of fall-run chinook salmon in the lower American River is presented in **Figure 2-6**. Spawning typically occurs from October through December, with fry emergence usually beginning in mid-to late January, with peak emergence usually occurring from mid- to late February.

Fall-run chinook salmon emigrate as post-emergent fry, young-of-year juveniles, and as smolts after rearing in their natal streams for up to six months. Fall-run chinook salmon emigration primarily occurs in the lower American River from January through June.

Overall, the entire lower American River is utilized by fall-run chinook salmon for one or more portions of their lifecycle (**Figure 2-7**). Spawning and rearing habitat exists along a considerable portion of the lower American River.

#### 2.2.2.1. POPULATION STATUS

Knowledge of the dynamics of fish populations is essential for developing appropriate management plans, restoration plans, and monitoring programs. In the present context of fish management, population dynamics include estimation of the changes in population numbers, composition, or biomass. Population size can be estimated from numerous methods. Spawning surveys represent one means of establishing annual spawning run size, and have included spawning stock escapement evaluations and aerial redd survey analyses on the lower American River.

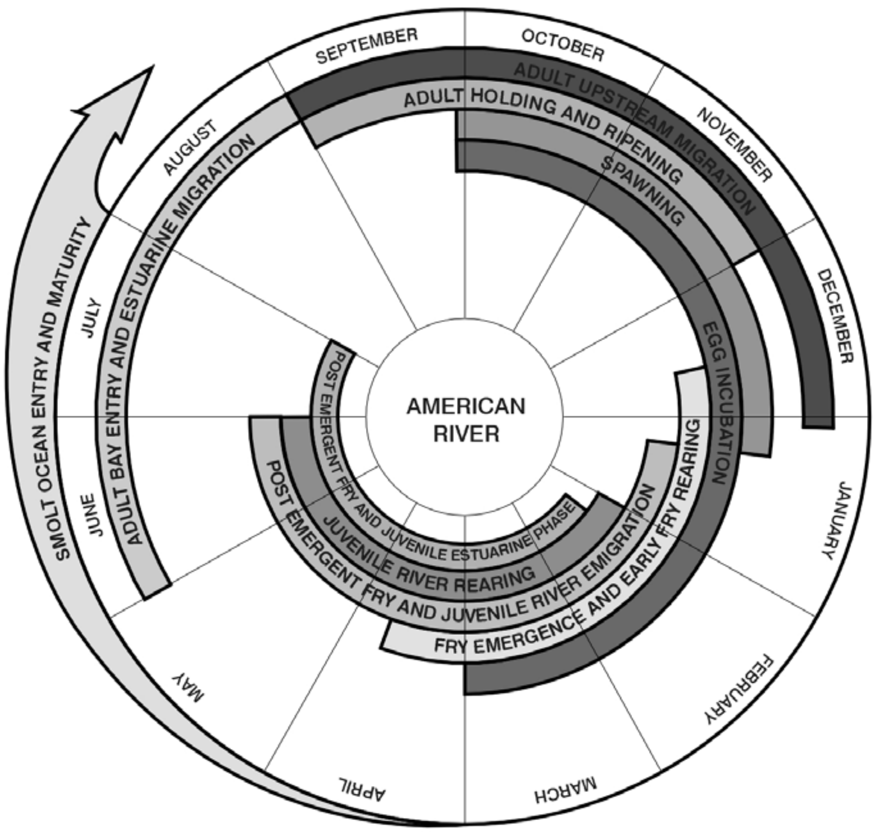


**Figure 2-6. Generalized fall-run chinook salmon lifecycle periodicity for the lower American River.**

Estimating the total annual fall-run chinook salmon population in the lower American River is predicated on numerous factors including: (1) extent of spawning below Watt Avenue; (2) spawning above the Nimbus Hatchery training weir; (3) extent of fish passage into the Nimbus Hatchery; (4) angler catch; (5) impingement on the Nimbus Hatchery training weir; and (6) unknown causes of fish disappearance. Spawning stock escapement estimation is addressed below. Aerial redd surveys are discussed in detail later in this *Baseline Report*.

### Annual Spawning Stock Escapement Estimation

Since 1944, CDFG has conducted periodic spawning escapement surveys to estimate the population of fall-run chinook salmon. Those surveys represent the best available source of information regarding adult fall-run chinook salmon population estimation for the lower American River.

**Figure 2-7. Fall-run chinook salmon temporal and spatial distribution on the lower American River.**

## Methodology

***Range of Sampling Protocol***

*Tag-and-Recapture Technique (Jaw Tag)*

Numerous estimation procedures and protocols have been used since 1944 (**Table 2-14**). The standard Schaefer method protocol involved the tagging of only fresh fish carcasses. However, with the initiation of the Jolly-Seber estimation model in 1988, the standard protocol was to tag both fresh and decayed carcasses. The combined fresh and decayed carcass data also have been used to calculate an estimate of population using the Jolly-Seber method. Fresh carcass data have been used by CDFG to calculate estimates of population using the Schaefer method. The modified Schaefer method has been consistently used since 1976 to estimate annual chinook salmon population size.

Under the tag-and-recapture method, carcasses are examined for freshness by examining the eyes for clarity and the gills for color. A fish with at least one clear eye, or with pink gills if eye clarity could not be determined, is considered "fresh." All fresh carcasses observed during the spawning period for fall-run chinook salmon are tagged with a color-coded hog ring inserted in the upper jaw to identify the week the carcass was tagged. Typically, non-fresh carcasses are counted and then cut through the backbone with a machete to eliminate them from any future survey. Each fresh carcass is then returned to the river just upstream from where it was collected, to emulate the disposition of dying salmon.

*Sampling Timing*

Hatchery data from 1956 to the present suggest that fall-run chinook salmon may be arriving in the lower American River as early as July and holding over until late October before spawning. Although the first arrivals at the hatchery are typically observed in mid- to late September, the first eggs are typically not taken until late October-early November.

Escapement surveys conducted in the 1990s have begun as early as the end of September and extended into late January. In 1992, CDFG found that the temporal distribution of carcasses appeared bimodal, suggesting the possibility that two distinct runs of chinook salmon were being observed, although the first mode comprised a small portion of the total annual run (**Figure 2-8**). The lowest point between the two modes occurred at the end of October when, presumably, the "true" annual fall-run began. The majority of the fish observed in the first "mode" of the survey in 1992 occurred in the first week, implying that the peak of the earlier run may have occurred prior to the first survey week (Snider et al. 1993). Early (August-September) chinook salmon runs have been previously noted in creel censuses and coded-wire-tag evaluations. Collected coded wire tag data indicated that the majority of the run was comprised of Feather River Hatchery fish (**Table 2-15**).

**Table 2-14. Fall-run chinook salmon escapement estimates for the lower American River.**

| Year | Grilse | % Grilse | % Female | Sample size | In River Adults | Total in River | Instream Harvest | Ocean Harvest | Total Hatchery | % Hatchery | Weir Fish |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1944[e] | | | | | | 30,592 | | | | | |
| 1945[e] | | | | | | 38,652 | | | | | |
| 1946[e] | | | | | | 38,388 | | | | | |
| 1947[e] | | | | | | -- | | | | | |
| 1948[e] | | | | | | 15,000 | | | | | |
| 1949[e] | | | | | | 12,000 | | | | | |
| 1950[e] | | | | | | -- | | | | | |
| 1951[e] | | | | | | 22,000 | | | | | |
| 1952[e] | | | | | | 25,000 | | | | | |
| 1953[e] | | | | | | 28,000 | | | | | |
| 1954[e] | | | | | | 29,000 | | | | | |
| 1955 | | | | | | 9,000 | | | | | |
| 1956 | | | | | | 4,900 | | | 1,543 | | |
| 1957 | | | | | | 6,832 | | | 890 | | |
| 1958 | | | | | | 17,300 | | | 10,210 | | |
| 1959 | | | | | | 17,900 | | | 13,235 | | |
| 1960 | | | | | | 25,200 | | | 32,641 | | |
| 1961 | | | | | | 11,200 | | | 14,341 | | |
| 1962 | | | | | | 14,400 | | | 12,668 | | |
| 1963 | | | | | | 37,810 | | | | | |
| 1964 | | | | | | 38,500 | | | 20,542 | | |
| 1965 | | | | | | 24,989 | | | 13,676 | | |
| 1966 | | | | | | 18,600 | | | 8,105 | | |
| 1967[a] | 3,132 | 17 | | | 14,868 | 18,000 | | | 5,147 | | 4,342 |
| 1968[a] | 2,777 | 11 | | | 23,423 | 26,200 | | | 5,233 | | 1,854 |
| 1969[a] | 8,208 | 19 | | | 35,425 | 43,633 | | | 8,184 | | 5,119 |
| 1970[a] | 2,753 | 10 | | | 25,927 | 28,680 | | | 8,624 | | 3,131 |
| 1971[a] | 5,210 | 13 | | | 36,470 | 41,680 | | | 9,146 | | 935 |
| 1972[a] | 3,352 | 19 | | | 14,107 | 17,459 | | | 7,106 | | 2,169 |
| 1973[a] | 4,688 | 6 | | | 77,554 | 82,242 | | | 12,535 | | 546 |
| 1974[b] | 1,769 | 3 | | | 51,827 | 53,596 | | | 8,200 | | |
| 1975[a] | 2,699 | 8 | | | 29,433 | 32,132 | | | 7,413 | | 961 |
| 1976[b] | 1,181 | 5 | | | 21,978 | 23,159 | | | 5,244 | | |
| 1977[b] | 4,701 | 11 | | | 36,904 | 41,605 | | | 7,065 | | |
| 1978[b] | 595 | 5 | | | 12,334 | 12,929 | | | 8,162 | | 527 |
| 1979[b] | 896 | 2 | | | 36,419 | 37,315 | | | 10,351 | | |
| 1980[b] | 8,805 | 26 | | | 25,454 | 34,259 | 4,000 | | 15,659 | | 240 |
| 1981[b] | 2,521 | 6 | | | 40,941 | 43,462 | 3,490 | | 20,588 | | 113 |
| 1982[a] | 4,323 | 13 | | | 28,677 | 33,000 | 3,158 | | 10,924 | | 778 |
| 1983[a] | 7,313 | 28 | | | 19,087 | 26,400 | 4,614 | | 9,081 | | 428 |
| 1984[c] | 2,196 | 8 | | | 25,251 | 27,447 | 7,550 | | 12,249 | | 1,146 |
| 1985[b] | 11,392 | 20 | | | 44,728 | 56,120 | 3,579 | | 9,093 | | 828 |
| 1986[b] | 4,443 | 9 | | | 44,929 | 49,372 | | | 5,695 | | 4,228 |
| 1987[b] | 2,960 | 14 | | | 18,185 | 21,145 | | | 6,258 | | 511 |
| 1988[d] | 1,905 | 12 | | | 13,974 | 15,879 | | | 8,625 | | |
| 1989[b] | 2,459 | 14 | | | 14,619 | 17,078 | | | 9,740 | | 1,313 |
| 1990[b] | 1,167 | 17 | | | 5,541 | 6,708 | | | 4,857 | | 204 |
| 1991[b] | 1,506 | 8 | 41 | 760 | 16,639 | 18,145 | | | 7,128 | | 1,622 |
| 1992[b] | 1,297 | 29 | 41 | 359 | 3,175 | 4,472 | | | 6,456 | 59.08 | 1,100 |
| 1993[b] | 6,161 | 23 | 51 | 1,465 | 20,625 | 26,786 | | | 10,656 | 28.46 | 2,273 |
| 1994[b] | 2,820 | 9 | 47 | 1,049 | 28,513 | 31,333 | | | 10,673 | 25.41 | 2,078 |
| 1995[b] | 7,010 | 10 | 45 | 1,104 | 63,086 | 70,096 | 5,961 | 198,478 | 6,439 | 8.41 | 288 |
| 1996[b] | 6,592 | 10 | 39 | 807 | 59,324 | 65,915 | 6,003 | 92,061 | 7,747 | 10.52 | 3,841 |
| 1997[b] | 4,220 | 9 | 32 | 763 | 42,668 | 46,888 | 4,651 | 86,949 | 5,650 | 10.75 | 4,078 |
| 1998[b] | 10,761 | 25 | 39 | 866 | 32,282 | 43,042 | 19,756 | 65,244 | 10,581 | 19.73 | 9,988 |
| 1999[b] | 7,716 | 16 | 43 | 740 | 40,509 | 48,225 | | | 8,361 | 14.78 | |
| Mean | 4,228 | 13 | 21 | 879 | 30,451 | 32,929 | 6,276 | 110,683 | 9,691 | 22 | 2,024 |
| Min. | 595 | 2 | 29 | 359 | 3,175 | 4,472 | 3,158 | 65,244 | 890 | 8 | 113 |
| Max. | 11,392 | 29 | 51 | 1,465 | 77,554 | 82,242 | 19,756 | 198,478 | 32,641 | 59 | 9,988 |

*Notes: Grilse are fish smaller than a maximum centimeter measure depending on the year. The fork length representing the break between the length frequency distributions is used to distinguish adults from grilse. The value is typically between 60 and 70 cm; Grilse=2 year olds; Males ≤70cm FL, Females ≤60cm (1993), ≤65cm (1994-1995); 25 Year Instream Escapement Average 1967-1991= 32,306; 8 Year Average (1992-1999)= 42,095*

[a] Expanded direct count; [b] Modified Schaefer method; [c] Petersen method; [d] Jolly-Seber method; [e] Calculated from Tagging and Tag Recovery Program

Source: Calculated and adapted from Table 3 (chinook salmon escapement estimates, lower American River, 1967-1999) from American River Salmon Spawning Stock Estimate, 1999. Department of Fish and Game, Region 2. Estimated escapement data for years 1944 through 1966 were obtained from Gerstung (1971). In river and ocean harvest data was obtained from Gerstung (1985), Murphy et al (1999) and USFWS and USBR (1999).

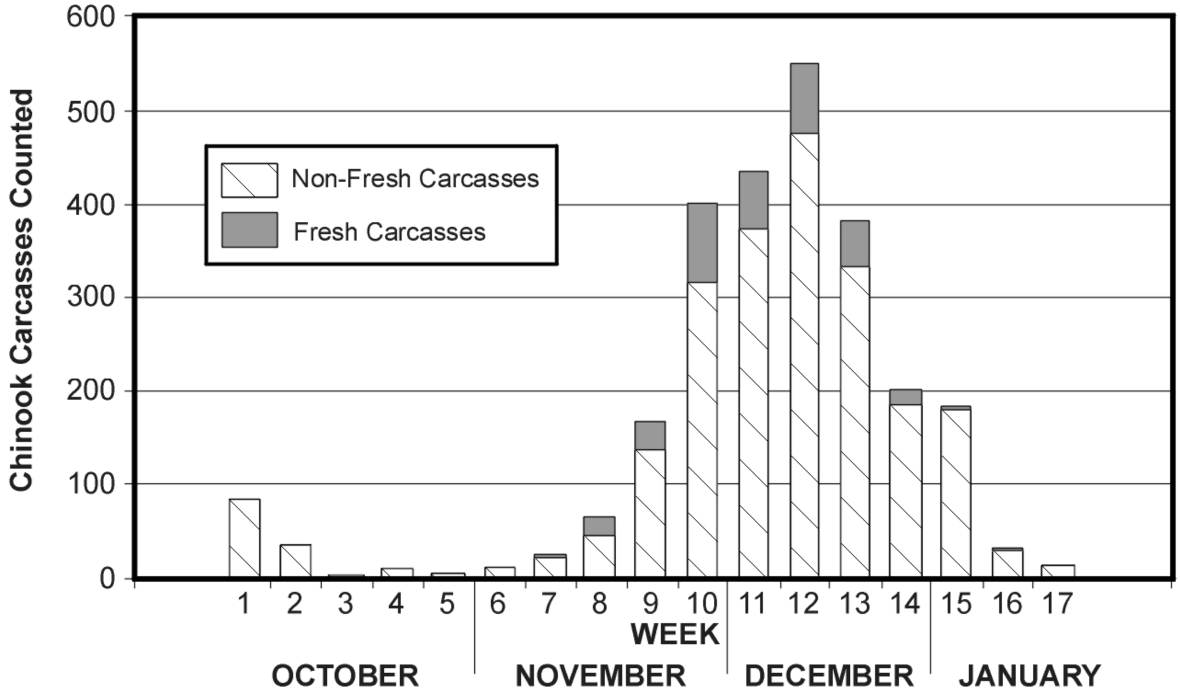


**Figure 2-8. Summary of fresh and non-fresh carcass counts, lower American River chinook salmon escapement survey, September 1992-January 1993.**

**Table 2-15. 1992 spawning escapement survey to determine origin of early chinook salmon in the lower American River (Snider et al. 1993).**

| Number of tags collected | | | |
|---|---|---|---|
| Hatchery | August | September | Total(%) |
| Feather River Hatchery | 32 | 52 | 84 (86) |
| Mokelumne river Hatchery | 5 | 6 | 11 (11) |
| Coleman Fish Hatchery | 0 | 2 | 2 (2) |
| Nimbus Fish Hatchery | 0 | 1 | 1 (1) |
| Total | 37 | 61 | 98 |

*Sampling Locations*

Since 1992, CDFG escapement surveys were initiated once spawning had commenced in the upper 13.7 miles of the river extending from the Nimbus Hatchery training weir downstream to Watt Avenue.

The surveys were limited to this uppermost 13.7 mile stretch of the river since it is generally accepted that the nine river miles downstream of Watt Avenue supports relatively little spawning (Snider and McEwan 1992; Snider et al. 1993a). The study segments for the escapement surveys divided the lower American River into three reaches (**Figure 2-9**); Reach 1 – Sailor Bar to Rossmoor Bar (RM 22.0 to 18.0); Reach 2 – Rossmoor Bar to Goethe Park Footbridge (RM 18.0 to 14.5); and Reach 3 – Goethe Park Footbridge to Watt Avenue (RM 14.5 to 9.0). Since 1996, an additional reach has been included extending from the Nimbus Hatchery training weir upstream to the base of Nimbus Dam.

**Figure 2-9. Location of lower American River spawning escapement survey reaches.**

### *Estimation Method*

Since the early 1970s, tag-and-recapture data have been collected to estimate adult spawning escapement to several Central Valley tributary streams, including the American River. From 1970 through 1973, estimates were derived from expanded direct counts. As previously identified, since 1974, three methods have been used by CDFG to estimate adult escapement to the lower American River: the Petersen method (Ricker 1975), the Schaefer (1951) method and the Jolly-Seber method (Seber 1982).

The expanded direct count method involves multiplying the number of observed fish carcasses by an estimated capture efficiency based on instream conditions such as flow and turbidity. For example, the estimate for a survey with a capture efficiency of 20 percent would be obtained by multiplying the carcass count by five. A capture efficiency of 20 percent is considered high. The Petersen method is perhaps the most simple, but least accurate, of the various spawning stock escapement methods (Law 1992). It has been used primarily when data are insufficient to allow calculation using the other models. It is occasionally used to calculate estimates for smaller tributary streams (e.g., Cosumnes, Merced, Stanislaus, and Tuolumne rivers), and was incidentally used to calculate the escapement estimate for the lower American River in 1984.

A review of early spawning escapement surveys (Rich 1985a) identified the need for a standardization of methodologies in surveying and estimating escapement populations in the lower American River (see **Table 2-16** and **Table 2-17**). The inconsistencies between various survey methods identified in Rich (1985a) included: (1) differences in the timing of weir installation and removal; (2) survey problems; (3) differences in spawning survey (mark and recapture) methodologies; and, (4) inaccurate and inconsistent spawning escapement estimation methodologies. Rich (1985a) outlined suggestions for improvement.

A detailed evaluation of the Schaefer and Jolly-Seber methods for estimating spawning stock escapement is provided by Boydstun (1992) and Law (1992). Both authors concluded that the Jolly-Seber method was more accurate than the Schaefer method, and that the latter method consistently overestimated actual population numbers. Specifically, Law (1992) found data generated by the Schaefer method to consistently lie outside the 90% confidence interval to the actual population. He also found the Schaefer method to be more acutely affected by changes in capture rates. Consequently, an estimate using the Schaefer method would be expected to progressively overestimate the population, especially when capture and recovery conditions decrease due to high instream flows or associated turbid conditions. Such deviations, however, were not significantly affected by increased tagging rates (Law 1992).

**Table 2-16. Status of past data records for chinook salmon spawning estimates at and above Nimbus Hatchery (Rich 1985a).**

| **Years** | **Status of Data** | |
|---|---|---|
| | Nimbus Hatchery/Problems | Above Nimbus Hatchery/Method of Escapement Estimate |
| 1981-84 | Removal of rack prior to end of spawning season | Counted number of carcasses seen on racks and along shore above racks |
| 1969-81 | | Assumed 85% recovery rate |
| 1968-69 | | Assumed 75% recovery rate |
| 1963-68 | In 1963-64 the weir was damaged and the ladder not in operation until later than usual | Assumed 80% recovery rate |
| 1962-63 | | Assumed 98% recovery rate |
| 1960-62 | | Assumed 91% recovery rate |
| 1957-60 | | Assumed 92% recovery rate |
| Before 1957 | No records available | |

**Table 2-17. Status of past data records for chinook salmon spawning escapement estimates in the American River below Nimbus Dam (Rich 1985a).**

| Years | Status of Data | | |
|---|---|---|---|
| | | Escapement Estimates | |
| | Survey Method Problems | Basic Method Used | Modifications of Basic Method Used |
| 1984-85 | High flows, water clarity, tag recovery | Schaefer (1951) as modified by Taylor (1974) | Combined first three weeks with last two weeks of data |
| 1983-84 | Terminated survey after 1 week, due to high flows | "Guestimate" based on consensus by biologists that run was 20% below previous year's run | |
| 1982-83 | Terminated survey after 4 weeks due to high flows | "Guestimate" based on comparison with 1979 results: assumed 1982 returns = 1979 returns | |
| 1981-82 | High flows, water clarity, tag recovery | Schaefer (1951) as modified by Taylor (1974) | Assumed escapement estimate of first 3 weeks was half total annual run |
| 1980-81 | Tag recovery first 2 weeks | Schaefer (1951) as modified by Taylor (1974) | Added 75 carcasses caught first 2 weeks to third week's tag returns. |
| 1979-80 | Tag recovery problems | Schaefer (1951) as modified by Taylor (1974) | |
| 1978-79 | Ceased survey one week, due to equipment failure | Schaefer (1951) as modified by Taylor (1974) | Added 125 carcasses to total and expanded this number by assuming 15% of tagged fish were recovered |
| 1977-78 | | Schaefer (1951) as modified by Taylor (1974) | |
| 1976-77 | Surveyed only upper portion of reach | Schaefer (1951) as modified by Taylor (1974) | Extrapolated from assumption that section surveyed accommodated 60% of run |
| 1975-76 | | Assumed 20% recovery rate | |
| 1974-73 | | Schaefer (1951) as modified by Taylor (1974) | |
| 1973-74 | Ceased survey one week, due to high flows | Tagged fish and assumed 10% recover rate | |
| 1972-73 | Because carcasses weren't chopped, may have re-counted some fish | Assumed 15% recovery rate | Doubled count from Sunrise Blvd. To Watt Ave., then assumed 15% recovery rate |
| 1971-72 | Because carcasses weren't chopped, may have re-counted some fish | Assumed 15% recovery rate | Doubled count from Sunrise Blvd. To Watt Ave., then assumed 15% recovery rate |
| 1970-71 | Because carcasses weren't chopped, may have re-counted some fish | Assumed 15% recovery rate | Doubled count from Sunrise Blvd. To Watt Ave., then assumed 15% recovery rate |
| 1969-70 | Water clarity some days | Assumed 25% recovery rate | |
| 1968-69 | Water clarity some days | Assumed 30% recovery rate | |
| 1966-67 | Water clarity some days | Assumed 25% recovery rate | |
| 1965-66 | Water clarity some days | Assumed 25% recovery rate in section I; assumed 20% recovery rate in section II | |
| 1964-65 | ? | Assumed 25% recovery rate | |
| 1962-64 | ? | ? | |
| 1961-62 | ? | Assumed 50% recovery rate | |
| 1960-61 | ? | ? | |
| 1953-54 | Water clarity due to pumping | Assumed 7% recovery rate | |
| 1951-52 | ? | ? | |

When the Jolly-Seber method was initiated in 1988, the protocol was to tag both fresh and decayed carcasses. Law (1992) observed, however, that the tagging of only fresh carcasses resulted in further reductions in population estimation under the Jolly-Seber method. Actual population was underestimated when only fresh carcasses were tagged. The Schaefer method provided estimates closer to the actual population when tagging was limited to fresh carcasses. The sensitivity of the two estimation methods relative to tagging fresh carcass only was dependent upon instream capture conditions. The Jolly-Seber method underestimated the population during “poor” capture conditions and overestimated during “good” capture conditions.

Both the Schaefer and Jolly-Seber methods require that certain assumptions be met that, according to both Boydstun (1992) and Law (1992), are difficult to achieve in large rivers. Boydstun (1992), for example, suggested that the capture rates on large rivers are typically too low to use either method correctly, especially since the methods were developed for estimating "live" populations. Additionally, Law (1992) believed that the assumptions dealing with random mixing of released, tagged carcasses and the maintenance of equal probability of recapture for all carcasses are not achievable in large rivers.

*Method Validation*

Method validation also is commonly used to verify year-to-year comparisons of spawning stock escapement. The validity of comparing one year to the next depends upon the level of accuracy. In order to measure the accuracy and precision of the method, it must either be used to estimate the population on a controlled static fish population, or the estimation method must be conducted on multiple years of total fish counts. A validation of the estimation method for the purposes of substantiating year-to-year comparisons has not been conducted for the lower American River. Thus, trends in fall-run chinook salmon population based on annual spawning stock escapement data prior to 1989 should be viewed cautiously, because they represent estimates from a variety of sampling and estimation techniques. CDFG (1997a) cautions that differing methods of field survey and estimation render year-to-year comparisons problematic. Also, Snider et al. (1993) cautions that the estimation methods should be evaluated for sensitivity to changes in flow during and between years. CDFG (1997b) suggested that recapture recovery rates may be associated with the magnitude and consistency of flows along the lower American River during the survey period.

An empirical validation of an estimation method would involve conducting an experiment where a known number of spawners are placed in the river and the estimation technique is tested on that known population. The lifestage dynamics of anadromous fish, however, prohibit this type of testing without physical interference with the actual run. An assessment of the total count of the run while also conducting tag and recapture could provide another means of validating estimates of spawning stock escapement. Total counts can be made in numerous ways including setting up a gate to count passing fish, split-beam bioacoustic monitoring, and closed circuit television monitoring, to name but a few. Even with these methods, however, careful deployment and scientifically sound analyses are required in order to reduce the uncertainty associated with these techniques. In practical terms, it is the expense of setting up, calibrating, and validating these methods that precludes most fishery management agencies from instituting such techniques.

***Estimation Corrections***

Apart from spawning stock escapement estimates based on tag-and-recapture surveys (i.e., carcass surveys), other portions of the entire population should be considered in order to develop an accurate accounting of the entire run. Returning adults often ascend the fish ladder and enter the Nimbus Salmon and Steelhead Hatchery. A significant number of early adult spawners also are capable of traveling past the Nimbus Hatchery training weir. In addition, adult spawners arriving throughout the spawning season have, in years past, been able to pass through gaps in the foundation of Nimbus Hatchery training weir. These fish can either be caught by anglers or die. A portion of the expired fish end up impinged on the weir (see Table 3-2). The hatchery operators routinely record "weir fish." Angling data can be reasonably estimated from creel surveys (see Table 3-2).

In recent years (1992-1999), three different mark-recapture estimation procedures have been used to obtain the estimates of spawning stock escapement: Schaefer, Jolly-Seber, and Peterson (see Table 3-2). A detailed evaluation of the Schaefer and Jolly-Seber methods is provided by Boydstun (1992) and Law (1992). From 1992 through 1995, the estimation procedure used consistently were the Schaefer or Jolly-Seber methods. From 1996 through 1999, the Schaefer and Peterson methods were preferentially utilized. Additionally, during this time (1996-1999), an attempt was made to account for hatchery spawners, weir fish, and estimates of fish lost due to angling and other undocumented losses. In 1999, however, the escapement adjustment of 5,000 fall-run chinook salmon applied to account for angling losses was discontinued (CDFG 2000).

## Population Trends

Annual spawning stock escapement estimates since 1967 are presented in **Figure 2-10**. The highest estimated adult escapement on record was 94,777 in 1973 (with an estimated 82,242 returning adults spawning in the river and the remaining 12,535 adults estimated spawning in the hatchery). During the last 10 years, spawning stock escapement has varied considerably from an estimated low of 4,472 in 1992 to a high of 70,096 in 1995. Last year (1999), it was estimated that there were 48,225 returning fish with an additional estimated 8,361 fish returning to the hatchery.

The Anadromous Fish Restoration Program (AFRP) of the Central Valley Project Improvement Act (CVPIA) has a goal of at least doubling the natural production of anadromous salmonids, including fall-run chinook salmon, over the 1967-1991 baseline period. The AFRP defines natural production as the number of fish not produced in hatcheries that reach adulthood, including adults that are harvested prior to spawning (USFWS 1995).

For Central Valley watersheds, including the American River watershed, the AFRP developed estimates of natural chinook salmon productions by accounting for each of the major adult production components including in-river spawning escapement, hatchery returns, in-river harvest, downstream sport harvest, ocean sport harvest and ocean commercial harvest. The total of these components was then multiplied by the fraction of total production attributed to natural production. For the lower American River, constants were assumed for each year of the baseline period for instream harvest and proportion of total production attributed to the hatchery.

**Figure 2-10. Yearly number of returning fall-run chinook salmon in the lower American River from 1967 through 1999.**

Although the main components included in the estimates of the total production and natural production vary on an annual basis, and therefore inject additional uncertainty into annual production estimates, total spawning escapement (in-river and hatchery returns, combined) serves as one index for comparative purposes. For the AFRP baseline period (1967-1991), in-river spawning escapement averaged 32,307 fish and hatchery returns averaged 8,733 fish, for a combined average of 41,040 spawning escapement (USFWS 1995). For the period extending from 1992-1999, in-river escapement averaged 41,933 fish and hatchery returns averaged 8,320 fish, for a combined average of 50,253 spawning escapement. The increase in average spawning escapement in recent years (1992-1999) relative to the AFRP baseline period (1967-1991) is evident even with the inclusion of the lowest annual estimated spawning escapement (1992) over the entire period examined (1967-1999).

Annual spawning stock escapement appears to be highly variable, and no consistent trend is readily apparent over the entire 1967 through 1999 period. However, in recent years (1992-1999), a general/increasing trend in fall-run chinook salmon spawning escapement can be observed (**Figure 2-11**).

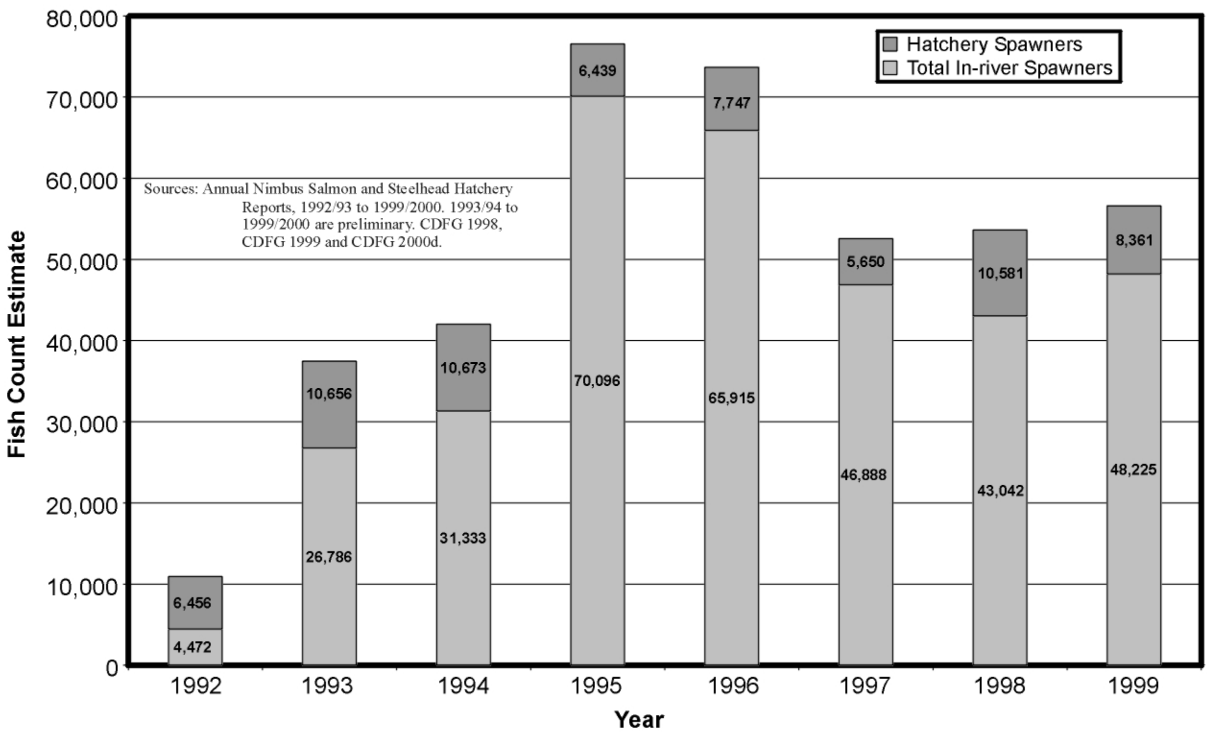


**Figure 2-11. Fall-run chinook salmon spawning stock escapement estimates in the lower American River, 1992-1999.**

### *Key Factors Potentially Affecting Population Trends*

Numerous in-basin and out-of-basin factors affect fall-run chinook salmon production in the lower American River. Regarding in-basin factors, under the conditions that currently exist in the lower American River, river flow and water temperature are two extremely important habitat influences with respect to the overall population of the fall-run chinook salmon. The interrelationship between fish population, flows, and water temperature is complex, with numerous factors influencing the relationships. Detailed discussions of the manner with which either flows or water temperatures affect the various lifestages (and, therefore, collectively the overall status of the fall-run chinook salmon population) is provided in separate discussions, by lifestage, later in this *Baseline Report*.

A general, qualitative consideration of river flow indicates that flow may be associated with fall-run chinook salmon spawning stock escapement. The majority of fall-run chinook salmon adults returning annually to the lower American River are three-year-old fish (see spawning age class, below). In general, the drought period from water year 1987 through 1992 may be associated with the relatively low number of adults returning to the lower American River in subsequent years. Also, the relatively wet period which began in water year 1993 may be associated with the relatively high number of fall-run chinook salmon which have returned since 1995.

Water temperatures, either directly or indirectly, influence survival and function in all fish. This is particularly so for coldwater anadromous salmonids whose life-cycle is complex and highly sensitive to changing water temperature conditions.

A definitive relationship between water temperatures and population status is difficult to establish, however, owing to the complexity of salmonid lifestages and the complex multivariable nature of most hydrologic instream environments. Studies regarding the effects of water temperature in anadromous salmonids have focused on specific lifestages. A compilation of numerous studies regarding temperature effects associated with various lifestages of chinook salmon, particularly fall-run chinook salmon, is presented in **Appendix B**, which is frequently referenced in the remainder of the *Baseline Report*.

<u>*Out-of-basin factors*</u>

Because only a relatively small portion of the lifecycle of anadromous fish is spent in tributaries like the lower American River, an evaluation of the status and trends in lower American River populations must also consider the role of numerous factors that affect production and survival outside the lower American River. Numerous factors have contributed to overall declines in Central Valley populations as a whole since the mid-1800s.

Survival of juvenile salmonids entering the Pacific Ocean, and the factors affecting their survival, is not well known. It is known, however, that the recreational and commercial ocean fisheries harvest a significant proportion of maturing fish that otherwise would return to Central Valley streams to spawn. Also, productivity of the ocean environment varies from year-to-year and can affect harvest and escapement of individual year classes (see Mysak 1986). Ocean effects can be more significant now that the age structure of most runs, late fall run being the possible exception, has been truncated so that escapement is generally dominated by three-year olds (see Reisenbichler, 1986). Without the 4, 5, and 6-year olds to buffer the effects of changing environmental conditions, years of low ocean productivity can result in wide variations in catch and escapement.

### *Ocean Harvest*

As with other populations of fall-run chinook salmon in the Central Valley, fall-run chinook salmon of the lower American River have been subjected to increasing ocean harvest rates over the years. Recent analyses of commercial and sport fishery data and salmon production estimates indicate that the proportional harvest (i.e., fraction of total production that is harvested) of Central Valley chinook salmon has been increasing by 0.5% per year for the last 40 years, for a total increase of about 20%. Until the late 1990s, harvest rates averaged 73% of total production, about twice the levels at which wild stocks can be sustained, but acceptable for hatchery stocks (The Bay Institute 1998). The recent upward trend from the early 1990s in spawning escapements in the lower American River may be due, in part, to harvest restrictions imposed in recent years.

Overall escapement to Central Valley streams has varied dramatically over the past three decades, especially since the early 1980s. Concurrently, ocean commercial and recreational harvest also has varied widely, with the commercial fishery catching most of the fish. **Figure 2-12** is a graph of the indices showing the fraction of the total number of adult salmon harvested in the ocean (catch divided by catch plus escapement, 1970-1999), indicating that the index has dropped from more than 70% from 1985 through 1995 to near 50% in the past few years.

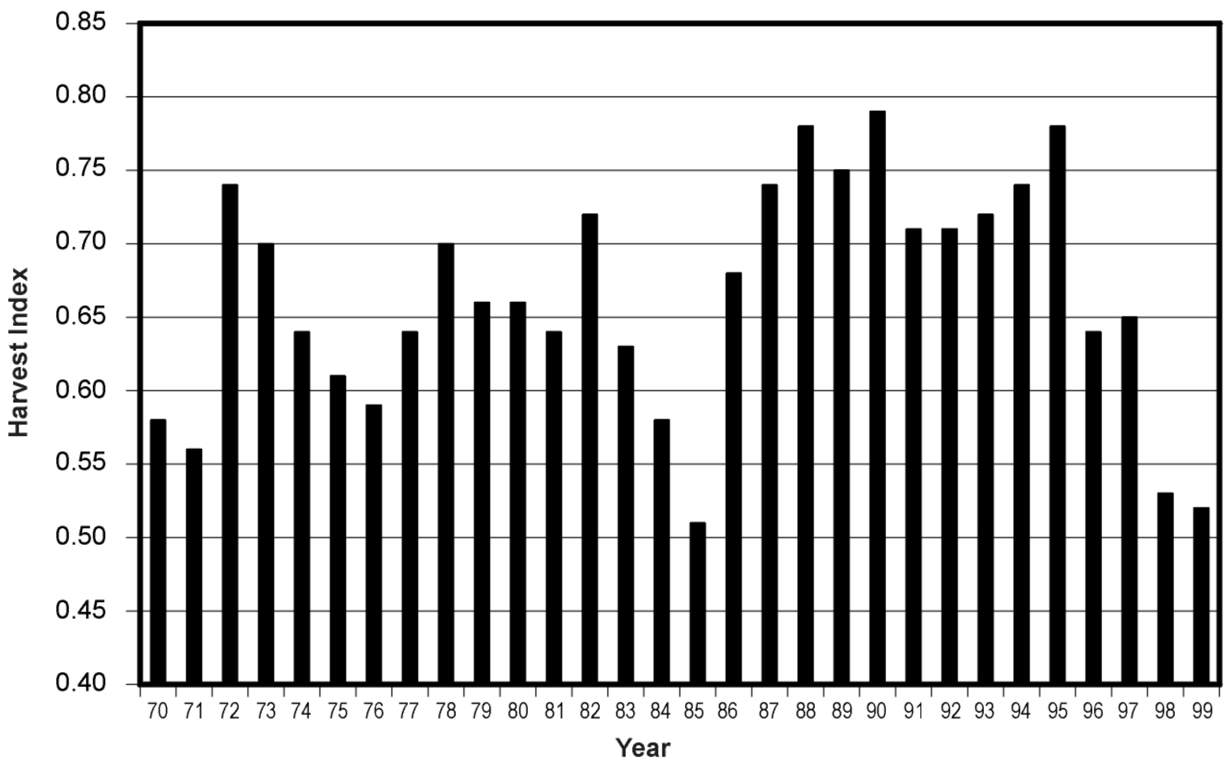


**Figure 2-12. Central Valley chinook salmon ocean harvest indices, 1970-1999. The Central Valley Index is comprised of ocean harvest of chinook salmon off all stocks south of Point Arena, California, and spawning escapements of all races of chinook salmon into the Central Valley, excluding inland recreational harvest. The harvest index is the ocean catch divided by the sum of ocean catch and Central Valley spawning escapement.**

Although the decline in percentage harvested can be due to many factors, it is at least in part due to changes in ocean fishing regulations to protect weak stocks such as the Sacramento River winter-run and Klamath River fall-run chinook salmon. If this trend continues, in upcoming years greater percentages of salmon will be returning to Central Valley streams including the American River. Changes in ocean harvest must be taken into account when assessing freshwater salmon enhancement activities.

One other aspect of ocean harvest and escapement – changes in hatchery practices - needs to be considered when evaluating the use of escapement data as an indicator of response to inland restoration. Although the data are somewhat limited, Dettman and Kelley (1987) and Cramer (1992) have shown that releases from Central Valley hatcheries, in particular the Coleman National Fish Hatchery, the Feather River Hatchery and the Nimbus Fish Hatchery, are the largest contributors to ocean catches. In recent years, CDFG has been using net pens to release a portion of Feather, American and Mokelumne river production into San Pablo Bay. In this technology, juvenile salmon are moved from transport trucks into the net pens, the pens towed towards the center of the bay before releasing the fish. This release strategy minimizes losses when compared to releasing fish directly from transport trucks to the bay shoreline. Preliminary unpublished CDFG data indicate that survival to the ocean fishery is enhanced by this release strategy. Analysis of subsequent escapement should consider the implications of changes in release strategy as well as any other changes in hatchery practices.

*Ocean Conditions*

Although no specific analyses have been conducted on lower American River salmonids, ocean conditions have been demonstrated to affect anadromous salmonids in California. For example, ocean conditions is one of the primary factors limiting anadromous salmonids (including chinook salmon and steelhead) in the upper Eel River, California (SEC 1998). The issue of ocean conditions limiting anadromous salmonids is further emphasized by the written testimony of David W. Welch, Ph.D., to the Committee on Energy and Natural Resources, United States Senate on June 9, 1999. Regarding the recent decline in Pacific salmon abundance, Dr. Welch stated that "*…the primary cause of the sharp declines has been a change in ocean survival.*" Dr. Welch explained that this reduced survival may be due to increasing ocean temperatures in the northeast Pacific, which may be caused by global warming.

Cramer (1992) reported a correlation between anadromous salmonid catch and an index of ocean upwelling off California. Hare et al. (1999) used principal component analysis of salmon catches and ocean conditions to suggest that differences in the ocean environment had significant effects on catch. Ocean conditions were related to climate associated with the Pacific Decadal Oscillation. The analyses suggested that the multi-decade ocean regimes alternately favored Alaska stocks and west coast stocks returning to Washington, Oregon and California. British Columbia stocks were intermediate. In the past several years unfavorable ocean conditions may have limited west coast salmon stocks. Hare et al. (1999) further suggested that ocean conditions were most important in the first few months after juvenile salmonids entered the marine environment. Finally, Adams et al. (2000) found that chinook salmon in the Gulf of Farallones fed in a predictable seasonal cycle involving Pacific herring, anchovies, juvenile rockfish and a euphausid. The seasonal diet cycle broke down during El Nino events, and the salmon had lower body weight and loss of condition. Peterson (1989) compiled an exhaustive examination of the various aspects of climate variability in the Pacific Ocean, although the effects on salmonids are not specifically discussed.

*Delta Factors*

Mortality of chinook salmon outmigrants in the Delta has probably increased since the 1950s. Sources of mortality include:

- Changes in flow patterns and migration pathways in the Delta resulting from changes in the magnitude and timing of freshwater inflows, Delta export pumping, and operation of the Cross Channel gates;
- Increases in entrainment and predation at the state and federal export pumps and other diversions in the Delta; and
- Predation, competition, and food limitation resulting from introductions of exotic species to the Delta.

CALFED's Ecosystem Restoration Plan (ERP) discusses the potential effects of Delta ecosystem management on the health of the chinook salmon population. It states that the key to improving chinook salmon populations will be maintaining populations through periods of drought by improving streamflow magnitude, timing, and duration; reducing the effects of southern Delta CVP/SWP export pumps, which alter Delta hydrodynamics, juvenile rearing and migration patterns, as well as cause entrainment at the facilities; and reducing stressors such as unscreened water diversions, high water temperatures, and harvest of naturally spawned salmon.

Juvenile salmon leaving the lower American River must pass through the Delta on their way to the ocean. The US Fish and Wildlife Service, as part of the Interagency Ecological Program, has studied survival of juvenile outmigrants for the past three decades. Although much of their work has focused on salmon smolts, it does shed light on overall juvenile salmon survival in the Delta.

Four Delta features are of particular importance to juvenile outmigrants: the Delta Cross Channel; Georgiana Slough; and the State and federal water projects diversions in the South Delta. Their roles in salmon survival are discussed below.

***Delta Cross Channel***

USBR constructed the gated cross channel in the early 1950s to allow more Sacramento River water to move into the interior Delta towards the Central Valley Project intake in the South Delta. The manually operated gates were typically closed when flows in the Sacramento River exceeded 25,000 cfs. USFWS studies indicated that, when the gates were open, marked releases of juvenile chinook salmon leaving the Sacramento River by way of the cross channel had significantly lower survival indices to Chipps Island than those released in the river below the gates. Although the exact causes of the lower survival have not been pinpointed, they were assumed to be due to the longer pathway to Chipps Island for those fish traversing the Delta, compared to those juveniles that remained in the mainstem Sacramento River. The longer pathway exposed them to predators and the effects of the South Delta diversions.

With listing of winter-run chinook salmon and the subsequent biological opinion on Central Valley Project and State Water Project operations, operation of the cross channel gates has been modified with the goal of protecting emigrating salmon. From October 1 through the end of January, the gates are typically open when Sacramento River flows are below 25,000 cfs, although gate closures can be requested to ensure better juvenile salmon survival. During the period February 1 through May 20, the gates are closed. Deteriorating Delta water quality conditions may result in opening the gates to allow Sacramento River water to push out intruding salt water. Balancing water quality and salmon protection is accomplished through a combination of real time data acquisition and analysis by the Data Assessment Team, the Operations and Fish Forum, and the CALFED Water Operations Management Team. CALFED and the Interagency Ecological Program have recently focused studies on the cross channel to develop a better understanding of biological and physical impacts of gate operation.

***Georgiana Slough***

Georgiana Slough, a natural channel leading from the Sacramento River to the interior Delta, is located just downstream of the cross channel near the town of Walnut Grove. As with the cross channel, flows from the Sacramento River into the slough vary with stage in the Sacramento and San Joaquin rivers, which in turn varies with flow and tidal stage. Releases of marked juvenile hatchery salmon in and downstream of Georgiana Slough have demonstrated that salmon released the slough survive to Chipps Island (and the ocean fishery) at a lower rate than those remaining in the river. Unlike the cross channel, there is presently no operational means of excluding emigrants from Georgiana Slough, nor of controlling the amount of flow entering the slough.

***CVP Intake Near Tracy***

The USBR constructed the 4,600 cfs intake to the Delta Mendota Canal in the mid 1950s. The intake is screened with a behavioral barrier (louver screen) to divert fish larger than about one inch to holding tanks, where operators periodically collect samples to identify and measure the collected fish. The collected fish are then loaded into tanker trucks and transported to release sites. Transport frequency depends on the numbers of fish being collected and provisions of the winter-run chinook salmon and delta smelt biological opinions that may mandate specific hauling schedules. The biological opinions also contain specific incidental take provisions and, when necessary, project operations may be modified to keep take below allowable limits. For chinook salmon, calculated take consists of prescreen losses (estimated at 15%), through-screen losses (calculated based on screen efficiency at various flows) and hauling and handling losses. These losses are derived from estimates of number of juvenile salmon salvaged at the intake.

The intake's location on Old River, which originates on the San Joaquin River near Stockton, influences the source of the juvenile salmon entrained and salvaged. Most of the salvaged fish originate in the San Joaquin system: however, some juvenile salmon from the Sacramento River system do find their way across the Delta to the federal intake.

***SWP Intake Near Byron***

Whereas the federal intake diverts directly from the Delta and generally operates around the clock, water for the State Water Project (SWP) is diverted during the higher tidal levels into a regulating reservoir, Clifton Court Forebay. Pumping capacity at the SWP intake is approximately 10,300 cfs, although environmental, regulatory and operational measures generally limit maximum pumping to less than 7,000 cfs.

Estimated prescreen losses are 75% at the SWP intake, mainly because mark-recapture studies using hatchery salmon have shown high losses as the fish move across the Forebay to the salvage facilities. Through-screen and handling and trucking losses are similar to those experienced at the CVP facility.

Captures at the CVP and SWP export facilities of marked juvenile salmon released on the Sacramento River above the cross channel and Georgiana Slough demonstrate that some Sacramento River fish find their way across the Delta, and that a higher percentage of these releases are captured at the SWP facilities relative to the CVP facilities. Typically the percentage of juveniles released on the Sacramento River recovered at the facilities is on the order of 1-2%, in part due to mortality as they move across the Delta.

The combination of the Delta cross channel, Georgiana Slough and the CVP and SWP intake facilities in the South Delta, river flows and other environmental variables act to influence juvenile salmon survival in the Delta in ways that are not completely understood. In recent years, salmon survival through the Delta, in particular for those fish originating in the Sacramento watershed, should have improved. Cross channel gate closures, incidental take statements, flow augmentation, and operational restrictions are intended to increase survival of all salmon races and steelhead. In the 2000-2001 outmigration season, another measure, CALFED's Environmental Water Account (EWA), also is available to provide additional flow augmentation.

## Population Characteristics

### *Spawning Age Class*

Estimation of the age-class distribution of adults returning annually to the lower American River is derived from recovery of tagged fall-run chinook salmon at the Nimbus Hatchery. Tagged fish recovered at the Nimbus Hatchery come from several sources including Feather River Hatchery tagged fish, Mokelumne River Hatchery tagged fish, as well as Nimbus Hatchery tagged fish. Nimbus Hatchery chinook salmon tagging ceased in 1989, and Nimbus Hatchery tagged fish have not been recovered at the hatchery since 1992. **Figure 2-13** presents a plot of adult age class return data for tagged chinook salmon at the Nimbus Hatchery for the period 1956 through 1999. Based on these return data, almost 70% of all returning adults were in the 3-year old age class. Smaller proportions of the returning adults were in the 2- and 4-year old age classes. Grilse typically make up a smaller portion of the total return adult spawners. **Figure 2-14** reveals that based on size criteria, grilse make up, on average, about 13% of the total fresh carcasses found during the period 1967 through 1999.

### *Percent Male/Female Spawners*

The relative abundance of female adult fall-run chinook salmon spawners is presented in **Figure 2-15**. Based on recent data (1991-1999), females comprise slightly less than 50% of the total spawning escapement population.

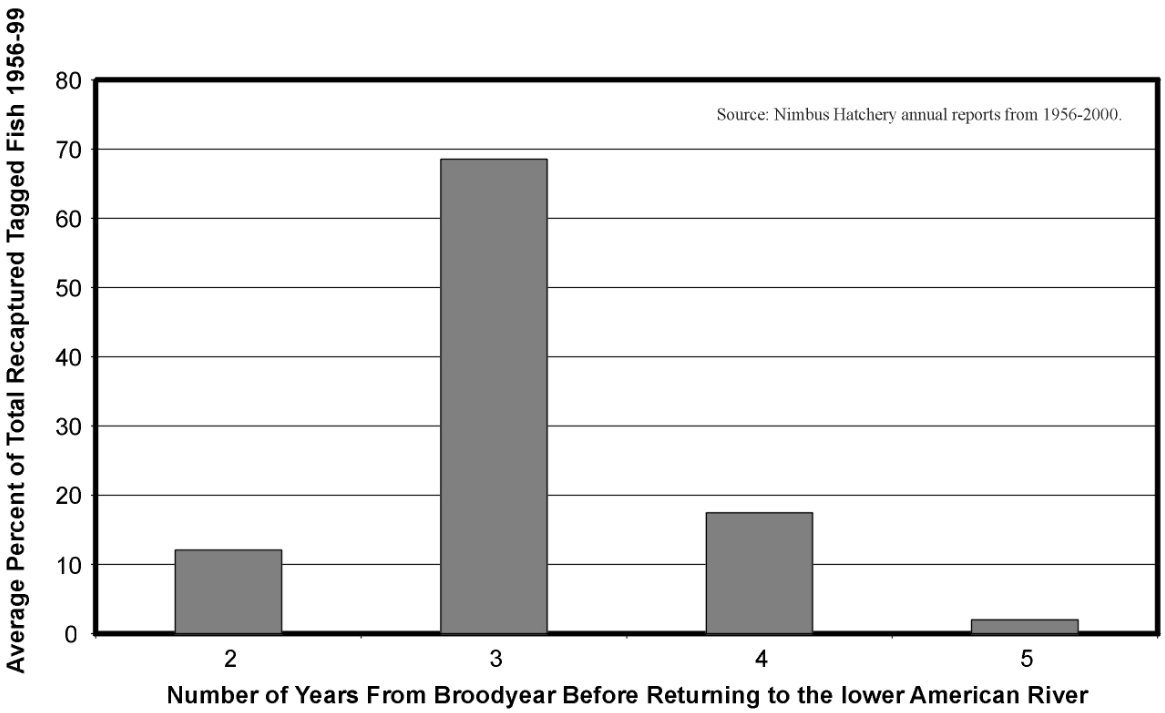


**Figure 2-13. Tagged chinook salmon returns as an average percentage of total recaptured tagged salmon in the lower American River from 1956 to 1999. Data used to produce this chart was compiled from annual hatchery data and was not the subject of a hatchery study nor was this data consistently recorded in the hatchery reports.**

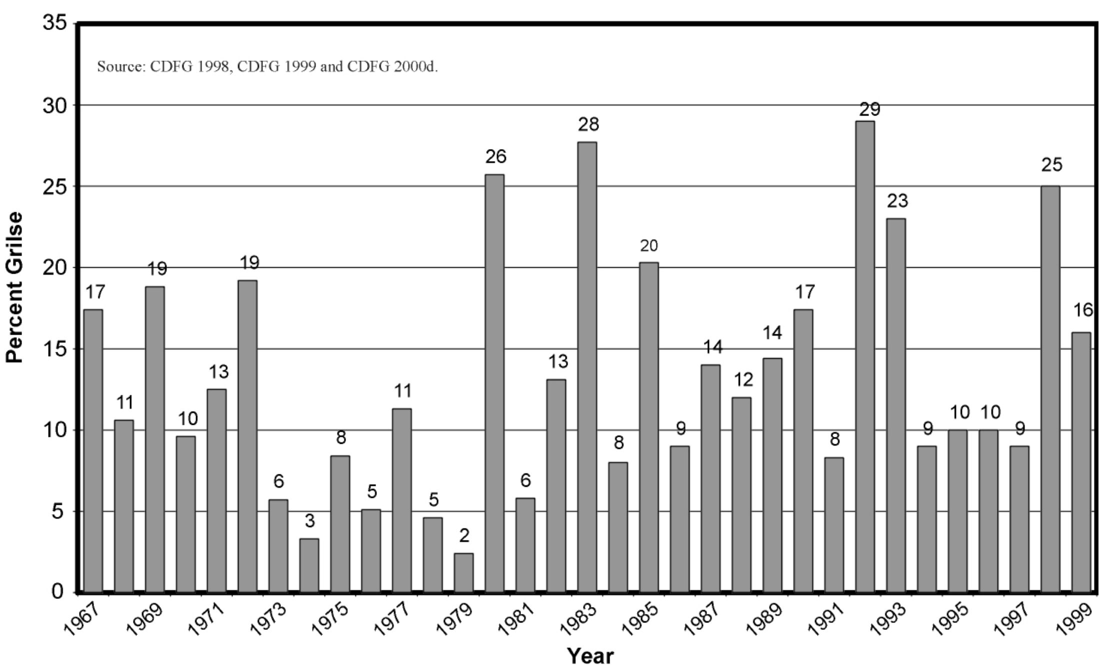


**Figure 2-14. Percentage of fall-run chinook salmon grilse as part of the total number of fall-run chinook salmon returning to the lower American River, 1967-1999. Grilse are fish smaller than 68 cm. Their counts are based on the percent of fresh carcasses found.**

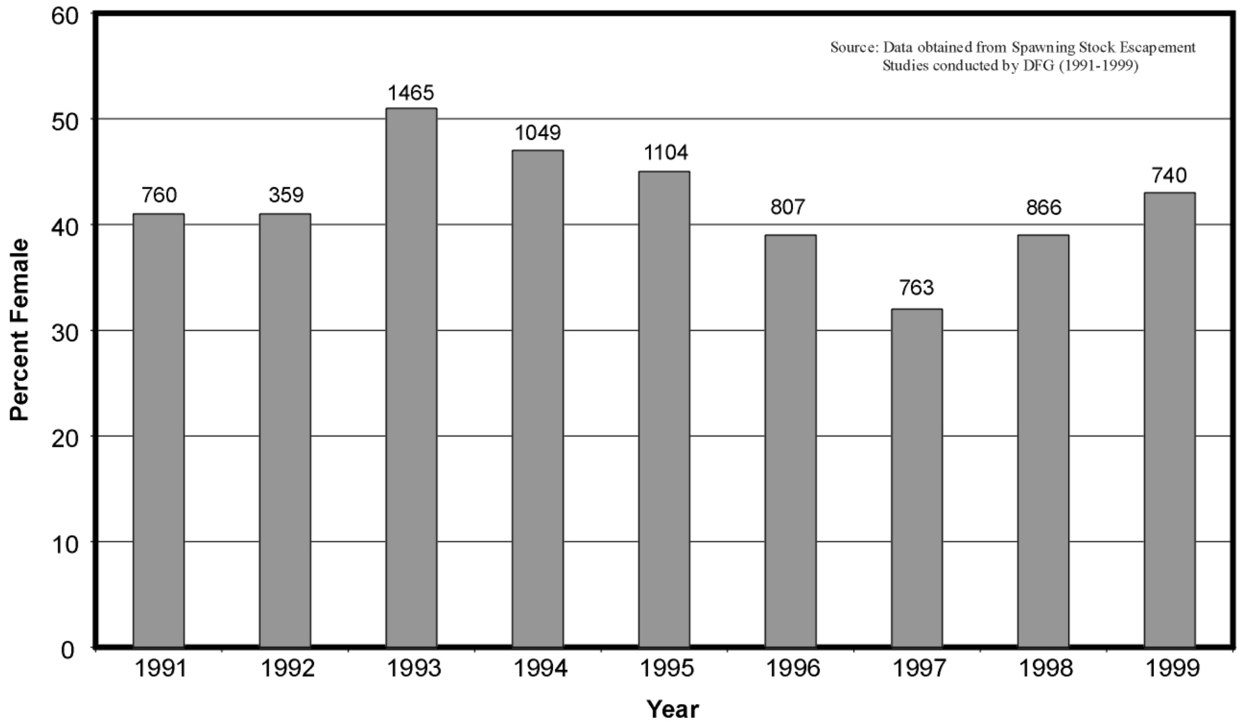


**Figure 2-15. Percentage of female fall-run chinook salmon as part of the total instream escapement population in the lower American River from 1991 to 1999. Numbers at the top of each column represent sample size.**

### *Size of Spawners*

The majority of the returning fall-run chinook salmon spawners are represented by three-year-old fish. As discussed previously, the remainder of the returning adult distribution consists of 2-year old grilse and 4-year old adults. Examination of length-frequency distribution of adult fall-run chinook salmon returning to spawn in the lower American River indicates that: (1) the size of the entire sample generally ranges from about 45-115 cm fork length (FL) annually; (2) no trend is readily apparent regarding size of returning spawners over the years examined; (3) no trend is consistently or readily apparent regarding the size distribution between males and females; and (4) no trend is consistently or readily apparent regarding the size distribution of either males or females over the course of an individual spawning season (CDFG 2000a; Snider and Bandner 1996; Snider et al. 1993).

For illustrative purposes, a fairly typical length-frequency distribution of fall-run chinook salmon, based upon the most recent (1999) spawning stock escapement estimation survey, is presented in **Figure 2-16**.

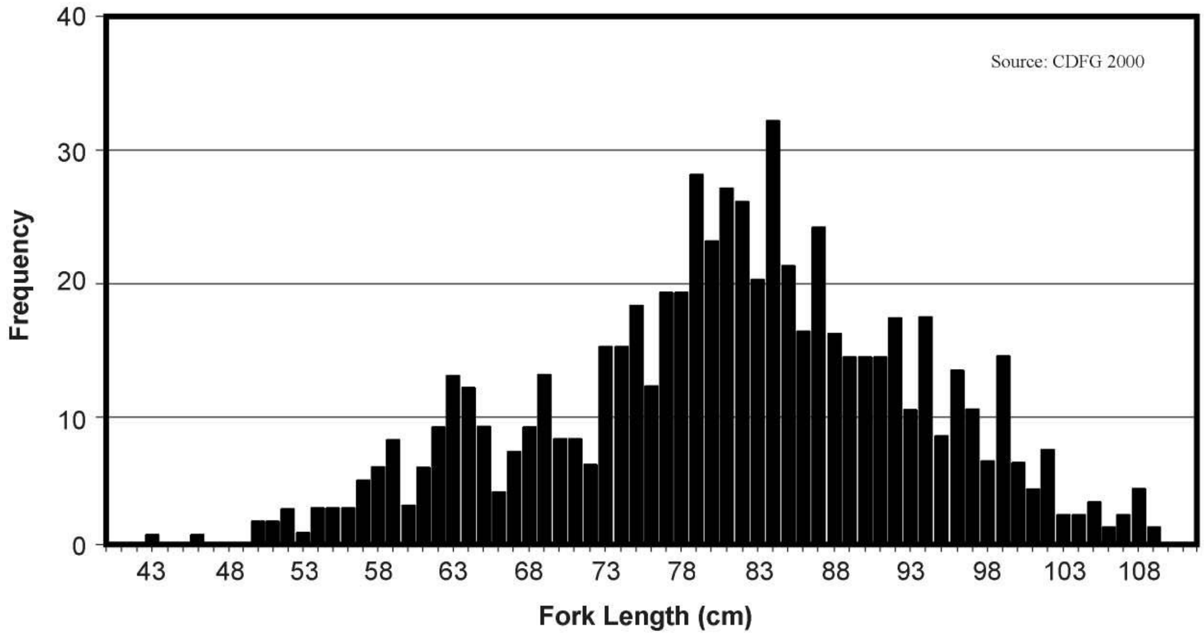


**Figure 2-16. The length frequency of chinook salmon in the lower American River during the 1999 spawning run.**

### 2.2.2.2. ADULT UPSTREAM MIGRATION

#### Temporal Distribution

Adult fall-run chinook salmon typically begin entering the lower American River in September and October, and continue through January. Both historic (fish passage at Old Folsom Dam, 1944 - 1946) and recent (i.e., 1991 through 1999) survey data indicate that adult chinook salmon arrivals in the lower American River peak in November. These data also indicate that typically over 90% of the run has entered the river by the end of November.

Because the arrival distribution of chinook salmon is dictated largely by maturation, photoperiod, and other seasonal environmental cues, it tends to be somewhat temporally similar from year-to-year in the lower American River. As demonstrated in the last ten years of spawning escapement surveys, redd surveys, and hatchery data, adults can arrive as early as July and extend to February, depending on the annual hydrology and water temperature conditions of the lower American River, as well as out-of-basin factors.

The length of time that fall-run chinook salmon spend in the lower American River prior to spawning is not specifically known. Results of biotelemetry studies conducted on the upper Sacramento River at the Red Bluff Diversion Dam (RBDD) indicate that fall-run chinook salmon may stay in the river for time periods ranging from several days to over one-and-a-half months between arrival in the upper river at RBDD and observed movement onto the spawning grounds both upstream and downstream of the dam. These results suggest that fall-run chinook salmon can spend considerable time in a river near their spawning grounds prior to spawning.

## Factors Affecting Temporal Distribution of Upstream Adult Migration

Historically, fall-run chinook salmon could migrate to the upper reaches of the American River unabated by prohibitive physical obstructions. Under such conditions, they were transiently exposed to the warmwater temperatures of the Delta and lower reaches of the Sacramento River before entering and ascending to cooler upstream reaches of the lower American River. Under current conditions, exposure to the cooler waters of the lower American River is dependent largely on the operations of Folsom and Nimbus dams in their regulation of flows and associated water temperatures.

***Water Temperature***

Upstream migrating fall-run chinook salmon may be exposed to elevated water temperatures in the lower American River depending on the time at which they enter the river and the duration of holding prior to spawning. Based on observed holding times of fall-run chinook salmon in the upper Sacramento River, similar holding times may occur in the lower American River.

Organisms respond to extreme high and low temperatures in a manner similar to the dosage-response pattern that is common to toxicant effects. Each fish species has a maximum upper thermal limit (often defined as the "incipient lethal temperature") that it can tolerate for short periods of time. Incipient lethal temperatures are the levels that will eventually cause the death of a stated fraction of the test organism—usually 50% (Warren 1971). High mortality is a result of the poor physiological performance and resultant changes in interspecies competition, disease, predation and other key ecological factors that occur at near-lethal temperatures (Fry 1967; USEPA 1973; Alabaster and Lloyd 1980). Fish tend to occupy habitats having water temperatures within the species' thermal tolerance range that are somewhat below their upper incipient lethal temperature limit (Baltz et al. 1987; Cech et al. 1990).

The effects of elevated water temperatures on adult chinook salmon are reported in several controlled lab and field studies. Marine (1992) reported that chinook salmon broodstock are considered to be thermally stressed and prone to lower handling tolerance when hatchery holding pond temperatures exceed 59°F. Confinement, handling, and thermal stresses can collectively act to effectively reduce the thermal tolerance of wild salmon broodstock under hatchery holding conditions.

The literature suggests that for chronic exposures, an incipient upper lethal temperature limit for pre-spawning adult salmon probably falls within the range of 62.6°F to 68°F (see Table 3-6). However, adult chinook salmon have been observed to tolerate short-term and transient exposure to temperatures ranging from 77°F to as high as 80°F during spawning migrations (DWR 1988; Piper et al. 1982).

Estimates of energetic costs due to increased stress velocities, delays at dams, and elevated water temperatures indicate potential detrimental effects on reproduction for both sockeye salmon and chinook salmon (Berman 1990; Berman and Quinn 1991). Exposure to elevated temperatures upon entering the river prior to spawning may result in fatty acid complements sequestered in the ova that are inappropriate for proper embryo development under declining temperatures during the late fall months.

The extent to which elevated river temperatures may be bioenergetically affecting the reproduction of early arriving fall-run chinook salmon in the lower American River is unknown. However, bioenergetic optimization through selection of cooler water temperatures when available is clearly important to pre-spawning chinook salmon, as shown by Berman and Quinn (1991) who demonstrated a pattern of behavioral thermoregulation for pre-spawning Yakima River spring-run chinook salmon. In this study, adult salmon outfitted with temperature sensitive radio transmitters consistently found cooler thermal refuges during the pre-spawning period, and maintained an average internal body temperature that was 4.5ºF below ambient river temperature. This behavioral thermoregulation accounted for an estimated energetic savings of 12 to 20 percent. In the lower American River, two potential opportunities, longitudinal and vertical temperature differentials, exist for adult fall-run chinook salmon thermoregulation.

*Longitudinal Temperature Gradient*

During the early portion of the adult fall-run chinook salmon upstream migration period (i.e., September and October) a longitudinal temperature gradient often occurs in the lower American River. Water temperatures at downstream locations can be up to several degrees warmer than at upstream locations. Water temperatures at various locations along the lower American River during the fall-run chinook salmon adult upstream migration period for 1999 are presented in **Figure 2-17**, as one example.

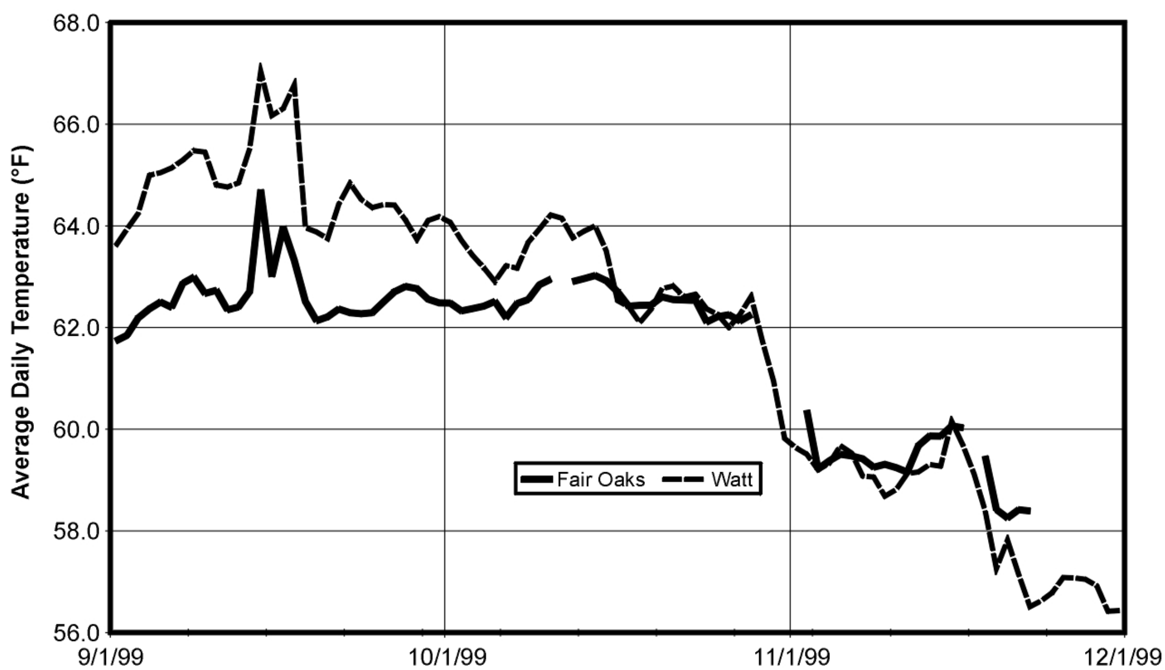


**Figure 2-17. Average daily temperatures at Fair Oaks Boulevard (RM 22) and at Watt Avenue (RM 9.5), September through November 1999.**

During the early portion of the adult upstream migration period in the lower American River (i.e., September and October), water temperatures can reach monthly averages of up to 65°F at Watt Avenue and even higher within the migration corridor (mouth to RM 5).

Vertical Temperature Stratification

Relatively little examination of the potential for vertical water temperature stratification has been undertaken on the lower American River. In July 1991, a deep pool survey was conducted by the CDFG in the lower American River (CDFG unpublished data). The deeper pools of the lower American River were sampled with the main intent of determining whether or not there was any temperature stratification within the pools. Sampling reconnaissance was conducted in July 11, 1991. A total of nine pools with depths greater than eight feet were sampled. The pool locations were as follows:

1. Old Fair Oaks Bridge, downstream side;
2. Approximately one-half mile upstream of Claybanks;
3. Claybanks (Elmanto Dr. access);
4. Ancil Hoffman park;
5. Arden Bar (approximately one-quarter mile upstream of Gristmill);
6. CSUS (between the Guy West and H Street bridges);
7. Approximately one-half mile downstream of the Business 80 and Southern Pacific rail bridges;
8. Between the rail and pedestrian bridges, upstream of Hwy 160 bridges; and
9. Between the pedestrian bridge and Hwy 160 bridges.

Depth and temperature data were collected from three points located diagonally across the width of each pool. The flow was approximately 4,250 cfs and temperature stratification did not occur in any of the pools. Temperature ranged from 58.1 to 59.9ºF. The greatest depth measured 28 feet. The survey was conducted again on August 20, 1991. The flow was still relatively high (2,250 cfs), six pools (1,3,4,5,6, and 9) were sampled, and no stratification occurred. Thus, available information indicates that vertical temperature stratification does not exist in the lower American River, at least over the range of flows examined.

***Water Depth***

Water depth in the lower American River is not a factor for migrating adult chinook salmon. The lower American River is a large perennial river with water depths well above those minimally necessary (1 to 2 feet) for successful migration, even during very low flow (e.g., 250 cfs) conditions.

***Infectious Disease***

The most definitive data on the effects of elevated water temperatures on adult chinook salmon are related to critical thresholds affecting acute mortality and disease outbreaks, both in hatcheries and in the wild. The deteriorating physiological condition of Pacific salmon upon their seasonal maturation and upstream spawning migration render them vulnerable to environmental stressors, such as elevated water temperature. Opportunistic pathogens can gain advantage over the salmon's natural immuniological defenses, resulting in disease (Marine 1992).

Elevated water temperatures can impose metabolic and physiological stresses, which can impair immuniological functions in salmonids and increase their susceptibility to disease. The stress that can be caused by exposure to elevated water temperatures in adult chinook salmon may exacerbate the already-compromised immune system that results from the dramatic physiological stresses associated with re-entering freshwater and final sexual maturation (Marine 1997).

Many of the previously described reports of temperature-induced pre-spawning mortality in chinook salmon mention associated pathogenic causes for this mortality (Marine 1992). The disease organisms which are most commonly reported in adult chinook salmon include *Aeromona salmonicida* (Furunculosis), *Ceratomyxa shasta* (Ceratomyxosis*), Flexibacter columbaris* (Columnaris Disease), *Dermatocystidium* spp. and *Saprolegnia* spp. (Fungal Diseases), *Renibacterium salmoninarium* (Bacterial Kidney Disease), and Infectious *Hematopoitic Necrosis* Virus (IHNV) (Marine 1992). With the exception of bacterial kidney disease and IHNV, the pathogenicity of these disease organisms increases as water temperatures rise over the range from 55°F to 81°F. Bacterial kidney disease, IHNV, and Furunculosis can be vertically transmitted to eggs and larvae through ovarian and seminal fluids. Therefore, the diseases that can be carried by adult chinook salmon potentially can be activated by chronic exposure to high river temperatures and passed on through the gametes to affect the subsequent survival of their offspring.

#### 2.2.2.3. INSTREAM SPAWNING AND INCUBATION

Female salmon select a suitable site to construct a spawning nest (redd) and defend this site against intruders, particularly other females. Redd construction is accomplished by the female turning on her side, placing her tail against the streambed surface material (substrate) and lifting her tail and body upward with a powerful muscular contraction, or flection. The resultant hydraulic suction loosens stones and finer material, which are then carried downstream by the water current. Repeated flections eventually produce a well-defined pit. Once the pit is constructed, the female and attendant male(s) simultaneously release their eggs and milt into the bottom of the pit. Immediately following the spawning act, the female salmon moves slightly upstream and, with repeated flections, buries the fertilized eggs under a mount of gravel carried downstream by the current. Breeding activity of individual pairs of chinook salmon may extend a week or longer. Soon after the spawning act, the male abandons the female salmon. The female, however, continues to defend the redd and the surrounding territory up to four additional weeks (Briggs 1953). This territorial behavior probably results in increased reproductive success when multiple fish are simultaneously present on the spawning grounds. Disturbance of a redd by subsequent spawners (redd superimposition) can cause mortality to developing embryos by exposure, predation, shock and trauma.

Eggs deposited in redds incubate until hatching, at which time they are referred to as alevins. Alevins remain in the gravel until most of the egg yolk is absorbed, and then begin to emerge from the gravel. Although the intragravel residence period of incubating eggs and alevins is highly dependent upon water temperature, the estimated intragravel lifestage period in the lower American River generally extends from about mid-October through March. Survival of chinook salmon eggs is believed to decrease rapidly when incubation temperatures exceed approximately 56°F for much or all of the incubation period (USBR 1991).

## Annual Redd Surveys

Fall-run chinook salmon spawning activity in the lower American River was intensely monitored for five consecutive years between mid-October and mid-January 1991 through the spawning period of 1995/96. Surveys also have been conducted subsequent to this period, but results have not been reported. Aerial photography was used to identify the magnitude of spawning, the temporal and spatial distribution of spawning, and the occurrence of redd superimposition. Aerial redd surveys, combined with field validation surveys, provide additional information on the potential limits imposed on chinook salmon spawning by the availability and characteristics of suitable spawning substrates (i.e., gravels) and flow regimes.

### Methodology

***Survey Method***

Since 1991, CDFG has conducted annual redd count surveys on the lower American River. Reports for years 1991 through 1995/1996 have been generated by CDFG and are the basis of this discussion. The study area covers an 18-mile section of the river from near Paradise Beach to the base of Nimbus Dam. The four reaches include: Reach 1 – Paradise Beach to Watt Avenue (RM 5 to 10); Reach 2 – Watt Avenue to Ancil Hoffman Park (RM 10 to 16); Reach 3 – Ancil Hoffman Park to Clay Banks (RM 16 to 18); and Reach 4 – Clay Banks to Nimbus Dam (RM 18 to 23). According to CDFG, the remaining five-mile-long reach downstream of Paradise Beach to the mouth of the American River does not contain potential salmon spawning habitat and was, therefore, excluded from the surveys (Snider et al. 1993).

CDFG implemented a double sampling survey procedure to better estimate and generate a measure of error during the first year of the surveys. The sample domain for this procedure was established in the 1991/92 survey and identified 76 of the 202 discrete habitat units containing at least one redd during the 1991/92 survey. These 76 sites represented the sample domain for all subsequent surveys. The applicability of the double sampling method is being evaluated (B. Snider, CDFG, pers. comm., 2001).

The spawning area was surveyed by plane each year and aerial photographs were taken on a weekly basis to record and track new redd construction. The aerial photographs were taken at a scale of approximately 1 inch to 200 feet (1:2400). Individual redds were located on the enlarged photographs and traced onto mylar overlays. Only discrete, newly constructed redds were counted for each flight. Superimposed redds were not reported as new redds. Redd superimposition was determined by comparing the last two successive flight tracings using the mylar overlays. Superimposition of redds was considered to have occurred if the tracings overlapped by at least 50%.

Ground-based redd counts were part of the double sampling procedure to improve accuracy and provide confidence limits for the aerial redd survey. Pool habitats were excluded from the double sampling survey. Each habitat surveyed was classified as being easy- or difficult-to-view, based on shade, vegetative cover and surface-water turbulence. Four samples of each view type were randomly selected to double sample on the ground. Field crews examined the sites either on the same day, 12-hours before, or after the aerial survey. During the 1991/92 assessment, SCUBA surveys were conducted to determine whether deepwater areas, where the river bottom may not have been visible in aerial photographs, were used by spawning chinook salmon. Chinook salmon redds were not observed in such areas. Accordingly, deepwater SCUBA surveys were not included in subsequent surveys.

***Estimation Method***

Double sampling computations are based on theory and procedures outlined in Jessen (1979). The basic procedures were modified to accommodate sample stratification (easy versus difficult to view from the air, and high versus low use areas). All computations were done for each strata with the combined results derived through computational procedures outlined in Hansen et al. (1953).

Adjustment ratios (Eberhardt and Simmons 1987 as cited by Snider 1992) and variances are computed for each strata, weighted, and combined to give overall ratios and variances. CDFG reported in their 1992 survey report that the equations in Cochran (1977), Jessen (1979), and Hansen et al. (1953) were modified to fit the specific design of the lower American River based on consultation with Dr. D. Hankin of Humboldt State University, and J. Geibel of the CDFG Biometrics Unit. CDFG used direct counts of redds from photographs in all years except 1992, when an estimation method was used. Ground reconnaissance efforts were made in each year to calibrate the aerial counts.

#### Annual Redd Count

Aerial fall-run chinook salmon redd counts by flight date, are provided for each year in **Figure 2-18**. Plots represent actual counts from aerial photographs and are not double sampling estimations, since the procedure was only applied for 1992. The 1992 double sampling estimate with 95% confidence was 2,469 ±797.

### Temporal Redd Distribution

Adult chinook salmon migrate into the lower American River and generally spawn from mid-October into January. Peak spawning activity occurs during November as shown in Figure 2-6.

Once in the lower American River, the timing of adult chinook salmon spawning activity is strongly influenced by water temperatures. When decreasing water temperatures approach 60°F, female chinook salmon on the spawning grounds begin to construct redds, into which their eggs (simultaneously fertilized by the male) are eventually released. Fertilized eggs are subsequently buried within the streambed gravel. In recent years, spawning activity in the lower American River has begun during late October or early November, and has continued through December and into January. Due to the timing of adult arrivals and occurrence of appropriate spawning temperatures, peak spawning activity has occurred during mid- to late-November in recent years (Snider and McKewan 1992; Snider et al. 1993; Snider and Vyverberg 1995).

The relationship between declining water temperature in the fall and the initiation of fall-run chinook salmon spawning is illustrated in **Figure 2-19**. Data from the nine years of surveys support the conclusion that the onset of spawning is strongly influenced by a decline in water temperature below 60ºF (Snider and Vyverberg 1995).

**Figure 2-18. Newly constructed fall-run chinook salmon redds, by flight dates, in the lower American River, 1991-1997.**

**Figure 2-19. Lower American River water temperature and fall-run chinook salmon cumulative spawning distributions from 1992-2000.**

The cold water pool in Folsom Reservoir is influenced by numerous factors, not the least of which are inflow, inflow temperatures, diversions, storage, and the volume of cooler, hypolimnetic waters in the reservoir. Water temperatures in the lower American River are also influenced by these factors, and also by decisions upon which elevation to draw these waters for release from the Folsom Reservoir shutters into the hatchery and down the American River. In 1996, for example, water temperatures released from Nimbus Dam were 64 to 65°F over the early part of the month of October. On October 9, the shutters were pulled to provide cold water for chinook salmon spawning in the American River. Within four days, water temperatures had declined from approximately 65°F to 58°F or less for the remainder of the month of October (**Figure 2-20**). The fish responded to the release of cold water. Spawning activity commenced and water temperatures were suitable for chinook salmon spawning throughout the remainder of the fall.

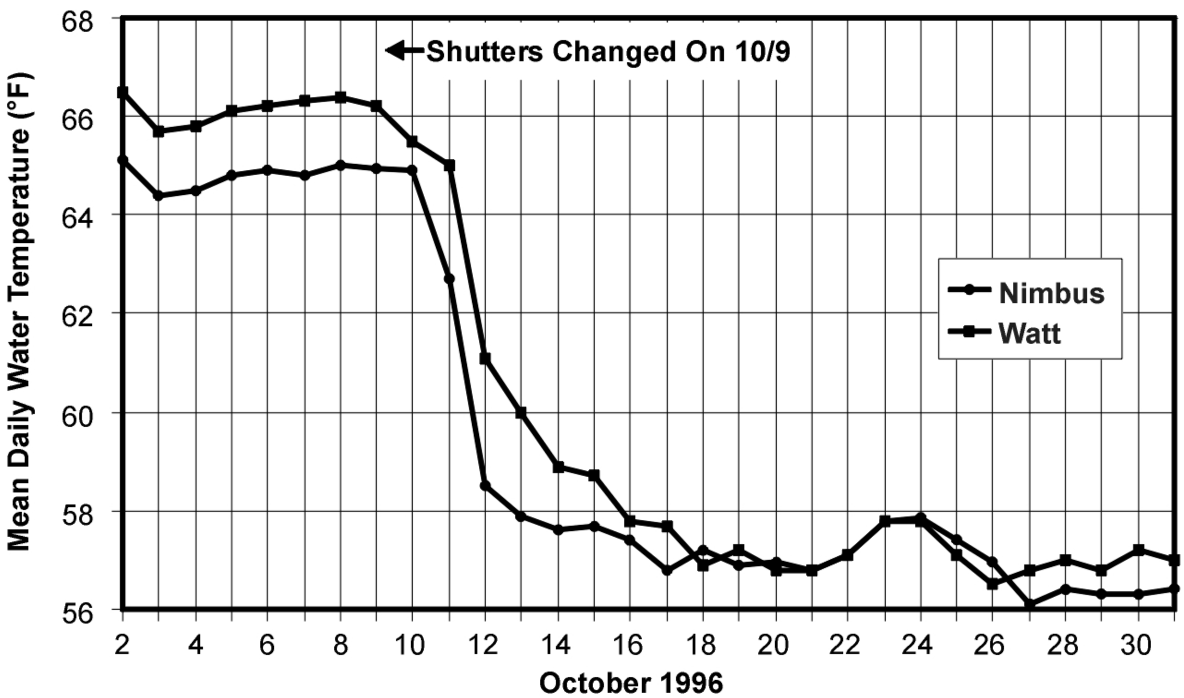


**Figure 2-20. Example of decrease in water temperature at Nimbus Dam and Watt Avenue in the lower American River as a result of manipulation of the powerstock inlet shutters at Folsom Dam during October 1996.**

The combined results of the 1991-1995 aerial redd surveys and the cumulative spawning distribution analyses conducted on the lower American River indicate that spawning distribution is influenced temporally by temperature, and spatially by flow (Snider and Vyverberg 1996).

Groves and Chandler (1999) conducted an actual field experiment on spawning temperatures observed in fall-run chinook salmon of the Snake River and found similar results to those seen on the lower American River. In that study, aerial surveys combined with remote underwater videographs were used to observe fish activity and underwater temperature to monitor the temperatures. Spawning generally began as water temperatures dropped below 16.0C (60.8F).

The temperature means over the entire sample set of redds averaged only 13.6C during the week of spawning initiation indicating that though spawning began at 16C, initial weekly mean temperatures associated more with population behavior was 13.6C. These results are consistent with observations from other investigations conducted through the Pacific Northwest (Burner 1951; Swan 1989; Dauble and Watson 1997). Spawning activity usually begins as weekly mean water temperatures fall below about 16C.

After alevins emerge from the gravel, they begin the rearing and emigration stages of their life histories. The time of fry emergence is dependent upon the timing of previous lifestages and water temperatures, and is estimated to generally extend from late-December through March in the lower American River.

### Spatial Redd Distribution

Spawning escapement studies and redd surveys conducted on the lower American River by CDFG between 1991 and 1999 have produced a substantial amount of information about the spatial distribution of various lifestages of chinook salmon and their use of various reaches and macrohabitats. The surveys for this time period (1991-1999) are of particular interest since they represent the current status of spawning habitat use.

For the years 1991 through 1997, CDFG conducted annual redd surveys along the lower American River. The results of these redd surveys (and a survey conducted in 1984 by McKee [1985]) show the majority of redds accumulated in the uppermost reach of the river, particularly above RM 16. **Figure 2-21** shows redd distribution by river mile for all available redd survey years. In 1991, about 91% of all salmon redds were located in Reaches 3 and 4. In 1992, Reach 4 contained 78% of the redds counted and Reach 3 contained 17%, whereas Reach 2 contained only 3.6% and Reach 1 the balance. In 1993, Reach 4 contained 80.8% of the redds, 12.9 % in Reach 3, and 4.5% in Reach 2. In 1994, Reach 4 had 70.3% of the redds counted, 16.9% in Reach 3 and 10% in Reach 2. In 1995, Reach 4 had 69.7% of the redds, 18% in Reach 3 and 9.5% in Reach 2. The 1996 redd distribution by river mile was somewhat anomalous, but the 1997 distribution returned to that of prior years. The 1996 distribution is clearly distinguishable from other years in that it has a broader distribution and a distinct dominance of redd counts in the middle two reaches, as opposed to the fourth reach.

Redd spatial distribution also changes temporally during the spawning season. In the 1991/92 spawning season, for example, Reach 4 had the highest electivity until late November. Reach 3 had the highest electivity through December to the first part of January, followed by Reach 1 thereafter (Snider and McEwan 1992).

Comparison of mean monthly fall flows for various years with corresponding macrohabitat use further support the concept that flows influence habitat use (Snider and Vyverberg 1995). From river flows of 1,750 cfs during the 1993 redd survey to flows of 2,500 cfs in 1995, the majority of redds have been located in flatwater glides in the upper reaches. At flows less than 1,500 cfs in 1991 and 1994, although the overall reach distribution was similar, the majority of the redds was located in bar-complex runs (Snider and Vyverberg 1996). Given the high selectivity fall-run chinook salmon have shown for flatwater glides for spawning compared to other habitat types, the difference in use of flatwater glides between years may reflect higher suitable flatwater glide habitat availability due to higher flows (Snider and Vyverberg 1996).

**Figure 2-21. The total number of fall-run chinook salmon redds counted, by location, in the lower American River, 1991-1997 and 1985.**

Spawning escapement studies have been conducted for every year between 1991 and 1999, providing information on spawning habitat use by reach. The 1993/94 and 1995/96 escapement surveys are typical of other surveys conducted in the 1990s and illustrate reach distribution of spawning salmon. The reach delineation is different than that for redd distribution, covering a shorter stretch of the river, as shown below.

| REACH | LOCATION | RIVER MILE |
|---|---|---|
| 1 | Sailor Bar to Rossmoor | 22 to 18 |
| 2 | Rossmoor to Goethe Park Footbridge | 18 to 14.5 |
| 3 | Goethe Park Footbridge to Watt Avenue | 14.5 to 9 |

In the 1993/94 survey, most carcasses were counted in Reach 1 (63% of all carcasses, 81% of fresh carcasses). Most fresh carcasses were collected from the upper portion of Reach 1 (above River Mile 20, at Sacramento Bar and Sailor Bar). Counts downstream of River Mile 17 were consistently very low (<10%). In the 1995 spawning escapement survey, most carcasses also were observed in Reach 1 (61% of all carcasses and 75% of the fresh carcasses). At least 69% of fresh carcasses were observed in Reach 1 during all weeks except for the last week of the survey when only one fresh carcass was seen, and that was found in Reach 2.

### Flow/Habitat Relationships

#### Theoretical Spawning Habitat Availability

Flow/spawning habitat relationships have been studied over the past 30 years in the lower American River. Spawning habitat use and availability for fall-run chinook salmon in the lower American River have been shown to be linked to flow. Under high flows (>2500 cfs) more habitat is used by spawners as compared to low flow conditions (<1500 cfs), indicating that suitable habitat availability is directly related to flow at these flow levels.

Previous spawning habitat availability studies focused on gravel availability at various flows. Operation of Folsom and Nimbus dams has reduced recruitment of suitable gravels into chinook salmon spawning areas. Results of the previously conducted redd surveys and reconnaissance gravel characterization study showed that the size distribution of gravels throughout many of the observed spawning areas in the lower American River, particularly in the upper reach of the river, included a disproportionate amount of relatively large cobble. In addition, many of the key spawning areas were characterized by surface substrate that was armored and embedded.

The size of available streambed gravels can limit the success of spawning by salmonids (Groot and Margolis 1991). The bed material may be too coarse for spawning fish to move, a problem particularly common where dams eliminate supplies of smaller, mobile gravels (e.g., Parfitt and Buer 1980). The spawning female must be able to move gravels to excavate a depression in the bed to create the redd although the fish need not move all rocks present.

Spawning gravels in the American River were surveyed by Osgood and Payne (1942), Hallock and Hacker (1950), and by Slater and Warner (1952). The 1942 and 1950 surveys involved only crude estimations of gravel riffle areas during a single flow. The 1952 study was more comprehensive and involved a one-mile long test section located 1.5 miles downstream from Fair Oaks bridge. Gravel composition was determined and water depths and surface velocities were recorded at flows of 400, 500, 900, 1100, 1300, 2700, 3400, and 4500 cubic feet per second. The data collected during the 1952 survey indicated that a stable flow of 500 cfs would provide a maximum amount of spawning habitat in the American River with a sharp decline in spawning area occurring as the flow increased from 500 cfs to 1,300cfs. The study results were used to develop the recommended minimum flow releases that were accepted by the CDFG in 1952. The flows were adopted by the State Water Rights Control Board in Decision 893. Subsequent modification of spawning survey criteria, refinement in survey techniques, and recognition of physical changes in the streambed resulting from the Folsom Project operation caused fish investigators to question the validity of the 1952 study and the adequacy of the flow recommendation for spawning purposes. An extensive survey using different techniques was initiated in 1966.

Two important, more recent studies were conducted on the lower American River in 1966 and 1981 by CDFG and USFWS. Both studies estimated spawning habitat availability at different flows. Results and recommendations from the 1966 CDFG study (Gerstung 1971) served as the basis for instream flow stipulations of the State Water Resources Control Board Decision 1400. The more recent of the two was conducted in 1981 by the USFWS (1983). The two studies used different methods to assess spawning habitat availability and obtained quite different results.

The 1966 CDFG study assessed spawning habitat at five representative reaches ranging from 400 to 2000 feet in length located from 1.2 miles (Sailor Bar) to 13.5 miles (Watt Avenue) downstream from Nimbus Dam. Gerstung (1971) reported the relationship between flow and chinook salmon spawning habitat in the lower American River. The data suggests that more habitat became available as flows increase from 250 cfs to 1,500 cfs in terms of riffle gravel area. In general, estimates of the amount of spawning gravel available at various flows were considerably less than what would come from the USFWS (1983) study estimates of WUA spawning habitat. Over the range of flows examined, the USFWS estimated an average of 1.7 times more spawning habitat available than did CDFG. CDFG spawning area estimates indicated that a flow of 1,250 cfs would accommodate only half as many redds as the USFWS estimates.

In 1981, the USFWS elected to implement an instream flow assessment study using a methodology developed by that agency called the Instream Flow Incremental Methodology (IFIM) (Bovee 1982). It is designed to define a starting condition (e.g., the present environment), and then provide data on incremental changes in the condition. The IFIM can be described as a collection of computer models and analytical procedures which are designed to predict changes in fish habitat due to increments in flow change. The methodology predicts the availability of habitat for fish within a range of specified stream flows based on water depth, water velocity, and substrate. Because the method allows for incremental assessments, it is not intended to generate a single solution, but rather to predict the impacts of different alternatives.

Field implementation of the methodology involves selecting representative river reaches which, when physically described, will characterize habitat conditions for chinook salmon in the lower American River. The USFWS selected four study reaches along the river (Ancil Hoffman, Sailor Bar, H Street and Grist Mill) as characteristic of the 23 miles of the river downstream of Nimbus Dam. At each site a series of transects were established across the river along which the physical variables of water depth, water velocity, and bottom substrate were measured at various flow releases. Measurements were made at flows of approximately 450, 1,200, and 2,475 cfs.

The physical data collected during field measurements were used with a computer program known as PHABSIM (Physical Habitat Simulation System) which simulated hydraulic conditions using a hydraulic model (IFG-4) and links the results to a model describing salmon habitat characteristics (HABTAT). The resultant analysis allows the prediction of salmon habitat availability over a wider range of flows than those actually measured. The desired output is normally a graph showing how fish microhabitat (expressed as weighted usable area, WUA), varies with discharge. The success of the methodology in describing the relationship of flow to salmon habitat, and the nature of that relationship depends on the quality of the hydraulic model simulation and the characterization of what constitutes salmon habitat.

In 1983, the USFWS reported that the modeled optimum (most weighted usable area) spawning habitat occurred at a flow of 1,750 cfs at the Sailor Bar reach, and 1000 cfs at the Ancil Hoffman reach. In 1984, USFWS defined an index for incubation flows as part of an overall habitat index model. They assigned flow reductions of 500 cfs or less (from spawning flows) at the highest index value, representing no adverse impact. It was assumed that water surface elevation dropped 1 inch for each 100 cfs decrease in flow. The USFWS concluded that a 500 cfs flow reduction would not adversely affect embryo incubation (USFWS 1984).

In January 1985, D.W. Kelley & Associates conducted a review of the literature of spawning habitat instream flow analyses. They concluded that the difference between the CDFG and USFWS estimates is caused by differences in the definition of exactly what constitutes spawning habitat. The CDFG study used only riffle areas in estimating spawning habitat availability, whereas much of the habitat defined as suitable for spawning in the USFWS study was deep glides and pools. By not restricting their estimates to habitat types actually used for spawning by chinook salmon, Kelley et al. (1985a) believed that the USFWS estimates exaggerate the amount of suitable spawning habitat available at any given flow. Kelley et al. (1985a) recommended to USFWS modification to the IFIM to account only for riffle areas actually observed being used.

In 1985 Beak Consultants also reviewed existing information on spawning habitat availability with respect to flow on the lower American River. Their assessment of the shortcomings and relation between the two models is essentially the same as that determined by Kelley et al. (1985a). Beak found that the only common ground for comparing the two studies is in relation to chinook salmon spawning habitat. However, at that time, the spawning habitat estimates were not directly comparable in terms of the amount of habitat available in relation to discharge since calculation errors in the USFWS study had not yet been corrected as suggested by Kelley et al. (1985a). Portions of two study sites were omitted from the calculation and several stream length values were incorrect. It was only possible to note that over the range of flows evaluated in the 1966 study, spawnable gravel availability increased with discharge. The 1981 study results showed the same trend over the same flow range.

In 1985, the USFWS re-ran their model (USFWS 1985a) showing a less steep curve about the optimum, yet optimum spawning habitat continued to occur at flows of 1,750 to 2,000 cfs at Sailor Bar, and 1,000 cfs at Ancil Hoffman.

In December 1985, Sacramento County investigated fall-run chinook salmon spawning habitat use and distribution to build upon existing information in Gerstung (1971) and USFWS (1985a). The purpose of the study was to provide information needed to answer two questions: (1) does Sailor Bar support 75% and Ancil Hoffman 25% of the spawning distribution as assumed by USFWS in their model; and (2) how accurate were the habitat use curves used by USFWS, particularly the probability of use for each value (i.e. water depth, water velocity, and substrate) within each parameter's continuum. The report sought to determine distribution of spawning chinook salmon redds, and develop habitat use curves for water depth, water velocity, and substrate of salmon redds in the lower American River. The field techniques used for developing the habitat use curves were those prescribed by the Instream Flow Group (Trihey and Wegner 1981). The assumptions regarding usable fisheries habitat employed by USFWS in their 1981 flow study were also followed so the County's results could be substituted into the IFIM data deck. These assumption were: (1) if no other factors are known to be limiting, then depth, velocity, temperature, and substrate are assumed to be important quantifiable fish habitat variables when considering changes in streamflow regime; (2) the probability that fish will choose to live in a particular hydraulic dimension (such as depth or velocity) is independent of the probability that they will chose to live in any other dimension; and (3) there is a direct relationship between the calculated suitability of habitat and the use of the habitat by fish. The study was conducted at only one flow level (1,500 cfs), however, limiting its applicability in describing habitat conditions at higher flows. Nevertheless, the study found that the probability-of-use curves developed specifically for chinook salmon spawning habitat in the lower American River differed from use curves developed for both species and lifestage level such as those used by USFWS in 1981. Differences included a greater range of use for mean column velocities, water depth only appeared to affect redd site selection when it was too shallow to allow salmon to access suitable habitat, and substrate appeared to be the primary factor affecting redd site selection.

Since large quantities of suitable gravel between Sailor Bar and lower Rossmoor Bar were either exposed or barely inundated at 1500 cfs, it appears that more suitable spawning habitat would be provided at higher flows, at least until all suitable gravels were inundated to the minimum spawning depth.

In March of 1986, the CDFG reviewed the instream flow requirements for spawning of the USFWS and other studies. In that report, CDFG defined optimum conditions as "*those that mimic historic, post-Folsom Project conditions which have sustained the fall run chinook salmon resource during the past 31 years*." CDFG, in their evaluation of the literature, decided that the best way to establish spawning flow requirement is to first identify optimum spawning habitat conditions, and then identify acceptable flows based upon data relating spawning abundance to smolt production developed specifically for the lower American River. This approach was similar in concept to that taken by Sacramento County in December of 1985. CDFG concluded, however, that flows required to sustain spawning habitat at optimum levels were not resolved as of yet. In review of Sacramento County's study photographs, CDFG found that even at 2,500 cfs, habitat conditions appeared suboptimal. CDFG concluded that although available data are inconclusive as to optimum spawning flow requirements, they believed that optimum microhabitat conditions should be provided by flows somewhere between 1,750 cfs (i.e., optimum flow defined by the USFWS study) and 4,000 cfs (i.e., optimum flow based upon the 1966 study). CDFG found that the conditions required to provide amenable water temperatures earlier in the spawning season were not known, and that in order to provide optimum natural production of salmon, further investigation of the relationship between spawning habitat (temperature) and flow must be made. In the interim, CDFG recommended a minimum of 2,200 cfs, the 30-year average fall flows in the lower American River.

## Actual Habitat Use

Redd surveys conducted on the lower American River by the California Department of Fish and Game from 1991 through 1995 support the concept that there is a relationship between spawning activity and abiotic factors like flow and temperature. Snider et al. (1993b) concludes that spawning distribution (timing and location) appears to be influenced by flow and temperature conditions and that habitat availability appears to be inversely related and directly affected by flow conditions. Snider and Vyverberg (1995) also concludes that habitat availability and utility are strongly influenced by river flows. The combined results of the 1991-1995 redd surveys indicates that spawning distribution is influenced temporally by temperature and spatially by flow (Snider and Vyverberg 1996). These are the premises behind many recent efforts to describe the relationship between spawning habitat and flow conditions.

In 1991, EBMUD and Sacramento County conducted a joint habitat evaluation that included spawning habitat evaluation. The study focused on gravel quality and use since it found, in a literature review, that existing data indicate that chinook salmon spawning in the lower American River was concentrated in certain geographic locations. This may be attributable to non-flow related physical or behavioral aspects of spawning site selection. Thus, substrate surveys were conducted. Results of this Phase I gravel characterization study showed that the size distribution of gravels through many areas of the lower American River included a disproportionate contribution by large gravel and cobble. Results of the spawning gravel survey also showed that, in many areas, gravels are armored and imbedded. The joint technical team recommended that a management program be developed which specifically identifies spawning areas which can be improved by reduction in armoring and placement of appropriately sized gravels on key spawning areas.

After reviewing the relevant literature, Healey (1991) emphasized that importance of subsurface flow for chinook spawning habitat. This hypotheses may explain why some areas of seemingly good spawning habitat are not used, and is a continuation of the theme of the EBMUD and Sacramento County joint study.

CDFG also conducted spawning gravel characterization studies in 1991. The report concluded that fine sediment is not a significant problem for salmonid spawning in the lower American River, but large gravel may be: 2 of the 44 samples taken by CDFG for the study exceeded a CDFG criterion for percent larger than 76 mm., and observations of spawning salmon made during the study indicated that females were unable to construct redds in some areas with embedded layers of large cobble. The report, like the joint study mentioned above, concluded that a gravel enhancement program would improve spawning habitat.

Results of CDFG redd surveys in 1992, 1993, 1994 and 1995 indicated that water flow (hydraulic attributes of velocity and depth), substrate particle size and habitat type did not explain observed spawning use in sites otherwise comparable in terms of water depth and velocity, and substrate and habitat type. Moreover, the variability in these attributes at extensively used sites also was high. Because these results indicated that further investigation into the factors influencing the quality and quantity of chinook salmon spawning habitat was necessary, CDFG conducted a quantitative evaluation of spawning habitat. The primary objective of the evaluation was to identify the physical attributes that differentiate habitat currently used for spawning from apparently suitable habitat that remains unused. The attributes chosen to evaluate were substrate gravel size, armoring, water velocity and depth, and substrate permeability.

In May of 1997, CDFG produced a comprehensive report on these lower American River chinook salmon spawning habitat evaluations. The report authors thoroughly evaluated the attributes used to define spawning habitat quality with all considerations made by previous studies, including flow conditions. This study is a positive step beyond that taken in the IFIM series of studies in that it evaluated actual habitat availability and use for parameters relevant to spawning habitat quality and developed criteria for evaluating habitat quality from empirical data.

Important findings of the study include: (1) particle size was not found to be a useful discriminator between high and low-use spawning areas; (2) water depth and velocity were the least discriminating of all variables evaluated as an indicator of spawning use; (3) spawning distribution was best explained by intragravel conditions, that permeability was significantly higher in high spawning use areas - gravel size alone did not adequately describe permeability, and that permeability is strongly influenced by gravel compaction; (4) spawning habitat in the lower American River may be improved by breaking up and redistribution coarse subsurface deposits and reducing compaction in areas with low permeability - addition of gravel to improve the gravel size distribution for spawning may not be necessary in this portion of the lower American River; (5) no temperature difference was found between surface and subsurface water, indicating that upwelling currents of cold groundwater are unlikely to be a factor influencing spawning site selection for chinook salmon in the lower American River; and (6) permeability did not vary significantly by habitat type.

As a result of the CDFG (1997) report, a pilot spawning habitat improvement project was initiated. Based on sites identified in the 1997 CDFG report as having otherwise suitable habitat but lacking high surface permeability caused by excessive armoring, the pilot project (locations at Sailor Bar, Lower Sunrise area, and Sacramento Bar) was instituted and completed before the fall of 1999 spawning season. Although the monitoring program is in progress and results have not yet been reported, spawning has been observed in these previously unused areas.

## Redd Superimposition

One indication of crowded conditions for fish spawning is the degree of superimposition. Superimposition refers to a fish coming in, building a redd, with subsequent fish digging that redd up and spawning on top of it, or overlapping.

Superimposition is related to spawning intensity, both temporally and spatially (Snider and McEwan 1992). Superimposition serves to indicate either a limited amount of, or inappropriate accessibility of, specific spawning areas. This can be due to gravel characteristics, or due to the relationship between flow and spawning gravel. With all other things being constant, one may surmise that superimposition would increase with the greater number of fish trying to spawn in a limited resource area.

Redd superimposition has been investigated as part of the CDFG redd surveys since 1991. Based on habitat type data provided in CDFG redd survey reports, the majority of superimposition occurred in the habitat types experiencing most of the spawning activity (i.e., bar-complex runs and riffles and flatwater glides in Reach 4, and bar-complex runs in Reach 3). In 1993, flatwater runs (21%) and bar-complex runs (17%) also experienced significant percentage superimposition.

The year-to-year, month-to-month and week-to-week variability of spawning habitat availability is primarily dependent on flow. Though it is reported in the literature that substrate composition is an important factor in salmon's choice of spawning site, this microhabitat parameter is not reflected in short term changes in habitat availability. The relationship between flow and habitat availability theorized and modeled in the last 30 years is reflected in the redd superimposition that has occurred annually, under variable flow conditions, since 1991. A determination of optimum flow to minimize superimposition must take into consideration that flow alone does not determine level of redd superimposition, through spawning habitat availability. Spawning run size and timing can also affect percentage superimposition.

As previously described, spawning stock escapement, or the number of salmon in the river attempting to spawn, can vary dramatically year to year. One of the lowest returns of chinook salmon to the lower American River occurred in 1992, when approximately 5,000 fish were estimated to naturally spawn in the lower American River. One of the highest years of return on record happened in 1995. In 1995, approximately 70,000 chinook salmon were estimated to spawn in the lower American River. In the 1992/93 spawning season, the changes in spawning concentration as evidenced by the decrease in sites used and the increase in superimposition, suggest that spawning habitat availability declined due to the lower flows during that season relative to the previous year. Because escapement estimates were substantially lower in 1992 than in 1991, the increased superimposition and spawning density were not due to an increase in the spawning population (Snider et al. 1993b). Superimposition occurring in 1994 was higher than in previous surveys, and was coincident with a larger spawning population and relatively low river flows (Snider et al. 1996). The 1995 spawning period, however, was characterized by the largest estimated spawning population and lowest percent superimposition to have occurred since the surveys began. Higher flows apparently accommodated the larger spawning population with only slight crowding in utilized spawning habitat (Snider and Vyverberg 1996). In addition, manipulation of the cold water pool with these higher flow releases resulted in earlier spawning in 1995 than in other years, and a more protracted spawning season. Examination of these years indicates that the high flow releases (i.e., about 2,500 cfs) starting in October were able to be maintained through December, spawning started earlier and was extended over a longer period of time, these flows accommodated a several-fold increase number in the number of fish returning to spawn in the river, with reduced redd superimposition (**Figure 2-22**).

### Redd Dewatering

In the 1991 redd survey, dewatered redds were observed in six different bar-complex riffles in the Sunrise (15 redds) and Sailor Bar (25 redds) areas when flows were dropped from 2,500 cfs. In the Sailor Bar area, one redd was dewatered when flows dropped to 1500 cfs, 4 when flows dropped to 1200 cfs and the remaining 20 when flows dropped below 1000 cfs. The redds in the Sunrise area were dewatered when flows dropped below 1000 cfs.

**Figure 2-22. Timing of spawning activity, flow rates during spawning, percentage of redd superimposition, and escapement levels of fall-run chinook salmon in the lower American River, 1991-1995.**

Dewatering of chinook salmon redds was not observed during the 1993 survey period. Flows during the fall 1993 survey period averaged 2,262 cfs , with a high of 5,000 cfs and a low of 1,000cfs. Flows were 2,000 cfs during initiation of fall-run spawning (during the week of October 25), dropped during the first week of November to 1,750 cfs, and remained at 1,750 cfs throughout the rest of the spawning period, with the exception of a 5,000 cfs peak during the second week of December.

In 1994, flows did not decrease after spawning started and redd dewatering did not occur. And in 1995, flows were decreased from 2,500 cfs to 2,000 during spawning season. CDFG reported that dewatering was unlikely.

Since 1996, CDFG has initiated field investigations to determine the relationships between flow and embryo survival. The study included design and evaluation of equipment to be used to investigate egg survival to emergence, and located suitable study sites based upon previous work regarding chinook salmon spawning distribution and the potential for flow to influence redd survival. Results of these investigations are in preparation.

### Temperature Effects

#### Longitudinal Temperature Variation

The summer trend of cooler water temperatures occurring at upstream areas, relative to downstream areas, does not persist into the fall. Thus, temperatures in the stretch of the lower American River most often used for spawning during the primary spawning time of the year are quite uniform. Based on the available temperature data, those temperatures are declining in October from as high as 65°F to approximately 50°F by January. During October-January, very little ambient or radiant heating occurs, making the temperatures uniform through the area highly used for spawning.

Several laboratory studies have been conducted to identify optimal, preferred, or suitable spawning temperatures of fall-run chinook salmon. Most of these studies address spawning and incubation temperatures as a unit. Studies that do exist point to a temperature of $\leq$60°F as the optimal upper daily average. Table 3-6 includes thermal studies and the lifestage at the focus of the study. Because few of these studies were conducted on lower American River or Nimbus Hatchery strain fall-run chinook salmon, results of these studies serve only as a guidance to assessing temperature conditions on the lower American River.

Nimbus Hatchery data also provide insight in identifying ranges of suitable spawning and incubation temperatures. In recent years, it has been Nimbus Hatchery policy to open the gates for fish entrance only when temperatures reach 60°F at the hatchery in response to high mortality in past lots of fish allowed to spawn at higher temperatures.

#### Egg Retention

**Figure 2-23** summarizes egg retention data taken during spawning escapement surveys conducted from 1992-1999 by CDFG on the lower American River. The apparent trend for the lower American River in-river spawners is a general decline with respect to percent of fish fully spawning.

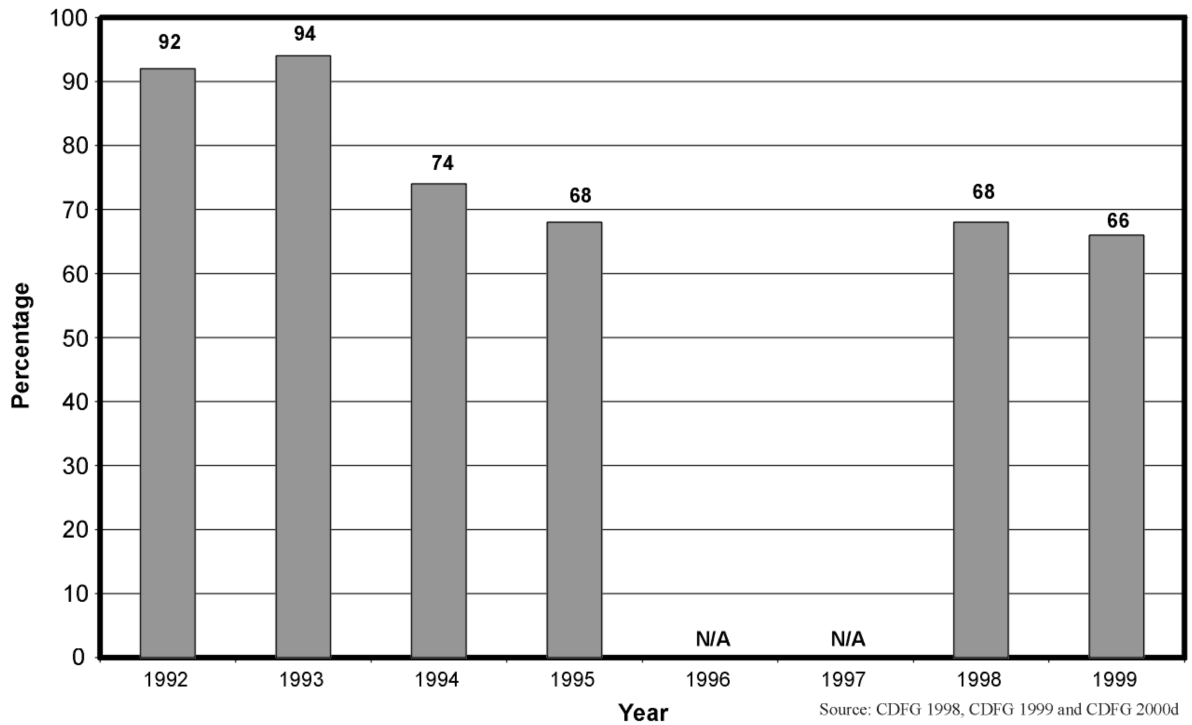


**Figure 2-23. Percentage of fully spawned female carcasses recovered as part of the total number of spawning females in the lower American River, 1992-1999. Fully spawned are fish that have released more than 50% of their eggs.**

There may also be a within-year trend in egg retention. For example, Snider and Bandner (1996) found that in the fall of 1994, early spawning females experienced high levels of egg retention (58% unspawned or partially spawned).

## Egg Size

Egg size data are not collected from in-river spawners in the lower American River, but annual average egg size data from the Nimbus Hatchery exhibit a generally stable trend in mean egg size (**Figure 2-24**).

Egg size has often been suggested as a potential factor reflecting some measure of egg quality such as quantity of yolk nutrients (Fowler 1972; Linley 1988). Egg size has been found to be primarily a function of fish size in chinook salmon (Nicholas and Hankin 1988). However, Berman (1990) and Bouck et al. (1975) both found that female salmon held at elevated temperatures during final maturation produced smaller eggs even when adjusted for female length and weight.

Berman (1990) also found trends in subsequent fry size with fry produced from females elevated temperature treatments at 66.2ºF being subsequently small than fry produced from females held at a control temperature of 57.2ºF. A biological consequence of this result is that smaller salmon fry are considered to have lower survival than larger fry due to increased vulnerability to predation, reduced overwinter survival, and alterations in downstream migration timing (Holtby et al. 1989).

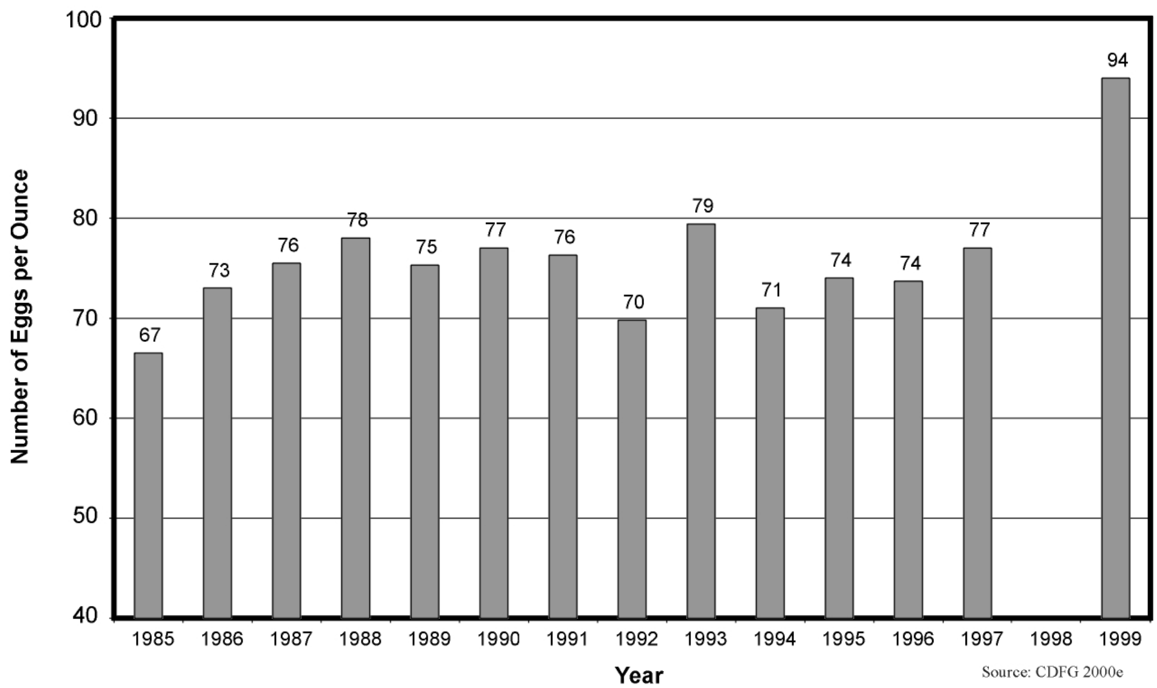


**Figure 2-24. Yearly average size of chinook salmon eggs at the Nimbus Hatchery on the lower American River, 1985-1999. Calculated by counting the number of eggs in one ounce of eggs and extrapolating for the lot.**

## Incubation time

Eggs deposited in redds incubate until hatching, at which time they are referred to as alevins. Alevins remain the gravel until most of the egg yolk is absorbed, and then begin to emerge from the gravel. Although the intragravel residence period of incubating eggs and alevins is highly dependent upon water temperature, the estimated intragravel lifestage period in the lower American River generally extends from about mid-October through March.

The rate of development of poikilothermic animals varies directly with temperature. Logistic and theoretical mathematical expressions have been proposed to describe the relationship of temperature to embryo development. Donaldson (1955) found that exposure to unfavorable temperatures past the pigmenting stage doubled the hatching period. Seymour (1956) in an experiment varying constant and fluctuating temperatures of incubation found that for Pacific fall-run chinook salmon the hatching period rapidly declines when constant temperatures change from 35 to 40°F, but, above 40°F, the length of the hatching period was short and without noticeable change with respect to temperature. Water temperature generally remains above 40°F in the lower American River throughout the chinook salmon incubation period.

## Acute Mortality and Latent Mortality to early fry stage

Healey (1979) found, in a constant temperature exposure experiment on Sacramento strain fall-run chinook salmon, that mortalities to the fingerling stage were 80% or more when temperatures during incubation of eggs and fry development were 61°F to 61.9°F. These type of experiments utilizing constant temperatures are common, but generally do not provide information concerning differences between constant and variable thermal conditions, which occur in the lower American River.

Seymour (1956) experimented both at constant and variable temperatures, but did not report a difference in mortality. He did find that, at temperatures of 34°F or 65°F, no eggs survived to hatching and at constant 60°F and 62.5°F eggs hatched but none survived through the yolk-sac stage. Also, at constant temperatures of 55°F and 57.5°F, hatching had a high success, but mortality increased to 50% or greater during the yolk-sac stage.

Donaldson (1955) in his experiment on effects of lethal temperature exposure to eggs for various lengths of time found that a 13-day exposure at 63°F killed 10%, and a 22-day exposure at 63°F killed 50% of the embryos. Both 65°F and 63°F groups, however showed few mortalities until temperature exposure approached hatching time. Other studies corroborate the sensitivity found by Donaldson (1955) and Seymour (1956) during late embryo (eleutheroembryo) and early fry (pre-emergent alevin) period which, under near optimal early incubation temperatures, will fall between 40 and 100 days after fertilization according to Seymour's relationship between temperature and days to hatching.

In a recent experiment conducted by the USFWS (1999), the latent effect of early-life temperature exposure observed in their experiment on fall-run chinook salmon is consistent with previous studies. USFWS (1999) suggests several mechanisms for latent mortality including embryo development and differentiation were altered by elevated temperatures, and yolk coagulation resulting in poor absorption. Heming (1982) reported faster yolk absorption and lower conversion efficiency as temperature increased. Fall-run chinook salmon in the lower American River are exposed to relatively high water temperatures (≥60°F) during the early part (i.e., October) of the spawning period every year.

***Temporal Temperature Gradient***

Temporal temperature gradients, or a general trend in water temperatures over time, occur in the lower American River. Water temperatures show a gradual decline during the fall (October-December) period when incubation begins. The exact temperature that exists on a daily basis varies with the flow regime. In the primary spawning areas, water temperatures can decline several degrees over the course of a month (for example, see water temperature data for 1991, **Figure 2-25**). Flow regimes dominant in recent years have generated monthly average temperatures in October of above 60°F and in November of >55°F. CDFG has found that spawning activity on the lower American River increases as temperatures decrease during this period (Snider and McEwan 1992). These temperatures, depending on the initial slope of the decline, can pose serious hazards to the incubation lifestage of fall-run chinook salmon.

Boles et al. (1998) found that eggs incubated at constant water temperatures greater than 60°F or less than 38°F have suffered high mortalities. Survival increases, however, for eggs taken at high water temperatures but incubated at temperatures that gradually decline to the mid-forty to mid-fifty degree (°F) range. Mortalities in fry were reduced to low levels when eggs were incubated at constant temperatures of from 50°F to 55°F, or under declining temperatures from initial incubation temperatures ranging up to 60°F.

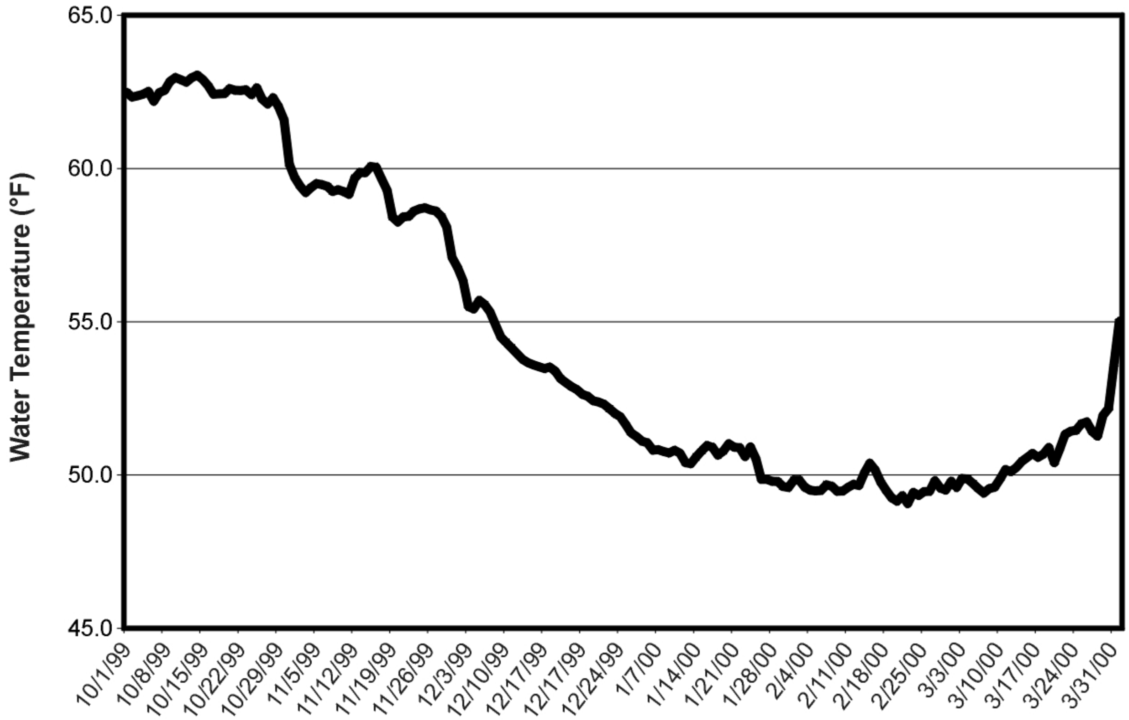


**Figure 2-25. Daily water temperatures in the primary spawning area (Ancil Hoffman Park) during the in-river residence period for fall-run chinook salmon during 1991.**

***Diurnal Fluctuation***

Daily temperature fluctuations on the lower American River occur throughout the year. For example, in January, water temperatures fluctuate only a few degrees, but in summer months can fluctuate up to 8 degrees. During the fall-run chinook salmon incubation period, water temperatures generally fluctuate diurnally up to about 3°F.

Variable water temperatures (those temperatures that emulate natural variation) have been shown to have reduced negative impacts at higher temperatures compared to constant temperature incubation. The EPA (1971) found that there was a significantly greater survival in eggs incubated at fluctuating temperatures with peaks above 63°F (17.2°C) and a significantly better survival for fry at all temperatures (with one exception) in the fluctuated temperature group, when compared with constant temperature groups. This indicates that there may be significant benefit to eggs and fry from a diurnal temperature fluctuation at all levels within a zone of tolerance of 42°F to 65°F (5.5°F to 18.3°C) (EPA 1971).

## Flow Effects

A thorough analysis of predominant flow conditions relevant to the fall-run chinook salmon incubation lifestage was conducted in the early 1990s. Results of these studies were reported by CDFG in 1997 (Vyverberg, Snider, and Titus 1997). The following discussion and results are taken directly from that report.

Vyverberg, Snider, and Titus (1997) used a three-factor ANOVA to evaluate differences in water depth and velocity in habitat sites relative to spawning use. Overall, they found that mean water column velocity and nose velocity varied significantly among habitat types, spawning use areas, replicates, and in combination with each term, and very little of the variation was explained by the models (mean column velocity model, $r<0.4$; nose velocity model, $r<0.3$). Within the observed range, mean column velocity and nose velocity did not distinguish high from low spawning use areas. They also found that mean water depth varied significantly among habitat types, replicates, and in combination with each term, but not as a function of spawning use area. Despite significant variation overall, within the observed range, mean water depth did not distinguish high from low use spawning areas.

## Intragravel Flow Conditions

Intragravel conditions are largely influenced by substrate permeability. The water velocity through the substrate (intragravel water velocity) is a function of permeability and local hydraulic gradient. Intragravel water quality, including dissolved oxygen and temperature, is directly related to flow through the gravel. Localized upward (upwelling) and downward (downwelling) movement of water through the substrate is related to permeability, hydraulic gradient and local channel form.

The mortality rate of salmonid eggs is strongly related to intragravel water velocity. For example, Gangmark and Bakkala (1960) found that chinook salmon egg survival was greater than 90 percent when intragravel water velocity was approximately 107 cm per hour to greater than 152 cm per hour.

## Intragravel Water Temperatures

In CDFG's studies on the lower American River, surface water temperatures varied from 17.5 to 22.5°C (63.5 to 72.5°F). Intragravel water temperatures varied from 17 to 22 °C (62.6 to 71.6°F). No significant difference was found between intragravel temperatures from the three sample depths (ANOVA, $p>0.9$) and, therefore, the individual measurements for an average value of a particular site's intragravel water temperature were combined. Similarly, no significant difference was found between surface and subsurface water temperatures (paired t-test, $p>0.5$), indicating that during the study period (October 3-14, 1994) the intragravel water sampled was very likely an extension of the surface water and not groundwater flowing into the river. These results were consistent with a reconnaissance study of intragravel water temperatures conducted in November 1990 that indicated upwelling currents of cold groundwater were not a significant factor influencing either spawning site selection for chinook salmon or subsequent temperature exposure for incubating eggs (Hanson et al. 1991).

### *Hydraulic Gradient*

In 14 habitat sites, the pressure head in the intragravel water and surface water was equal. In four sites, even after stabilizing for a minimum of 30 minutes, the intragravel water level in the piezometer remained below the level of the surface water level. This indicated that the intragravel water at these sites was under unique negative pressure. There are at least three explanations for this effect: (1) a channel form-induced downward infiltration of surface water (e.g., at the point of transition between the tail of a pool and head of a riffle); (2) gravel compaction at depth had increased resistance to flow and reduced permeability; or (3) the intragravel water sampled was a unique body of water separated from the water above it by a confining layer that had impaired or broken the connection with the surface water by restricting the downward movement of water.

### Substrate

For successful incubation, gravel must be sufficiently free of fine sediment that the flow of water through the gravel is adequate to bring dissolved oxygen (DO) to eggs and carry off metabolic wastes (Groot and Margolis 1991). Studies relating intragravel water properties to emergence success indicate that minimum levels of DO necessary for survival vary (with temperature, in part), but generally fall between 2 and 8 mg/L (Silver et al. 1963; Davis 1975). Other studies have shown that interstitial fine sediment can reduce gravel permeability and lead to less intragravel flow, which can result in lower levels of DO and suffocation of embryos (McNeil and Ahnell 1964).

After hatching, alevins live in the intragravel environment for a period, then migrate through the gravel to the surface. Successful emergence requires connected pore space through which the alevins can pass. Field and laboratory studies have demonstrated that, in some gravels, although eggs may incubate successfully and alevins hatch and live in the intragravel environment, alevins cannot migrate upward to the surface because fine sediment blocks intragravel pore spaces (e.g., Phillips et al. 1975; Hawke 1978). The sediment sizes held responsible for blocking emergence are typically between 1 and 10 mm (Bjornn 1969; Phillips et al. 1975; Harshbarger and Porter 1982), and those blamed for reducing permeability are finer than 1 mm (McNeil and Ahnell 1964; Cederholm and Salo 1979; Targert 1984). Thus, emergence requirements set another limit to interstitial fine sediment, but of a coarser caliber than those of concern for incubation.

### Permeability

Permeability describes the capacity of sediment to transmit fluid, and depends largely on particle size distribution, degree of gravel compaction, and upon the viscosity of the water, which depends on water temperature.

Spawning salmon have been observed to preferentially utilize areas where upwelling and downwelling water currents flow up from or down into the stream bed (Chapman 1943; Healey 1991). As noted by Healey (1991)*…"The chinook's apparent need for strong subsurface flow may mean that suitable spawning habitat is more limited in most rivers than superficial observation might suggest, so that at high population density many chinook spawn in areas of low suitability, and their eggs consequently suffer high mortality."*

The presence of upwelling and downwelling currents associated with transitional areas from one habitat type to another has been demonstrated in the field (Hobbs 1937; Chambers 1951; Stuart 1953), and simulated in the laboratory (Cooper 1953; Stuart 1953; Vaux 1962). Transitions from one habitat type to another are typically associated with changes in gradient that induce upward or downward currents of water. For example, at the point of transition from the tail of a pool to the head of a riffle downstream, the steeper gradient of the riffle creates a hydraulic gradient that induces downwelling at the tail of the pool and upwelling at the head of the riffle.

Several investigators have developed indices for spawning gravel quality based on the dependent relationship between gravel particle size and permeability (Lotspeich and Everest 1981; Plattes et al. 1983; Tappel and Bjornn 1983; Young et al. 1991). Rather than site-specific permeability measurements, these models use, in part, substrate particle size as an indicator of stream bed permeability.

Hanson et al. (1991) used a model developed by Young et al. (1990) to estimate survival to emergence of salmon fry from each of the gravel samples collected during a 1990 reconnaissance survey on the lower American River. The regression equation by Young et al. (1990) used to define the relationship between substrate size and survival to emergence for chinook salmon eggs is:

Survival to emergence = 33.7 + 110.2(log dg), where dg is the geometric mean particle size.

On the lower American River, the predicted level of survival exceeded 80% for all but a few of the reconnaissance survey gravel samples.

Although broadly applied, the model developed by Young et al. (1990) seems to be a poor index of spawning gravel suitability because it is determined by mean gravel size and, therefore, is not sensitive to the fine sediment content that can impair permeability to the detriment of incubating embryos. A two-factor ANOVA was used to model variance in permeability as a function of habitat and spawning use (Vyverberg, Snider, and Titus (1997)). They found that permeability varied significantly as a function of spawning use but not habitat type, and was the only attribute measured that distinguished high- from low-use spawning areas.

Vyverberg, Snider, and Titus (1997) used a model developed by Tappel and Bjornn (1983) to predict embryo survival to emergence. Predicted survival to emergence for all of the habitat sites sampled was >80% even though hydraulic gradient and permeability varied from site to site by more than two orders of magnitude, and intragravel flow was low enough in some areas as to be considered essentially static.

No significant relationship was found between the permeability calculated for the sites on the lower American River and salmonid survival to emergence as predicted by the Tappel and Bjornn (1983) model. However, this result may reflect the uncertainty associated with estimating values of both the dependent (salmonid survival to emergence) and the independent (permeability) variables. (Permeability is estimated by measuring inflow and inferred from a permeability and inflow rate calibration curve, while salmonid survival-to-emergence is estimated by measuring the particle size distribution and then calculating survival from a model).

Rates of groundwater movement through the gravel substrate, while related to particle size and the permeability of the substrate materials, can also be strongly influenced by other substrate characteristics such as substrate compaction and hydraulic pressures related to stream gradient. Vyverberg, Snider, and Titus (1997) suggest that unless such substrate characteristics can be accounted for in the various particle size relationship indices used to describe spawning gravel quality, it is probably inappropriate to use particle size alone as an indicator of substrate permeability to predict embryo survival or as a single-variable descriptor of spawning gravel quality on the lower American River.

In an emergence study on Mill Creek, a tributary to the upper Sacramento River, Gangmark and Bakkala (1958, 1960) found that the mortality rate of chinook salmon eggs was dependent in large measure on the intragravel water velocity. Their data indicated that the optimum velocity relative to survival of chinook salmon eggs was roughly 107 to 152 cm per hour. Vyverberg, Snider, and Titus (1997) used the data from Gangmark and Bakkala (1960) as an empirical framework within which to consider embryo survival and potential mortality relative to the permeability inferred from intragravel water velocity calculated for each site in the lower American River. A potentially strong relationship exists between embryo mortality and intragravel water velocity ($r^2 = 0.88$) such that mortality decreases exponentially with increasing velocity.

As with permeability, intragravel water velocity varied significantly between high- and low-use spawning areas (ANOVA, $p<0.03$). Using the data collected from the lower American River, no correspondence was found between survival of chinook salmon embryos as predicted from intragravel water velocity (Gangmark and Bakkala 1960), and survival as predicted from particle size composition (Tappel and Bjornn 1983).

### Gravel Size And Composition

Several investigators have suggested that coarsening of the surface gravel substrate layer has reduced the availability of spawning habitat in the lower American River (Kelly 1985; Hanson et al. 1991). Reportedly, a high percentage of cobble-sized substrate in the lower American River contributes to the concentration of spawning activity and superimposition of redds as observed during the 1991-1995 spawning surveys (Snider and McEwan 1992; Snider et al. 1993; Snider and Vyverberg 1995; Snider and Vyverberg 1996; Snider et al. 1996).

In general, when spawning, chinook salmon select gravel with a median diameter between 7 and 100 mm (Platts et al. 1979; Rieser and Bjornn 1979; Kondolf 1988). Within this range, the particle sizes used to construct redds vary with the size of the fish (Burner 1951; Kondolf and Wolman 1993). Larger fish can excavate larger gravels. If the size of the surface particles is too coarse for female salmon to move, the available spawning area is reduced. In general, fish can spawn in gravels with a median diameter ($D_{50}$) up to about 10% of the body length (Kondolf and Wolman 1993). This relationship between fish size and gravel size can be viewed as an envelope that defines maximum gravel size tolerances.

On the lower American River, adult female fall-run chinook salmon range in fork length from 65 to 100 cm (Snider et al. 1995; Snider and Bander 1996). Based on the relation between fish length and gravel size (Kondolf and Wolman 1993), the median diameter of the upper limits of gravel sizes lower American River chinook salmon will likely be able to move is from 65 mm to 100 mm.

The occurrence of the coarse subsurface deposits in more than half of the sites sampled may explain the observations made by several investigators that salmon abandoned redds at depths of 10 cm to 46 cm after encountering what was thought to be an impenetrable clay layer or an embedded layer of cobble which limited further excavation (Beak et al. 1990; Hanson et al. 1991). Cobble size and the depth at which the cobble was found suggest that cobble deposits may be remnant egg pockets from past redd construction. As chinook salmon females excavate finer material from the redd, larger immovable rocks are left at the bottom of the excavation near the center of the egg pocket.

## Substrate Armoring

Armoring is the development of a surface layer that is coarser than the material beneath it. Substrate coarsening frequently occurs downstream of dams, at least in part, due to winnowing finer materials from the surface layer by the excess energy of the clear, sediment-free water typical of dam releases (Parker 1980). A well-developed armor can threaten the success of spawning salmonids. If armor gravels are too large to be moved by a salmon during redd construction, the spawning site may be abandoned. Fall-run chinook salmon have been observed to abandon spawning sites on the lower American River after encountering what was conjectured to be a layer of coarse cobble several inches below the substrate surface (Hanson et al. 1991).

In concept, it should be possible to identify the presence of armoring by comparing surface and subsurface particle size distributions. Additionally, it should be possible to compare surface particle size to subsurface particle size for an index of the relative degree of armoring, A;

$$A = \frac{d_a}{d_{sub}}$$

where da is the median grain size (D50) of the armored layer, and dsub is the median grain size (D50) of the subsurface particles (Parker 1982). An index of 1 would indicate the absence of armoring. The presence and relative degree of armoring would be indicated by values greater than 1. The armor index does not describe coarseness of the surface layer, but rather the disparity between surface and subsurface particle size distributions.

The relative degree of armoring reported for gravel bed streams is typically between 1.5 and 3 (Parker 1982). The degree of armoring at the sites sampled on the lower American River was fairly typical of reported armoring values. The degree of armoring at the sampled habitat sites ranged from 0.8 to 7.2 with a median value of 1.5. Two sites were unarmored, two sites had armoring slightly coarser than optimal, and two sites had armoring that exceeds the spawning gravel size criteria typically used for coarse sediment. All six sites received low spawning use during the past four survey years.

The remaining 14 habitat sites had varying degrees of armoring. However, the particle sizes comprising the surface layers of these sites was not excessively coarse and was within the range of sizes typically considered suitable for potential spawning gravels.

### Data Limitations and Considerations

Much of the recent literature on salmonid spawning gravels has been devoted to the search for a single statistic drawn or computed from the streambed particle size distribution to serve as an index of gravel quality. However, a natural gravel mixture cannot be fully described by any single statistic, because gravel requirements of salmonids differ with lifestage, and this the appropriate descriptor will vary with the functions of gravel at each lifestage. To assess whether gravels are small enough to be moved by a given salmonid to construct a redd, the size of the framework gravels (the larger gravels that make up the structure of the deposit) is of interest, and the $d_{50}$ or $d_{84}$ of the study gravel (the sizes at which 50% or 84% of the sediments are finer) should be compared with the spawning gravel sizes observed for the species elsewhere. To assess whether the interstitial fine sediment content is so high as to interfere with incubation or emergence, the percentage of fine sediment of the potential spawning gravel should be adjusted for probable cleansing effects during redd construction, and then compared with rough standards drawn from laboratory and field studies of incubation and emergence success. An assessment should also consider that the fine sediment content of gravel can increase during incubation by infiltration, that the gravels may become armored over time, or that downwelling and upwelling currents may be inadequate. These considerations are incorporated in a nine-step, life-stage-specific assessment approach proposed in Kondolf (2000).

#### 2.2.2.4. JUVENILE REARING AND EMIGRATION

CDFG has been evaluating anadromous salmonid rearing and emigration for the past several years. Snider and Titus (2000) state that the objectives of these investigations include: (1) identify the general attributes of emigration on the lower American River, including timing, abundance, fish size and lifestage composition, and fish condition; (2) relate these attributes primarily to flow-dependent, environmental conditions; (3) develop an empirically-based model to link emigration with flow conditions; (4) develop procedures to quantify or index the size of the emigrating population; and (5) associate production and survival with environmental conditions by combining emigration data with information being collected on spawner population size, numbers and distribution of redds, and the magnitude and dynamics of the rearing phase of chinook salmon precedent to emigration.

### Fish Surveys

Numerous techniques have been employed to sample juvenile salmonids in the lower American River. Early studies (1945-1947) on salmonids emigrating from the American River used fyke traps. Since 1991, juvenile salmonids have been sampled in the lower American River by seining, fyke netting, gill netting, dip netting, Kodiak trawling, rotary screw trapping, angling, snorkeling, SCUBA diving, backpack electrofishing, and boat-mounted electrofishing. A study in 1991 (Hanson et al.) was conducted by representatives of CDFG, Sacramento County, and EBMUD to evaluate sampling efficacy in the lower American River. Intensive surveys by Brown et al. (1992) also were conducted to develop baseline fisheries distribution information. Since the early 1990s, CDFG has been conducting fish community surveys by seining, snorkeling, and emigration surveys by rotary screw trapping. During 1992 and 1993, CDFG conducted preliminary evaluations and resolved numerous difficulties associated with rotary screw trapping (Snider 1992; Fothergill 1994). Rotary screw trapping has been conducted by CDFG annually since 1994.

Provided below is a brief summary, primarily taken from information presented in Snider and Titus (2000), of the fall-run chinook salmon information provided from the CDFG fish community and emigration surveys. Reference to data collected since 1997 is preliminary and has not been reviewed by CDFG. For a detailed discussion of all surveys, see Snider 1992, Snider 1993, Snider and McEwan 1993, Fothergill 1994, Snider and Keenan 1994, Snider and Titus 1995, Snider and Titus 1996, Snider et al 1997, Snider et al. 1998, and Snider and Titus 2000.

### Rearing

<u>**Habitat Utilization**</u>

Typically, when salmon fry emerge, they occupy the quiet water along the river edge, unable to swim against a very fast current (Briggs 1953). Those that enter the faster current in the lower

American River are probably swept down river into slower moving water downstream of H Street, or all the way to the Sacramento River and downstream locations. The residence period of fry remaining in the American River may be influenced by a variety of factors including stream discharge (e.g., frequency of freshets), water temperature, food availability, physical habitat availability and density dependent behavior.

Fall-run chinook salmon fry emerge from the gravels during winter months when high magnitude floods historically occurred in the lower American River. In general, juvenile chinook salmon spend very little time in the lower American River for rearing. Most fall-run chinook salmon emigrate during the fry stage and, at the latest, the early juvenile stage in May and June. Snider and McEwan (1993) found larger average size and higher occurrence of fish greater than 50 mm FL below river mile five during February suggesting that fish may be moving after growing slightly in the upper reaches and not all moving immediately after emergence.

At any given sampling period, chinook salmon at downstream sites are larger than fish from upstream sites, suggesting that fish moved downstream as they grew larger (older). Moreover, chinook salmon larger than 80 mm are rarely found, indicating that most fish exceeding this length had already emigrated from the river. According to Moyle (1976), juvenile chinook salmon in California seldom spend more than 30 days in freshwater. This trend has clearly been observed in the lower American River.

Although most fall-run chinook salmon fry emigrate shortly after emergence, some extended rearing also occurs in the lower sand-bedded reaches or on the spawning grounds (gravel-bedded reaches) in the lower American River. The margins of point bars and backwater zones downstream of point bars generally provide suitable depth and velocity conditions, substrate composition and cover, and an abundance of benthic and terrestrial invertebrate food resources. Juvenile chinook salmon are associated with areas of moderate current and some cover in the form of large substrate or surface turbulence (Brown et al. 1991).

Several attempts have been made to relate fish abundance to physical variables such as flow and temperature. Brown et al. (1991) found that the correlation between juvenile fall-run chinook salmon abundance with physical variables were generally significant, but low. A full discussion of these attempts follows in the *Theoretical Rearing Habitat Availability* section of this *Baseline Report*.

The distribution of rearing juvenile chinook salmon found by CDFG community surveys on the lower American River is illustrated in plots developed from fish community surveys conducted on the lower American River throughout the 1990s and appear in **Figure 2-26** through **Figure 2-30**. From available data, it appears that rearing of fall-run chinook salmon primarily occurs in the upper 18 miles of the lower American River, leaving the lower 5 miles primarily as a migration corridor. Snider and McEwan (1993) found spatial distributions to be significant relative to reach during February, but not in March, April, or May. Variability was so great within reaches that no significance could be attributed to within-reach spatial distributions. Distribution relative to habitat type was found to be significant during February and April, but not during March and May (Snider and McEwan 1993). Snider and McEwan (1993) suggest that the positive associations observed between reach and catch during February corresponds with redd concentrations and that the absence of a clear association between reach and catch in subsequent months may reflect the effect of dispersion from the upper river area.

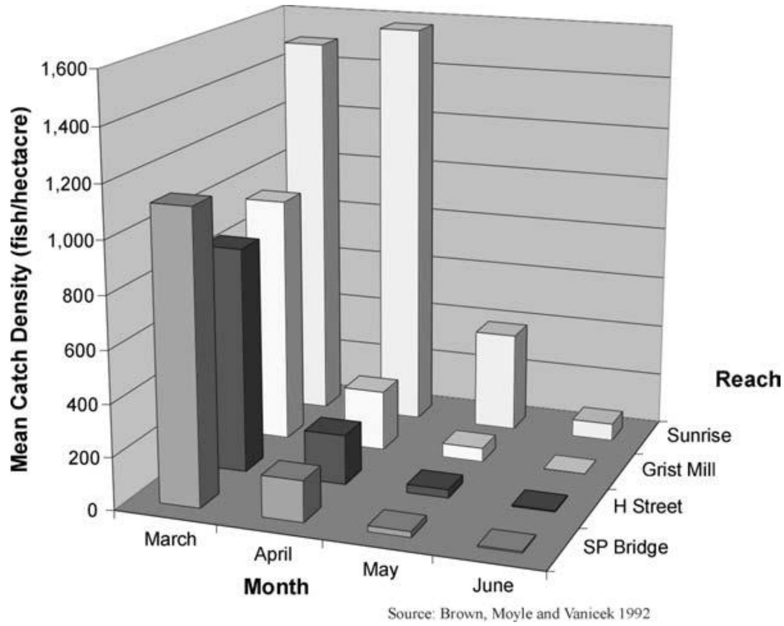


**Figure 2-26. Monthly mean catch densities of fall-run chinook salmon at Sunrise, Gristmill, H Street, and SP Bridge on the lower American River, March through June 1991.**

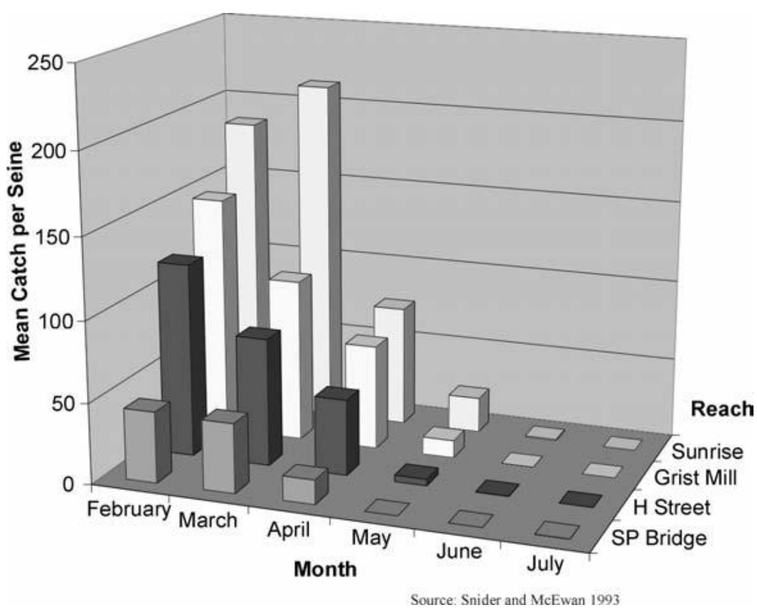


**Figure 2-27. Monthly mean fall-run chinook salmon catch per seine at Sunrise, Gristmill, H Street, and SP Bridge on the lower American River, February through July, 1992.**

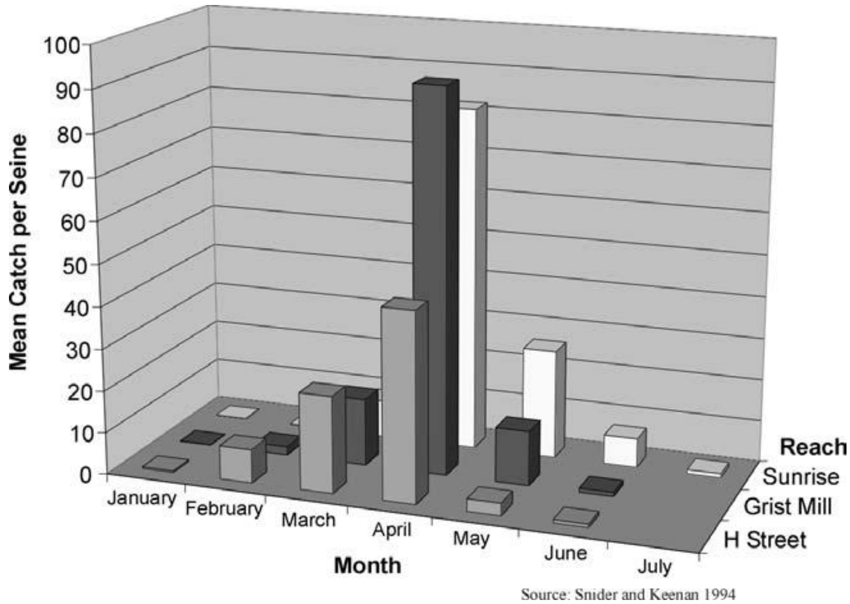


**Figure 2-28. Monthly mean fall-run chinook salmon catch per seine at Sunrise, Gristmill, and H Street on the lower American River, January through July 1993.**

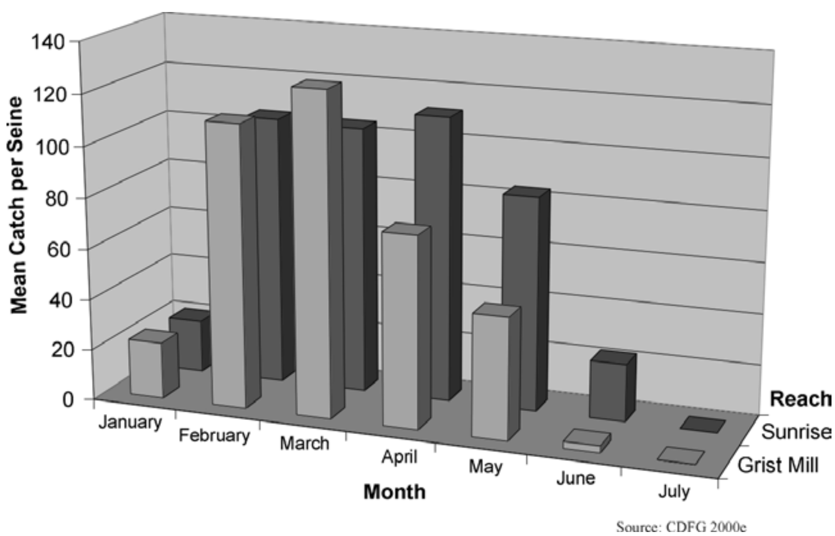


**Figure 2-29. Monthly mean fall-run chinook salmon catch per seine at Sunrise and Gristmill on the lower American River, January through July 1994.**

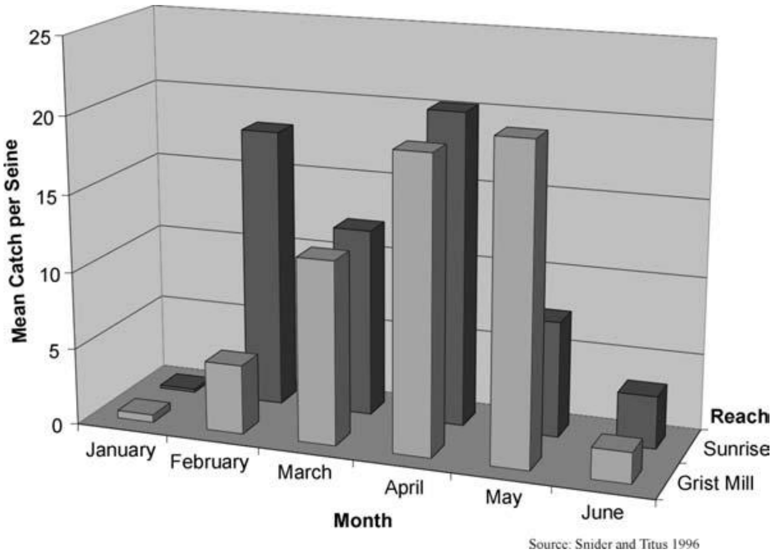


**Figure 2-30. Monthly mean fall-run chinook salmon catch per seine at Sunrise and Gristmill on the lower American River, January-June, 1995.**

Apparent trends in habitat use suggests that backwater runs and glides contained the majority of fish early when fish were small. As fish grow, the proportion of fish in pools increased while the proportion in backwaters declined. Riffles typically contained the smallest number, but larger average size of fall-run chinook salmon (Snider and McEwan 1993). In Snider and Keenan (1994), chinook size distribution appeared similar in all habitat types through May. In June, slightly larger fish were found in the backwater areas and runs; fish collected from riffles, pools and glides were consistently small throughout the study.

Preliminary examination of data collected by CDFG in their emigration surveys also suggests a relationship between mean March and April temperatures and mean fork lengths of fall-run chinook salmon for different years. Snider and Titus (1996) suggests that differences in mean fork length with reach may be due to a water temperature difference between reaches and its associated effect upon growth. This difference could, however, also be attributed to higher proportion of larger, emigrating salmon in the downstream reaches. Comparison of the 1992 and the 1993 emigration surveys indicate that the mean size of juvenile fall-run chinook salmon is significantly larger (~8mm) throughout March and April in 1992 than in 1993.

Mean March and April temperatures in 1992 were 2°F to 5°F higher than in 1993. The timing of spawning can also cause a difference in mean fork length at different rearing times. However, for these two years, both peak spawning periods fell at the end of November. Notwithstanding, 1992 spawning distribution over time produced a broader curve indicating a more uniform spawning distribution than in 1991, which may have contributed to a greater mean fork length at an earlier date for juveniles produced from the 1992 spawning. The temperature profile for this growth period indicates that prevailing temperatures may be responsible for this difference.

The effect of a temperature gradient may be that rearing fish occupy the upper reaches of the lower American River in higher concentration and for longer duration during the rearing season, holding for shorter periods of time as they progress downstream. CDFG community survey results indicate that a greater concentration of juveniles rearing is found at the Sunrise location than lower reaches, particularly early in the rearing season. CDFG community survey results shown in **Figure 2-31** through **Figure 2-35** also suggest that at later dates in the spring and higher temperatures, fish that occupy the lower reaches are generally larger. Larger fish at downstream locations may be associated with two phenomena: (1) general downstream migration; and (2) an increase in the tolerance to higher temperatures in lower reaches resulting in an expansion of foraging range downstream. The two phenomena may be working cooperatively to optimize growth and modulate emigration.

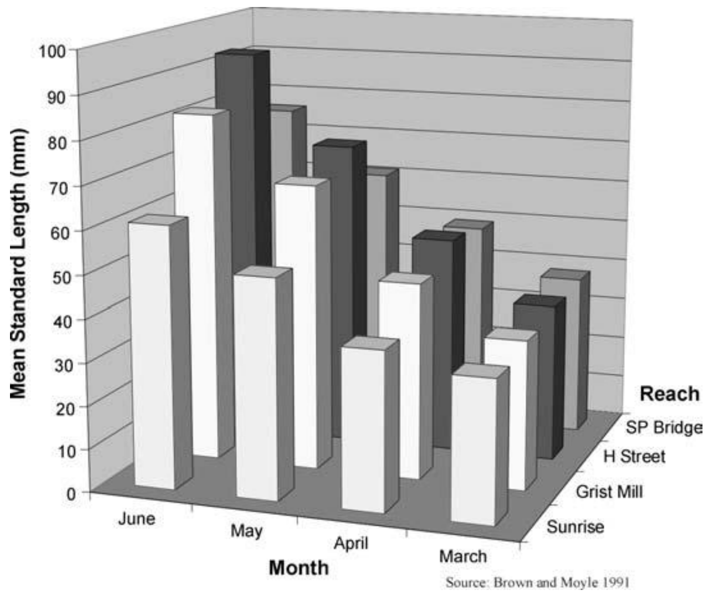


**Figure 2-31. Mean fall-run chinook salmon length at Sunrise, Gristmill, H Street, and SP Bridge on the lower American River, June through March, 1991 (fish caught by seining).**

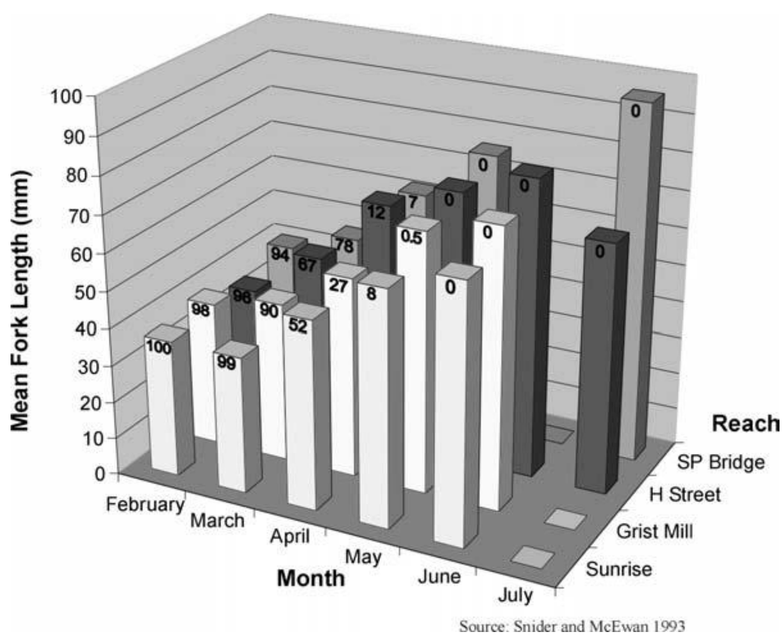


**Figure 2-32. Mean fork length for fall-run chinook salmon at SP Bridge, H Street, Gristmill, and Sunrise on the lower American River, February through July 1992.**

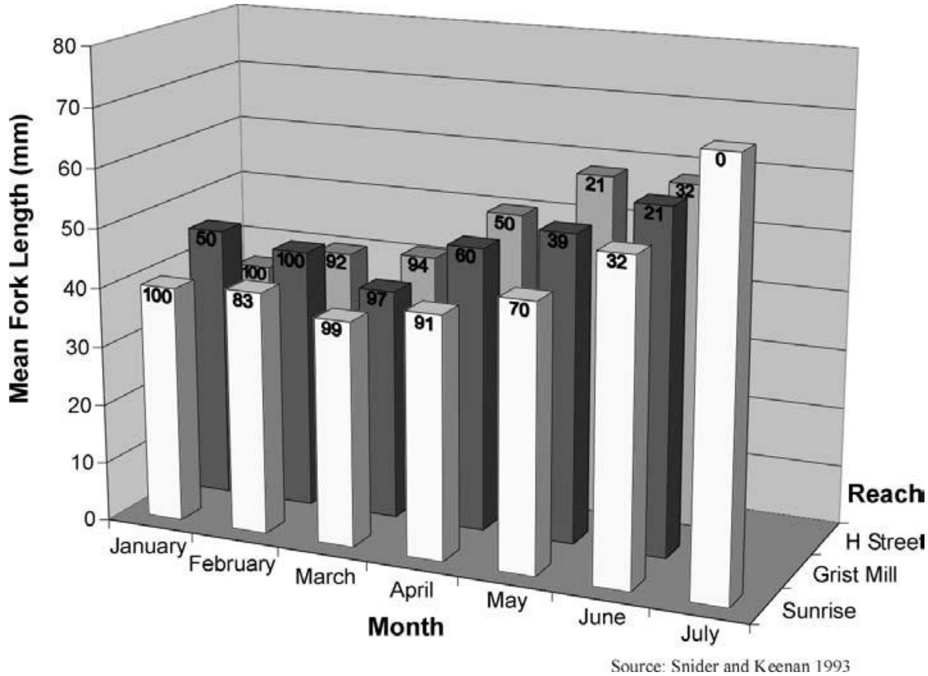


**Figure 2-33. Mean fork length for fall-run chinook salmon at H Street, Gristmill, and Sunrise on the lower American River, January through July 1993.**

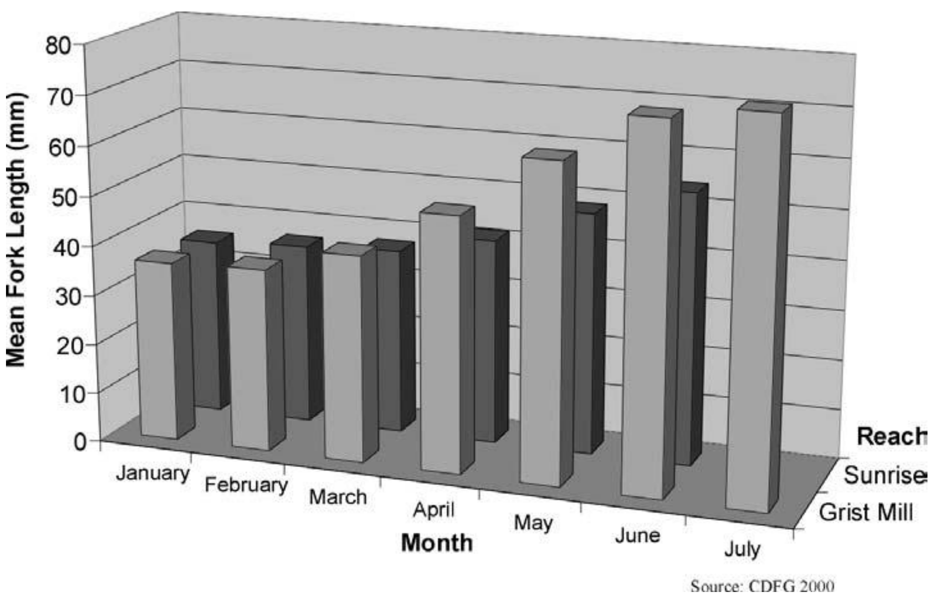


**Figure 2-34. Mean fork length for fall-run chinook salmon at Sunrise and Gristmill on the lower American River, January through July 1994.**

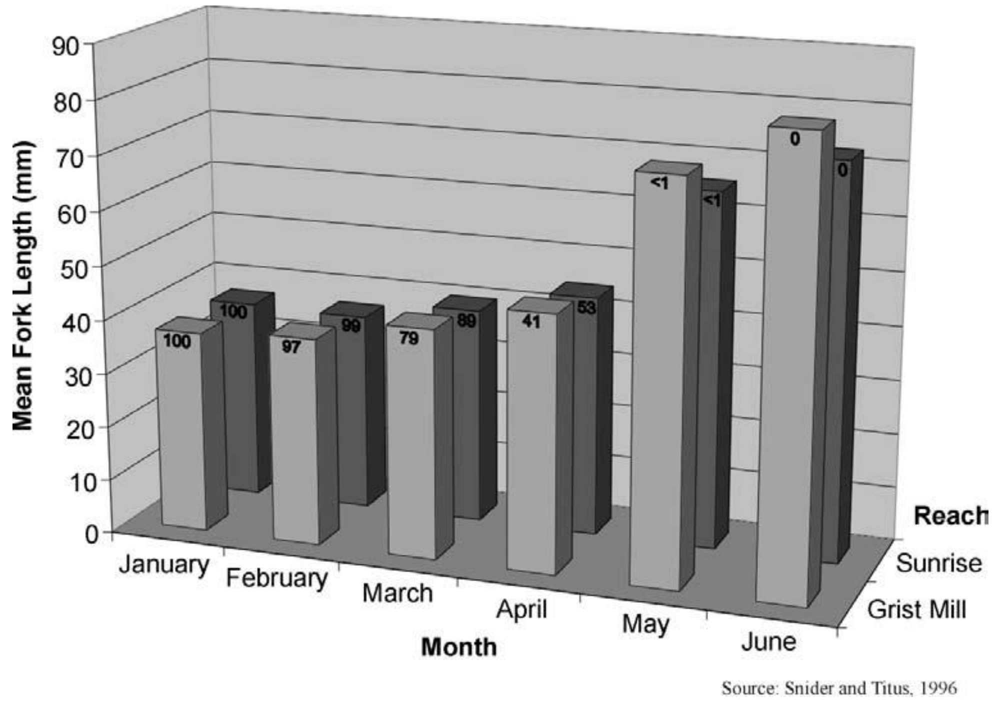


**Figure 2-35. Mean fork length for fall-run chinook salmon at Sunrise and Gristmill on the lower American River, January through June 1995.**

The habitat classification hierarchy utilized for the lower American River has provided a means of identifying, at a gross level, habitat utilization and selection by juvenile chinook salmon. During low flow, Jackson (1992) observed no juvenile chinook salmon in the Flatwater major channel feature over the study area. About twice as many juvenile chinook salmon were observed in the Bar Complex major channel feature over the study area at high flow. Nearly three times as many juvenile chinook salmon were observed in Reach 1 at high flow. Over 50% of all the observations during high flow were in Bar Complex major channel features pooled in Reach 1. The presence of greater numbers of juvenile chinook salmon in Bar Complex areas, and the upstream-to-downstream distribution, makes sense in consideration of water temperature warming from upstream-to-downstream, food production associated with cobble substrate, and possible high velocities delivering drift with available velocity shelters.

***Shaded Riverine Habitat***

Juvenile chinook salmon in the lower American River exhibit trends in habitat selection and behavior similar to what has been observed by other researchers in other rivers. Jackson (1992) found that juvenile chinook salmon occurred in groups of two fish to schools of thousands, and ranged from 50 to 120 mm (FL) but predominantly were 50 to 80 mm in length. Schools were almost always associated with cover which provided visual and/or velocity shelter, the latter of which was utilized most often.

As the juvenile chinook salmon became larger (80 to 120 mm), a progression toward utilizing deeper and faster water was observed. The larger fish were either paired, or more often alone utilizing large cobble/boulder substrate as velocity cover, and would move quickly to and from their shelter to feed on drift organisms. Individual juvenile chinook salmon were aggressive and territorial.

Jackson (1992) also found that during high flow, a considerable amount of terrestrial vegetation was submerged and utilized extensively by juvenile chinook salmon. Root wad/woody debris jams are limited in quantity in the upper two reaches of the lower American River. These were utilized extensively and provided a significant juvenile chinook salmon microhabitat niche. On all occasions where root wad/woody debris jams were available as a cover type, except in the BC run in Reach 2, large schools of juvenile chinook salmon were observed. No juvenile chinook salmon were observed at either flow period utilizing the one area surveyed along the entire lower American River with rip-rap substrate. During high flow, juvenile chinook salmon were observed utilizing eddies and small microniches within undulating sandy substrate.

SRA habitat is important for the survival of rearing chinook salmon. SRA serves as a refuge from unfavorable diurnal temperatures and resident predators. It also is a source to which fry and juveniles use to forage for food. River productivity is increased at all trophic levels by the allochthonous materials and energy input from terrestrial vegetation.

SRA cover is defined as the nearshore aquatic area occurring at the interface between a river and adjacent woody riparian habitat. The principal attributes of this valuable cover type include: 1) the adjacent bank being composed of natural, eroding substrates supporting riparian vegetation that either overhangs or protrudes into the water; and 2) the water containing variable amounts of woody debris, such as leaves, logs, branches and roots, as well as variable depth, velocities, and currents. The USFWS has established the goal to achieve no loss of existing habitat value, acreage, and riverside length of SRA habitat.

Several reports discussing the location, value, scarcity and irreplaceability of SRA cover have been prepared by the USFWS (DeHaven and Taylor 1988; DeHaven and Weinrigh 1988a; DeHaven and Weinrigh 1988b; DeHaven 1989a, 1989b; CDFG 1992). These reports conclude that SRA cover is becoming increasingly scarce throughout the Sacramento River system.

***Flow Fluctuation (Stranding)***

Fluctuating flows are believed to result in considerable stranding and loss of fall-run chinook salmon (and steelhead) juveniles in the lower American River. For example, on May 31, 1990, a flow reduction in the lower American River resulted in the stranding of several thousand juvenile chinook salmon and steelhead in the vicinity of Fair Oaks below Nimbus Dam. Mortality of young salmonids that become stranded outside of the main channel as a result of rapid instream flow reductions is near 100%. Sources of mortality in such cases include predation by fish and avian predators, as well as acute thermal stress.

Fluctuating flow releases from Folsom and Nimbus dams influence the amount of habitat available to salmonids in the lower American River, and produce fish mortality when receding flows expose eggs to desiccation and isolate fry and juvenile fish from the main river channel. Flow fluctuation, as an important source of fish mortality, is recognized in the Central Valley Project Improvement Act (CVPIA).

The CVPIA requires the development and implementation of a program to eliminate, to the extent possible, losses of anadromous fish due to flow fluctuations caused by the operation of any Central Valley Project storage or re-regulating facility. In addition, the CVPIA states that the program shall be patterned where appropriate after the agreement between the California

Department of Water Resources and CDFG regarding operation of the California State Water Project Oroville Dam complex and the effects of operations on flow in the Feather River.

A stranding study on the lower American River in March through May of 1998 has been conducted, but results have not been reported. Preliminary results of that effort were obtained from researchers at CDFG and are presented in **Figure 2-36**.

Preliminary review of the data suggests that flow fluctuations in the ranges witnessed during the survey were responsible for significant amounts of stranding. Also, it appears from the data that the H Street area presents the greatest problem of stranding of the four sites studied.

***Theoretical Rearing Habitat Availability***

Quantitative methodologies to estimate the relationship between flow and rearing habitat for juvenile chinook salmon (and steelhead) in the lower American River have been problematic. The fundamental problem is that habitat use by juvenile salmonids in large rivers is not well understood because gear/sampling problems are formidable, and turbidity and high water velocity often make direct observation difficult or impossible, or overly restricts locality of observation. However, limited understanding of habitat utilization over a broad range of conditions exacerbates the problem of attempting to develop simplified descriptions that capture the features of the environment that are important to juvenile salmon.

Brown et al. (1991) and others have identified significant relationships between physical variables and juvenile fall-run chinook salmon abundance. Brown et al. (1991) found that the abundance of juvenile fall-run chinook salmon on the lower American River was negatively correlated with velocity, water temperature and average depth. That study also found that the juveniles were positively correlated with dominant substrate. Although these correlations were significant, they were weak (Brown et al. 1991).

A critique of instream flow studies of rearing habitat in the lower American River, presented in Special Master Reports for the initial study period 1990-1993, is summarized below.

The 1966 CDFG study of the lower American River did not assess juvenile salmon rearing habitat. Therefore, the first study focusing on rearing habitat in the lower American River was conducted by the USFWS in 1981.

In September through October 1981, the USFWS used the “Instream Flow Incremental Methodology” (IFIM) to make the first estimates of how streamflow affects juvenile salmon rearing habitat in the lower American River. Using techniques described by Trihey and Wagner (1981), the USFWS staff chose four stations (Sailor Bar, Ancil Hoffman, Watt Ave., and H Street) to represent the depths, velocities, and streambed conditions in the lower American River. At each station, the USFWS set up 5 to 11 transects crossing each, and measured depth, velocity, and substrate at approximately 10-foot intervals across the channel. Using a hydraulic model (IFG-4) and their transect data, the USFWS predicted water surface elevations, depths, and mean water column velocities at streamflows ranging from 300 to 3,000 cfs.

**Figure 2-36. Number of fall-run chinook salmon stranded at Sunrise, Gristmill, H Street, and SP Bridge on the lower American River, and lower American River flow at Fair Oaks (USGS Gage 11446500) from March 4 through July 8, 1998.**

The USFWS used another computer program called HABTAT and a set of criteria defining habitat suitability to predict how much habitat would be available at flows ranging from 300 to 3,000 cfs. The HABTAT model calculates weighted usable area (WUA), an index of the quality and quantity of rearing habitat. Calculations depend upon prediction of velocity, depth, and substrate, as output of the IFG-4 Hydraulic Simulation Model, and the results are usually summarized as "weighted usable area" per foot of stream at the various flows.

It is assumed that juvenile chinook salmon prefer habitats where they have been most frequently observed. The components of the habitat such as velocity, depth, and substrate are measured and compared to the percent frequency of observations of juvenile chinook salmon in those areas. The data are presented in the form of probability-of-use or "preference" curves to illustrate how the preference changes with the changes in habitat.

Habitat preference curves for juvenile chinook salmon were originally developed by the Instream Flow Group of the USFWS at Fort Collins, Colorado, from studies of Everest and Chapman (1972), and unpublished data of the Oregon Game and Fish Commission. For the American River study, the USFWS modified these original preference curves on the basis of field notes and observations by CDFG, and produced a set of curves "specific" to the American River. These "preference" curves when applied to the IFG-4 Model indicate that the maximum amount of rearing habitat for juvenile chinook salmon in all reaches of the lower American River is created by flows ranging from about 300 to 750 cfs. The USFWS did not use this model to recommend flows because: (1) the preference criteria used to generate the curves need better definition; (2) assuming the preference criteria are valid, the curves index only the amount of physical habitat available at different flows on the unvalidated assumption that food availability within the habitat of a given quantity is equal at all flows; and (3) the curves do not consider water temperature. USFWS ignored the preference curves in their report when concluding that from January 1 through June 30, the optimum flow for juvenile salmon is 1,250 cfs "*or higher as needed to maintain the instantaneous water temperature at the mouth at 65ºF or less*."

The USFWS initiated a study of juvenile chinook salmon habitat in the lower American River during 1983 to refine the habitat suitability curve that they used in computing their original curves of flow versus habitat. High flows and turbidity in 1983 made observing juvenile salmon difficult, and they were forced to rely upon beach seining to collect fish. The use of beach seining data to develop suitability curves interjects significant bias into the shape of the curves. Sampling efficiency with a beach seine is dependent upon many factors including water velocity, substrate conditions, the amount of organic matter and debris in the stream, turbidity of the water, and the investigator's skill. The USFWS concluded that the data gathered from beach seining could not be used to refine their initial curves. New seining data gathered in the spring of 1984 were more useful but USFWS did not change their flow recommendation. Rich and Leidy (1985) reviewed the results of the USFWS modeling and criticized its recommendations stating that USFWS did not use quantitative assessment to determine the rearing flow value of 1,250 cfs. CDFG criticized the USFWS effort for not considering cover as a microhabitat variable. Salmonid preference for other microhabitat variables, including water depth, velocity and substrate, is affected by the presence of cover (Glova and Duncan 1985). CDFG claimed that salmonid microhabitat preference cannot adequately be described just in terms of velocity and depth, as was the case with the USFWS study.

In May and June 1984, Kelley et al. (1985) conducted field studies on juvenile salmon habitat in the lower American River. They developed a method for estimating juvenile chinook salmon abundance in early May of that year. After fish were counted through a grid, mean depths and water velocities were measured on the right and left edges of each segment. Substrate composition in each segment was visually estimated. From this effort, Kelley et al. (1985) developed new habitat preference criteria. The USFWS ran the new data through their habitat modeling program. The results showed that maximum amount of juvenile habitat existed at flows ranging from 500 to 750 cfs during the spring.

Kelley et al., in an addendum to the January 1985 report, proposed an alternative to the use of HABTAT altogether since they found that velocity, depth, and substrate are dependent upon each other in the way they influence population density. The results from this new model, when combined with the physical habitat model IFG-4, indicated that flows of 750-1,000 cfs maximize the area covered with the best combination of velocities, depths, and substrate in the upper 16 miles of the lower American River.

The estimation of streamflow requirements for juvenile salmonids, including at least five variations in application of PHABSIM in the lower American River, is extremely complex because of the interaction of numerous physical, chemical, and biological factors. Physical, biological and chemical characteristics, as habitat utilization predictors, are a complex multivariate function. Because of the significant uncertainty associated with habitat utilization and hydraulic modeling of large riverine systems such as the lower American River, PHABSIM predictions for rearing habitat availability may not be useful.

## Temperature Conditions

The issues associated with identifying and prescribing temperature requirements for a single species, race, and lifestage of fish are complex and heavily debated. The cause for the thermal debate was well-stated at the SWRCB lower American River hearings in the late 1980s. In her testimony, Dr. Rich characterized the debate as stemming from two problems: (1) the lack of standardization of methodologies for thermal studies; and (2) misinterpretation of thermal physiology (i.e. growth, preference, avoidance, tolerance) studies.

The variety of methodologies used to assess thermal impacts can result in a variety of interpretations of the data. The lack of standardized methodologies and the inappropriate application of laboratory studies to field conditions can lead to erroneous conclusions.

Fall-run chinook salmon are poikilotherms or “cold-blooded.” Cold blooded animals do not have the ability to internally thermoregulate. Fish species are at the mercy of the thermal characteristics of their environment. Thus, salmonids respond immediately to environmental temperature changes, either metabolically (by changing their metabolic rate which in turn, affects all organ systems within the body), or behaviorally (e.g. moving to a cooler or warmer area, if such areas are available). Behavioral thermoregulation can be a significant mitigating factor when prevailing temperature conditions are not optimal.

Because the first priority for fish is immediate survival, metabolic requirements are always satisfied before energy is spent on other functions, such as swimming, growth, or reproduction. If there is enough food available and if dissolved oxygen conditions are sufficient, then the fish will grow, within certain thermal ranges. But if either oxygen or ration become limiting, the range of thermal tolerance narrows.

Less than optimal temperatures can affect rearing juvenile fall-run chinook salmon through acute impacts, or sublethal chronic stress. The lower American River is not normally subject to temperatures that pose acute mortality in fall-run chinook salmon, although it may result in sublethal chronic stress. Established indicators of thermal stress on fish include: (1) disease outbreaks; (2) reduction in growth; (3) reduction in food conversion efficiency; (4) loss of appetite; (5) hyperactivity or disorientation; and (6) secretion of stress hormones such as adrenaline. Sublethal acute changes in water temperatures and exposure to seasonal water temperature extremes act as environmental stressors requiring physiological compensation by fishes. While sublethal water temperature extremes may be within a range of temperatures tolerated by a particular species or lifestage, latent deleterious effects may act on ontogenetic events during growth and development, or may negatively affect ecological interactions such as predation or competition (Sylvester 1972; Coutant et al. 1979; Fagerlund et al. 1995).

The literature base does not support the contention that all deviations from optimal conditions will result in negative impacts to the population. For example, according to Brett (1959) "*The thought behind 'requirements' is that of necessity rather than desirability or the maintenance of ideal conditions. ...It can be stated that a major requirement for a physical environmental factor like temperature is that it should provide for a level of activity commensurate with maintaining the species at a population level which is more than just a token sample. The particular range of temperature to meet this provision is not fixed…It must allow for all those activities which relate to maintenance, food procurement and adequate digestion, not at an optimum level, but, to repeat, at a level commensurate with species survival. It is obvious that there can be no simple pronouncement of thermal requirements."*

A summary of the relevant conclusions for studies conducted on the lower American River and other rivers supporting chinook salmon are presented in **Appendix B**. For the juvenile rearing lifestage, there is uncertainty in the literature regarding the effects of temperatures between about 60º and 66ºF. This uncertainty has two major elements:

1. Whether food conversion efficiencies and growth rates increase or decrease as temperatures increase in the lower American River. For example, Rich (1987) observed slight decreases in these factors as temperatures increased from 60º to 66ºF. By contrast, Cech and Myrick (1999) observed slight increases in these factors as temperatures increased in this range.

2. Whether populations of fall-run chinook salmon in the lower American River would be adversely affected by temperature increases within this range. While Rich (1987) observed increases in disease and mortality in this temperature range due to a disease outbreak in her laboratory study, it is uncertain how disease and mortality in fish in the lower American River would be affected by changes in temperature in this range, and whether other factors such as growth rates would predominate over disease and mortality in the overall effect on the population.

Many studies report that survival of outmigrating fall-run chinook salmon smolts decrease dramatically with increasing water temperatures between 59ºF–75.2ºF. Water temperatures associated with field distributions of fish are commonly observed to differ from laboratory determined thermal preference, and are usually lower than thermal preferences observed in the laboratory experiments (Reynolds 1977). Several plausible explanations exist for these discrepancies, including artifacts of experimental design (e.g., acute thermal tolerance versus chronic field exposure), artifacts of fish behavior in laboratory apparatus, and temperature-affected biases in field sampling. By contrast, laboratory conditions can serve to elevate the effects of temperature on laboratory fish when disease outbreaks occur. Fish in laboratory experiments cannot avoid the constant temperatures by behaviorally thermoregulating, and disease incidence in circulating laboratory water may exacerbate mortality at each temperature.

Marine (1997) conducted an analysis of temperature's impact on emigration success, which indicated that both acceleration and inhibition of Sacramento River chinook smolt development may occur at temperatures above 62.6ºF, and significant inhibition of gill Na-K ATPase activity and associated reductions of hypo-osmoregulatory capacity may occur when chronic elevated temperatures exceed 68ºF. Temperature mediates the physiological response to photoperiod inhibiting smoltification at cooler temperatures, and stimulates smoltification at warmer temperatures, up to a limit.

The major consequence of an accelerated smolt development pattern is a foreshortened period of smolting. Such a contraction of the duration of smoltification may result in asynchronous timing of smoltification, emigration, and arrival at the estuary such that hypo-osmoregulatory capability may not be at an optimal functional level upon ocean entry. In such a case, juvenile salmonids may require additional time in fresh or brackish water to adapt to higher salinities which could lengthen residency in the lower reaches of rivers or the estuaries. Several lines of evidence and explanatory hypotheses have suggested that the specific period for emigration of juvenile salmonids from the freshwater stream environment to the sea is probably adaptive, minimizing predation risks and maximizing growth opportunities (Marine 1997). Potential temperature-induced alteration of smoltification timing that results in premature migration or accelerated parr-smolt reversal could disrupt the synchrony of optimal smolt development timing of ocean entry.

In the lower American River, most juvenile salmon emigrate as post-emergent fry. Snider and Titus (1995) found that nearly all emigrants required additional growth and development after leaving the lower American River and before entering the ocean in order to attain a size conducive to survival to adulthood.

***Ration***

At restricted food availability optimal, or peak, growth rates will occur at lower water temperatures (Brett et al. 1982; Rich 1987). Effective methods of quantifying the ration level existing in the natural stream have yet to be applied to the lower American River. Brett (1982) in his study of juvenile chinook salmon on the Nechako River in Canada, used models relating ration, growth rate, and temperature to approximate the natural ration level as 60% of satiation. As such, he reduced his optimal rearing temperature recommendation from 66ºF to 59ºF for natural conditions. Kelley et al. (1985) used the relationships developed by Brett, Clark, and Shelbourn (1982) between growth rates, water temperature and food ration to estimate ration levels in the lower American River at 95% satiation (Kelley 1985a). Kelley et al. (1985b) revised that estimate to 80% of satiation for fish collected in June, which may have included hatchery-reared fish released into the river. The study was conducted again with fish captured in April and May to reduce the effects from hatchery released fish, and produced a ration estimate of 84% satiation.

***Macroinvertebrate Distribution and Fish Food Utilization***

Drift and benthic macroinvertebrate communities existing on the lower American River have been examined in several studies. A brief synopsis of those studies is provided below.

Kelley et al. (1985a, 1985b) examined macroinvertebrate drift density, benthic abundance, and stomach contents of juvenile fall-run chinook salmon. Results were not conclusive due to lack of intensity of the surveys, and lack of control of factors affecting food item concentration (Kelley et al. 1985a, 1985b). Examination of 115 juveniles chinook salmon stomachs found that the dominant organisms were chironomids of the subfamily *Orthocladinae*, and nymphs of the mayfly *Baetis insignificans*. They also concluded that zooplankton from Folsom or Natoma lakes were sometimes numerous in the stomachs, but were too small to provide much volume.

In 1991, Brown et al. (1991) found that in general, the diet of lower American River juvenile fall-run chinook salmon was similar to that reported for this species in other rivers and for this river by Kelley et al. (1985a and 1985b).

Hanson et al. (1991) suggested that benthic macroinvertebrate populations may be relatively low in a number of areas in the lower American River, and that food supplies may potentially be a factor influencing the survival and growth for a number of fish species, including juvenile chinook salmon and steelhead.

USFWS (1984) examined the stomachs of 296 juvenile chinook salmon captured by seining in the lower American River from March through June of 1983. The stomachs contained primarily benthic macroinvertebrate larvae and pupae. Zooplankton from Folsom Lake were also commonly eaten, but are very small and probably not a significant food source. The most abundant aquatic insects were small midges, or chironomids.

Merz (1994) found that both chinook salmon and steelhead fed heavily on aquatic insects, with diets similar to those found in studies described above. Baetid mayflies and hydropsychid caddisflies were the highest percentage of biomass observed in the diets of young salmonids, indicating that fall-run chinook salmon and steelhead fed more in fast waters frequented by those food items. Juvenile fall-run chinook salmon first appeared in late January or early February and steelhead fry began appearing in the river approximately one month later. Because of the additional growth period and the fact that emerging chinook are larger than emerging steelhead, dietary overlap was not significant during the early part of the season. As the steelhead grew, their diets overlapped more with the chinook. Merz (1994) found that this overlap did not become significant until April and May, when chinook salmon have, or continue, to emigrate from the river. Diel sampling indicated greatest feeding for chinook salmon at dawn and dusk. Steelhead feeding peaked at dawn, although feeding activity occurred throughout the day with only one major decrease at noon. Dramatic changes in river flows were observed during the 1993 season, corresponding to a shift in the diet of all juvenile salmonids predominantly to chironomids, indicating flow may have a major impact on the diets of these fish (Merz 1994).

## Turbidity

Turbidity changes during the course of the year may be one abiotic environmental factor helping to modulate migratory behavior in fall-run chinook salmon. Turbidity also plays a role in limiting the feeding. When levels are high, >10 NTU, juveniles have difficulty viewing potential food. Chinook salmon feed by sight and high turbidity can be a direct barrier to feeding. Monthly average turbidity measured at the Fairbairn Water Treatment Plant intake structure (RM 7.5) are below levels that would impact foraging for the period of the year most significant to rearing juvenile fall-run (February through May).

## Predation

The effects of environmental stressors such as temperature may have indirect impact on performance capacity and reduce a fish's scope for coping with additional stressors. In Marine (1997), exposure to water temperature between 62.6ºF and 75.2ºF for 2.5 months resulted in incremental increases in predation vulnerability, relative to juvenile salmon rearing at 55.4ºF–60.8ºF for the same time period. Marine (1997) could not rule out size selectivity as a potential mechanism affecting the results, although swimming performance, shoaling, or schooling behavior are documented to affect predation vulnerability in fish and may be affected by elevated rearing temperatures.

Predators of juvenile salmonids, including pikeminnow and striped bass, are common in the lower American River. Predation by these species is generally considered to be greater near instream obstructions and diversions where unusual flow patterns disorient or concentrate smolts. Because of the general absence of these conditions in the lower American River, it is likely that predation losses of juvenile salmonids are probably lower in the lower American River than in many other rivers.

Laboratory predation challenge tests have not been conducted on lower American River salmon or steelhead, nor have field studies of predation been conducted in the lower American River. Kelley et al. (1985) made underwater observations during their studies in 1994 and 1995, and suggested that there was an absence of serious predation on young salmon in the lower American River.

## Additional Growth and Condition Considerations

Growth and condition of anadromous fish have commonly been used to indicate the health and success of rearing juveniles. Growth is used to determine the effects of environmental conditions, including thermal history, on rearing juveniles. Measuring the condition of fish is theorized to probe the current physiologic health of the fish, which is supposed to reflect the suitability of the environment in which the fish is dwelling. The successful correlation between environmental stressors and growth or condition factors rests on the accuracy and reproducibility of the methodologies used to measure growth and condition.

Growth rates have been estimated from the otoliths, or ear stones, of juvenile chinook in the lower American River. Salmonid otolith increment formation reflect daily periodicity. Pannella (1971) first demonstrated the existence of daily increments in the otoliths of fishes. Campana and Neilson (1985) proposed that the periodicity of increment formation is under endogenous control and coupled to photoperiod, although other factors could cause the formation of sub-daily increments. Evidence for this proposition and its limitations in extreme environmental conditions comes from Campana (1984), Radtke and Dean (1982), or Wright et al. (1991).

Castleberry (1991, 1992), in his studies of growth and performance of lower American River chinook salmon, used the Biosonics Optical Pattern Recognition System to read incremental growth rings and distances between rings, after removing the otoliths with techniques in Schneidervin and Hubert (1986) and preparing them with techniques from Neilsen and Geen (1982). The method was not validated on wild salmonids, including lower American River salmonids, until 1993 when Castleberry (1993) conducted a field verification in a Feather River enclosure of fish caught in the Feather River by seining, and confirmed that wild fish formed one increment per day on their sagital otoliths in a 42-day study. Although the incrementation was found to vary with extremes in environmental conditions, they postulated that in the low elevation waters of the Central Valley, extremes are unlikely and therefore otolith analysis can be used on all Central Valley streams that are similar to the Feather River, including the lower American River. Since 1993, additional work on otolith analyses has been conducted by CDFG (Snider and Titus) to refine techniques and, consequently, management applications.

In the lower American River, Castleberry et al. (1991) examined additional indicators of growth, condition, and physiologic performance. These indicators included short-term growth rate (RNA/DNA) ratios), long-term growth rate (otolith analysis), lipid content, gill Na+K+ATPase activity, histology and morphometry, critical swimming speed, and seawater challenge on juvenile fall-run chinook salmon and steelhead. In general, they found no evidence of decreased health and condition of juvenile salmonids over the range of water temperatures (up to approximately 65ºF) at which fish were collected.

### Emigration

Correlation between environmental factors and juvenile outmigration characteristics (e.g., timing, magnitude, rate, etc.) are difficult to make with statistical certainty because the mechanism of migration is a complex hierarchy of cues depending on the species, stock, life history, environmental conditions, season and other factors. An extensive multivariate analysis over many years would be necessary for any particular stream, race of fish and lifestage in order to determine the importance of a single environmental stress or the mechanism by which it operates. Pribble and Diamond (1978) in the Columbia River Basin note…*"It should be noted that although correlations were found between the peak in migratory activity and temperature, flow, and turbidity, statistically they were not significant."*

Emigration of juvenile chinook salmon occurs through either passive or active displacement. Northcote (1984) presents evidence for active transport of rainbow trout fry observed in streams by infra-red viewing. Thorpe (1988) presents an argument for passive transport, also proposed by Hoar (1953). Because migration of juveniles is mainly nocturnal, it coincides with a relatively inactive period in territorial species. Thorpe (1988) argues that a reduction in swimming performance at this time makes the fish unwilling to resist high stream velocities (twice their body length per second) and, thus, the fish are reluctantly and passively transported in diurnal cycles.

During diel electrofishing in the lower American River conducted in 1991, juvenile fall-run chinook salmon and steelhead were only caught after midnight and in the early morning, suggesting movement during darkness (Brown et al. 1991). Hoar (1953) suggests that diurnal migration is characteristic of many fish, and explains the mechanism for the prolonged residence but eminent displacement of territorial juvenile salmon. For juvenile salmon and steelhead, the exhibition of greater night movement results in downstream displacement during the time of coolest water temperatures and lowest vulnerability to visual predators (Brown et al. 1991).

Rotary screw traps have been used to monitor juvenile salmonid emigration in the lower American River since 1992. Snider (1992) found that based upon the average size of salmon caught between March 27 and May 6, it appeared that the rotary traps were collecting outmigrating salmon, as opposed to milling salmon. Estimating juvenile outmigrant abundance with rotary screw traps involves the use of "trap efficiency" tests (e.g., Thedinga et al. 1994). Fish are captured at a trap and a portion of these are marked, transported upstream and released. The proportion of the total number of fish marked that is recaptured at the trap is an estimate of the trap efficiency. Trap efficiency estimates are necessary to extrapolate capture data to population estimates.

CDFG has calculated trap efficiency for four of the six years that emigration surveys were conducted in the lower American River. **Figure 2-37** shows the outmigrant juvenile fall-run chinook salmon population estimates for the six years the study was conducted. The estimates were calculated by taking the total count for the survey period and dividing it by the mean capture efficiency for the survey period. In 1993, 1996, 1997, 1998, 1999, capture efficiencies were calculated on a weekly basis for short sample periods, and were used to represent the entire survey period. For years 1992 and 1995/96, because no capture efficiency analysis was conducted, the average efficiency from the years that it was performed was applied to calculate populations for 1992 and 1995/96, for trend comparison purposes.

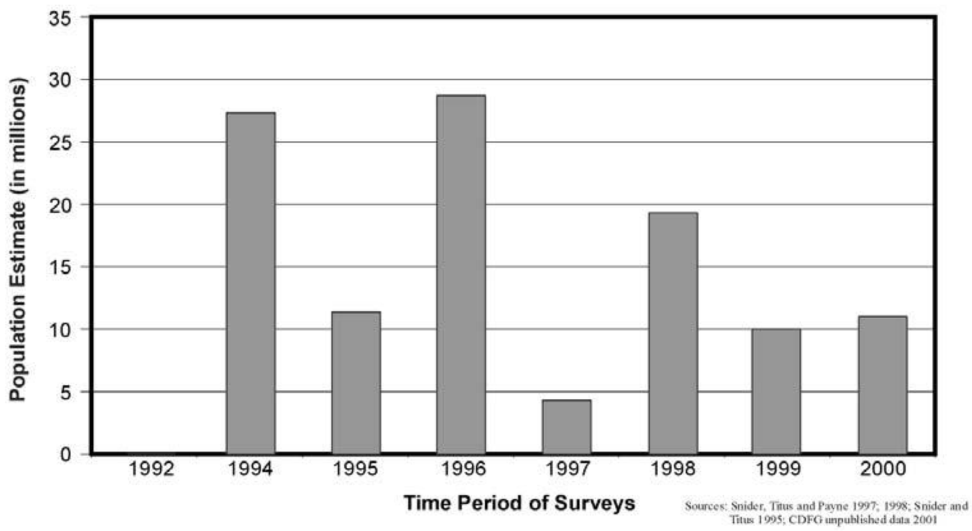


**Figure 2-37. Annual population estimates for juvenile fall-run chinook salmon in the lower American River, 1992 through 2000. Estimates were calculated by dividing total fish caught by the mean capture efficiencies. No trap efficiency evaluation was conducted on the 1992 and 1995 emigration surveys; instead, an average of mean capture efficiencies from the remaining surveys were used to calculate the 1992 and 1994-1995 population estimates. The estimate for 1992 was only 30,300, which is not visible at this scale.**

Because environs downstream of the lower American River change depending on the time of the year, timing of emigration is crucial. Post-Folsom Dam emigration timing is comparable to that described in the lower Sacramento River near Hood, both prior to and after completion of Shasta Dam (Schaffter 1980), and to fall-run chinook salmon emigration observed since construction of

Oroville Dam on the Feather River (Painter et al. 1977). Chronic changes in emigration timing can ultimately affect population persistence (Park 1969).

Juvenile salmonid emigration was monitored in the American River from 1945 to 1947 (USFWS 1953). Fry emigrants were detected as early as January, but did not increase in numbers until March, attaining a peak in April. Fingerling emigration began in late May and continued into mid-June.

The 1944-1946 brood stocks of chinook salmon had access to the upper reaches of the American River. Thus, the 1945-47 emigration timing may have been due to possible differences in spawning and adult migration timing, longer incubation, later emergence, and slower growth associated with typically colder, more oligotrophic conditions found in the upper reaches of the American River.

Water temperature influences chinook salmon emigration timing from the lower American River through incubation and growth rates, and through moderation of genetic migration timing signals. Relatively earlier emergence and emigration currently observed in the lower river is likely a result of the temperature-moderating effect of Folsom and Natoma reservoirs. Emigration in both 1995 and 1997 surveys started 3 weeks later than in the 1996 survey and 3 weeks earlier than in the 1994 survey. Peak catch occurred at essentially the same time during 1994, 1995, and 1997, and nearly 1 month later than in 1996. Average water temperature in December 1996, prior to the 1997 emigration, was 51.4ºF, comparable to that observed in December 1994, prior to the 1995 emigration (52.0ºF) when timing was very similar. However, it was substantially cooler than in December 1995, prior to the 1996 emigration (55.7ºF), when timing was substantially earlier, and somewhat warmer than in December 1993 (48.9ºF), prior to the 1994 emigration, when timing was relatively later.

The proportion of yolk-sac fry, fry, parr, silvery parr, and smolt emigrants is variable from year to year and are likely influenced by flow and temperature conditions during incubation and early rearing. Notably, the proportion of parr in 1997 (47.7%) was considerably higher than in the three previous survey years. The combined fry and yolk-sac fry fraction in 1997 (48.3%) was the lowest observed during the survey years from 1994 through 1997. Snider et al. (1997) identified mean February temperatures as possibly explaining why fewer fish emigrated at the yolk-sac fry and fry stages in 1995 relative to other years.

Early high flows in January of 1997 may have killed many of the salmon that would have otherwise emerged early and emigrated as fry, resulting in a smaller number, thus smaller proportion of the catch. In general high flows may affect the life stage at which emigration occurs. Also different turbidity conditions may speed up or delay emigration allowing more or less fry to become parr before emigrating. Different flows between years may provide more or less rearing habitat for fry, resulting in a different proportion of recently-emerged fry departure (Snider et al. 1997).

The signals that actually trigger emigration are similar to those that moderate the timing of emigration (i.e., flow, temperature, fish size) but occur post emergence (usually after mid-January). Brown et al. (1991) found that emigration of juvenile salmon was associated with higher flows after the emergence period. However, this positive correlation is probably reversed when flows reach higher levels. Snider et al. (1998) found that in 1994, 1995,1996, and 1997, there was no evidence that peak emigration was related to peak winter or spring flows. In 1995, for example, most emigrating salmon were caught when flow ranged from 4,000 to 10,000 cfs, whereas maximum flow ranged from 30,000 cfs in January to 40,000 cfs in March.

Turbidity has also been cited as a contributing factor in triggering emigration. Snider and Titus (1995) found that increases in turbidity in the lower American River at Fairbairn Water Treatment Plant was coincident with early peaks in fry emigration.

The annual estimated number of juvenile emigrants also appears to be strongly influenced by flow during the incubation period (primarily January). Snider and Titus (2000) found that mean flow in January 1997 (32,617 cfs) was substantially greater than that observed during any of the previous three survey years (1,755 cfs in 1994, 2,186 cfs in 1996, and 8,576 cfs in 1995). Those years when January flows were stable and flood events were absent (flow <25,000 cfs) also produced the highest, estimated total emigration population (total catch/mean efficiency). Snider and Titus (2000) compared the mean and maximum January flows with an index of survival (emigration population estimate divided by the spawning escapement population size for that brood) indicating that survival may be inversely related to January flow conditions (r= -0.743).

The relationship between flow and total population identified above apparently was not influenced by spawner population size. Snider and Titus (2000) found that the estimated annual emigration population was not related to spawner population ($r^2$= 0.0001). The highest estimated spawner escapement yielded the second highest emigration population estimate (1996 survey year); the second highest spawner escapement estimate yielded the lowest emigration population estimate (1997 survey year). The highest estimated emigration population occurred in the 1994 survey year following the second lowest estimated spawner escapement population. An index of survival to emigration (estimated emigration population/escapement estimate) was negatively correlated with both mean January flow and peak January flow ($r$ = -0.74).

The downstream environs are very important to the survival of lower American River fall-run chinook salmon. As in the previous three survey years, nearly all (>99%) emigrating chinook salmon observed in 1997 were pre-smolts. These findings suggest that the smolting process is not completed in the lower American River, but will continue downstream, or, alternatively, that returning adults are primarily from hatchery plants. A summary of emigration results is provided in **Table 2-18**.

#### 2.2.2.5. NIMBUS HATCHERY OPERATIONS

Nimbus Hatchery was constructed to mitigate for the loss of spawning grounds which resulted from the construction of Nimbus and Folsom Dams of the CVP. A USFWS and CDFG (USFWS and CDFG 1953) study indicated that approximately 73% of the salmon and 100% of the steelhead once spawned in the area now above Nimbus Dam. Thus, the Nimbus Hatchery was a means of maintaining the runs by substituting artificial spawning for the natural spawning lost when areas above Nimbus Dam could no longer be reached by anadromous salmonids.

**Table 2-18. Comparison of results from lower American River emigration surveys conducted 1994-1997 and corresponding spawning escapement and incubation flows (Snider and Titus 2000).**

| | Year | | | |
|---|---|---|---|---|
| | **1994** | **1995** | **1996** | **1997** |
| Total catch | 162,089 | 45,478 | 132,040 | 32,064 |
| Mean efficiency | 0.72 | 0.72a | 0.68 | 0.75 |
| Estimated emigration population | 18.2 million | 5.9 million | 19.4 million | 4.3 million |
| Spawner escapement | 28,754 | 27,733 | 68,000 | 67,000 |
| Emigration survival index | 633.4 | 213.0 | 285.6 | 63.8 |
| Mean January flow | 1,755 | 8,552 | 2,186 | 32,617 |
| [a] Estimated as the mean efficiency observed during 1994, 1996, and 1997. | | | | |

The Nimbus Salmon and Steelhead Hatchery and the American River Trout Hatchery are located on the American River, approximately one-quarter mile downstream of Nimbus Dam. The Nimbus Hatchery was constructed to compensate for the loss of riverine habitat resulting from the construction of Folsom Dam in 1955. The hatchery is operated by CDFG under contract with the United States. Originally, the hatchery was planned to incubate 30 million chinook salmon and steelhead trout eggs, and to rear the fry to a size suitable for release in the American River.

The diversion structure consists of eight piers on 30-foot spacings, including two riverbank abutments, which span the river and guide upstream migrants to the fish ladder and into the hatchery. Fish rack support frames and walkways are installed each fall via an overhead cable system. A pipe rack is then put in place, which supports pipe pickets (three-quarter inch steel rods spaced on two and one-half inch centers). The pipe rack rests on a submerged steel I-Beam support frame, which has numerous voids underneath. Since there is no concrete foundation between the piers, riverbed scour underneath the support frame does allow for passage of migrants upstream, although the aim is to divert all of them into the hatchery.

Water temperatures in the hatchery are dictated by the temperature of water in Lake Natoma, which is dependent on the temperature of water releases from Folsom Reservoir and meteorological conditions.

### Hatchery Production Goals

CDFG operates the Nimbus Salmon and Steelhead Hatchery and the American River Trout Hatchery, both located at the same facility immediately downstream from Nimbus Dam. This hatchery facility (referred to as the Nimbus Hatchery when discussing chinook salmon and steelhead in the *Baseline Report*) receives its water supply directly from Lake Natoma.

Based on the 1944 to 1952 average spawning stock escapement estimate of 25,948 chinook salmon, a fecundity estimate of 6,500 eggs per female taken from the Tuolumne River, the estimated above Nimbus Dam spawner proportion of 73%, and the male-to-female proportion between 1944 and 1952 of 38.8%, the chinook salmon egg production goal for the Nimbus Hatchery was estimated to be about 48 million. However, because of the experimental nature of the undertaking, it was decided construction of a hatchery with an initial capacity of 30 million eggs and potential for enlargement to a 50-million-egg capacity would be prudent (USBR 1986). This goal was incorporated into the first Nimbus Hatchery operations contract between USBR and CDFG dated June 1, 1956. The original contract included a termination provision providing that either party could unilaterally terminate the agreement if salmon and steelhead spawning naturally in the American River below Nimbus Dam equaled the average run, which prevailed in the American River during the period 1944 to 1954 (25,948 fish).

The current production goal for fall-run chinook salmon is to take 8 million eggs to produce 4 million smolt-size (60 fish/lb.) fish (West, CDFG, pers. comm., 1999). The hatchery's fish ladder is opened to fall-run chinook salmon annually when the average daily river temperature declines to approximately 60°F, which generally occurs in October or early November (West, pers. CDFG, comm. 2000). The fall-run chinook salmon produced are released directly into the Delta. In the event that the hatchery's inventory of chinook salmon requires reduction before releasing all of the year's production, chinook salmon fry are released into the Sacramento River at either Miller Park or Garcia Bend (West, CDFG, pers. comm., 2000).

The Nimbus Hatchery receives water for its operations directly from Lake Natoma via a 60-inch-diameter pipeline. Water temperatures in the hatchery are dictated by the temperature of water diverted from Lake Natoma which, in turn, primarily depends on the temperature of water released from Folsom Reservoir, air temperature, and retention time in Lake Natoma. The temperature of water diverted from Lake Natoma for hatchery operations is frequently higher than that which is desired for hatchery production of rainbow trout, steelhead, and chinook salmon. Under such conditions, more suitable temperatures may be achieved by increasing releases at Folsom Dam and/or releasing colder water from a lower elevation within Folsom Reservoir. However, seasonal releases from Folsom Reservoir's limited coldwater pool to benefit hatchery operations must be considered in conjunction with seasonal in-river benefits from such releases.

### Hatchery Methods

#### Sampling

Currently, the Nimbus Hatchery opens the fish ladder when water temperatures in the lower American River decrease to a daily maximum of 60°F. Access may be curtailed if conditions become unfavorable subsequent to opening the ladder. In the past, the hatchery lowered the weir and opened the ladder based on the run timing and not on favorable spawning conditions. The weir was often installed (and ladder opened) in August. Now the weir is consistently placed in the river in late September and the ladder not opened until water temperature conditions become favorable, usually by mid-October to mid-November. A summary of Nimbus Hatchery chinook salmon statistics is presented in **Table 2-19**.

All fall-run salmon adults and grilse entering the Nimbus Hatchery are presently retained for egg taking or fertilization. Eggs are screened after they are allowed to reach the eyed stage. At that point the eggs are addled, or given a low voltage shock to rupture the membranes of unfertilized eggs causing them to float, whereas fertilized eggs are more resilient and maintain their density and do not float. This procedure allows hatchery operators to scoop the unfertilized eggs from the top (Veek, CDFG, pers. comm. 2000).

**Table 2-19. Summary statistics of Nimbus Hatchery operations from 1956-1999.**

| Chinook Salmon Hatchery Statistics | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Run Data | | | | | | | | | | | | | | |
| Year | Total Adults (Swam up Ladder) | Date Weir installed | Date oper. | Date of first fish entering hatchery | Date of last fish taken | Grilse 2yr | Total Males | %Male Spawned | Total Females | %Female Spawned | % Returning Male | % Returnin g Female | Tagged Nimbus Stock | Other Tagged Hatchery Stock |
| 1955 | | | | | | | | | | | | | | |
| 1956 | 1,543 | 11-Sep | 11-Sep | 17-Sep | 18-Jan | 774 | 267 | | 502 | 82 | 34.00 | 65.00 | | |
| 1957 | 890 | 13-Sep | 13-Sep | 17-Sep | 31-Jan | 252 | 297 | | 341 | 48 | 46.55 | 53.45 | 102 | |
| 1958 | 10,210 | 18-Aug | 18-Aug | 14-Sep | 26-Jan | 1,538 | 4,471 | | 3,689 | 61 | 54.79 | 45.21 | 460 | |
| 1959 | 13,235 | 22-Sep | 22-Sep | 24-Sep | 4-Feb | 2,866 | 3,003 | | 7,366 | 87 | 28.96 | 71.04 | 513 | |
| 1960 | 32,641 | 31-Aug | 31-Aug | 31-Aug | 24-Feb | 9,331 | 13,455 | | 6,487 | 74 | 67.47 | 32.53 | 350 | |
| 1961 | 14,341 | 5-Sep | 5-Sep | 7-Sep | 16-Apr | 1,638 | 3,446 | | 9,257 | 78 | 27.13 | 72.87 | 72 | |
| 1962 | 12,668 | 22-Aug | 22-Aug | 1-Sep | 2-Mar | 3,442 | 5,088 | | 4,138 | 69 | 55.15 | 44.85 | 359 | |
| 1963 | | | | | | | | | | | #DIV/0! | #DIV/0! | | |
| 1964 | 20,542 | 26-Aug | 24-Sep | 18-Oct | | 4,436 | 7,209 | | 8,799 | 84 | 45.03 | 54.97 | 574 | |
| 1965 | 13,676 | 1-Oct | 1-Oct | 12-Oct | | 744 | 5,295 | | 7,637 | 90 | 40.94 | 59.06 | 13 | |
| 1966 | 8,105 | 20-Aug | 20-Aug | 20-Oct | 14-Feb | 550 | 2,434 | | 5,121 | 85 | 32.22 | 67.78 | 169 | |
| 1967 | 5,147 | 22-Aug | 22-Aug | 1-Sep | | 733 | 2,022 | | 2,392 | 68 | 45.81 | 54.19 | 572 | |
| 1968 | 5,233 | 10-Aug | 10-Aug | 18-Sep | 19-Feb | 1,175 | 1,318 | | 2,740 | 95 | 32.48 | 67.52 | | |
| 1969 | 8,184 | 26-Aug | 16-Oct | 16-Oct | 7-Jan | 521 | 1,488 | | 1,061 | 90 | 58.38 | 41.62 | | 28 |
| 1970 | 8,624 | 19-Aug | 21-Oct | 21-Oct | 7-Jan | 770 | 3,027 | | 4,827 | 59 | 38.54 | 61.46 | 32 | 24 |
| 1971 | 9,146 | 15-Aug | 16-Sep | 24-Oct | 1-Feb | 1,269 | 3,384 | | 4,493 | 79 | 42.96 | 57.04 | 372 | 300 |
| 1972 | 7,106 | 11-Aug | 30-Aug | | | 1,659 | 2,195 | | 3,252 | 79 | 40.30 | 59.70 | 361 | 236 |
| 1973 | 12,535 | 24-Aug | 5-Sep | 5-Sep | | 1,676 | 5,155 | | 5,704 | 48 | 47.47 | 52.53 | 435 | 263 |
| 1974 | | | | | | 671 | 2,762 | | 4,746 | | 36.79 | 63.21 | | |
| 1975 | 7,413 | 3-Sep | 3-Sep | 3-Sep | | 846 | 2,734 | | 3,833 | 84 | 41.63 | 58.37 | 11 | 114 |
| 1976 | 5,244 | | | | | 849 | 2,002 | | 2,340 | | 46.11 | 53.89 | | |
| 1977 | 7,065 | | | | | 498 | 3,496 | | 2,874 | | 54.88 | 45.12 | | |
| 1978 | 8,162 | 1-Sep | 21-Sep | 10-Oct | | 2,047 | 2,348 | | 3,767 | 82 | 38.40 | 61.60 | | 137 |
| 1979 | | | | | | 3,067 | 4,799 | | 2,394 | | 66.72 | 33.28 | | |
| 1980 | 15,659 | 3-Sep | 15-Oct | 28-Oct | | 2,068 | 6,122 | | 7,553 | 82 | 44.77 | 55.23 | | 95 |
| 1981 | 20,588 | 26-Aug | 7-Oct | 21-Oct | | 2,805 | 10,497 | | 7,286 | 63 | 59.03 | 40.97 | | 52 |
| 1982 | 10,924 | 28-Aug | 3-Oct | 25-Oct | | 2,576 | 4,535 | | 3,813 | 60 | 54.32 | 45.68 | | 52 |
| 1983 | 9,081 | 5-Oct | 21-Oct | 2-Nov | | 2,514 | 3,081 | | 3,486 | 47 | 46.92 | 53.08 | | 100 |
| 1984 | 12,249 | 13-Sep | 26-Oct | 30-Oct | | 1,953 | 4,548 | | 5,748 | 7 | 44.17 | 55.83 | | |
| 1985 | 9,093 | 11-Sep | 31-Oct | 1-Nov | | 1,305 | 3,349 | | 4,439 | 74 | 43.00 | 57.00 | | |
| 1986 | 5,695 | 30-Sep | 3-Nov | 4-Nov | | 910 | 2,168 | | 2,617 | 82 | 45.31 | 54.69 | 60 | 38 |
| 1987 | 6,258 | 15-Sep | 18-Nov | 20-Nov | | 2,913 | 1,759 | | 1,586 | 54 | 52.59 | 47.41 | 41 | 26 |
| 1988 | 8,625 | | | | | 661 | 3,777 | | 4,187 | 71 | 47.43 | 52.57 | | |
| 1989 | 9,740 | 20-Sep | 30-Oct | 31-Oct | | 511 | 4,105 | | 5,125 | 85 | 44.47 | 55.53 | 57 | 9 |
| 1990 | 4,857 | 16-Sep | 24-Oct | 24-Oct | | 823 | 1,773 | | 2,251 | 90 | 44.06 | 55.94 | 133 | 46 |
| 1991 | 7,128 | 24-Sep | 4-Nov | 7-Nov | | 359 | 3,245 | | 3,524 | 93 | 47.94 | 52.06 | 224 | 88 |

| Chinook Salmon Hatchery Statistics | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Run Data | | | | | | | | | | | | | | |
| YEAR | TOTAL ADULTS (SWAM UP LADDER) | DATE WEIR INSTALLED | DATE OPER. | DATE OF FIRST FISH ENTERING HATCHERY | DATE OF LAST FISH TAKEN | GRILSE 2YR | TOTAL MALES | %MALE SPAWNED | TOTAL FEMALES | %FEMALE SPAWNED | % RETURNING MALE | % RETURNIN G FEMALE | TAGGED NIMBUS STOCK | OTHER TAGGED HATCHERY STOCK |
| 1992 | 6,456 | 29-Sep | 12-Nov | 16-Nov | | 1,349 | 2,458 | | 2,649 | 81 | 48.13 | 51.87 | 63 | 8 |
| 1993 | 10,656 | 28-Sep | 8-Nov | 9-Nov | | 3,313 | 3,181 | | 4,162 | 86 | 43.32 | 56.68 | | 6 |
| 1994 | 10,673 | 20-Sep | 7-Nov | 8-Nov | | 892 | 3,382 | | 4,247 | 89 | 44.33 | 55.67 | | |
| 1995 | 6,439 | 20-Sep | 11-Nov | 11-Nov | | 1,324 | 2,937 | | 2,178 | 97 | 57.42 | 42.58 | | 14 |
| 1996 | 7,747 | 18-Sep | 22-Oct | 24-Oct | | 505 | 3,520 | | 3,777 | 71 | 48.24 | 51.76 | | 70 |
| 1997 | 5,650 | 23-Sep | 3-Nov | 4-Nov | | 321 | 2,997 | | 2,332 | 97 | 56.24 | 43.76 | | |
| 1998 | 10,581 | 9-Sep | 15-Oct | 16-Oct | | 1,682 | 2,918 | | 2,701 | 131 | 51.93 | 48.07 | | |
| 1999 | 8,361 | 18-Sep | 2-Nov | 3-Nov | 21-Dec | 3,337 | 3,052 | 59.2 | 2,323 | 76.9 | 56.78 | 43.22 | | |
| Hatchery data obtained from Nimbus Hatchery annual reports 1956 through 1999. Estimates for years 1988 through 1991 were obtained from USFWS (1995)<br>Data was also obtained from a tabulation of Hatchery data found in USFWS (1986) | | | | | | | | | | | | | | |

| Table 2-19. Summary statistics of Nimbus Hatchery operations from 1956-1999 (Cont). | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Egg Production (Fecundity) | | | | | | | | | | |
| YEAR | DATE FIRST EGGS TAKEN | INITIAL HOLDING TIME (DAYS) | TOTAL EGG COUNT | AVERAGE EYED EGG SIZE (#/OZ) | PRODUCTION QUOTA (EGGS KEPT) | EGGS PER SPAWNED FEMALE | % EGGS TO REACH EYE | NUMBER OF CHINOOK SALMON PLANTED IN THE AMERICAN RIVER | | |
| | | | | | | | | FINGERLINGS | SMOLTS | YEARLINGS |
| 1955 | | | 10,634,330 | | | | | 2,236,370 | 0 | 0 |
| 1956 | 26-Oct | 39 | 2,415,356 | | | 5867.64 | | 210,636 | 0 | 30,750 |
| 1957 | 27-Oct | 40 | 895,600 | | | 5471.65 | | 1,233,191 | 0 | 0 |
| 1958 | 20-Oct | | 13,283,000 | | | 5902.79 | | 7,818,382 | 0 | 52,657 |
| 1959 | 15-Oct | | 39,784,000 | | | 6208.08 | | 21,549,987 | 0 | 334,320 |
| 1960 | 24-Oct | | 27,152,200 | | | 5656.26 | | 15,004,583 | 0 | 80,536 |
| 1961 | 23-Oct | | 45,744,800 | | | 6335.44 | | 18,422,559 | 0 | 174,618 |
| 1962 | | | 17,033,700 | | | 5965.81 | | 13,081,056 | 0 | 474,534 |
| 1963 | | | 6,084,987 | | | | | 4,088,390 | 0 | 108,000 |
| 1964 | | | 45,531,380 | | | 6160.25 | | 15,363,588 | 0 | 198,838 |
| 1965 | | | 41,400,000 | | | 6023.31 | | 24,153,583 | 0 | 78,781 |
| 1966 | | | 27,679,300 | | | 6358.89 | | 185,228,785 | 0 | 0 |
| 1967 | | | 8,483,625 | | | 5215.69 | | 5,301,685 | 0 | 65,775 |
| 1968 | | | 13,646,660 | | | 5242.67 | | 1,023,945 | 1,501,129 | 171,040 |
| 1969 | 3-Nov | | 7,018,510 | | | 7349.99 | | 3,334,415 | 1,552,571 | 0 |
| 1970 | | | 15,680,500 | | | 5505.93 | | 8,480,100 | 1,595,364 | 34,155 |
| 1971 | | | 20,523,720 | | | 5782.19 | | 1,003,885 | 1,187,360 | 171,195 |
| 1972 | 26-Oct | | 14,638,755 | | | 5698.05 | | 1,135,205 | 1,110,485 | 253,635 |
| 1973 | 15-Oct | | 13,369,715 | | | 4883.16 | 84.50 | 245,705 | 0 | 28,350 |
| 1974 | | | 13,366,055 | | | | | 1,844,810 | 34,700 | 2,680 |
| 1975 | 17-Oct | | 18,659,860 | | | 5795.49 | | 335,471 | 0 | 0 |
| 1976 | | | 9,443,625 | | | | | 1,130,000 | 0 | 0 |
| 1977 | | | 21,420,000 | | | | | 330,120 | 0 | 0 |
| 1978 | 24-Oct | | 14,876,210 | | | 4815.96 | | 863,224 | 18,375 | 229,040 |
| 1979 | | | 8,450,000 | | | | | 2,759,000 | 0 | 0 |
| 1980 | 28-Oct | | 32,273,066 | | | 5210.83 | | 12,355,809 | 0 | 270,281 |
| 1981 | 21-Oct | | 23,817,480 | | | 5188.79 | | 7,735,684 | 0 | 0 |
| 1982 | 25-Oct | | 11,752,490 | | | 5137.03 | | 2,952,845 | 0 | 0 |
| 1983 | 21-Nov | | 6,606,980 | | | 4032.53 | | 1,722,585 | 0 | 0 |
| 1984 | 30-Oct | | 18,246,755 | | | | | 9,290,380 | 0 | 0 |
| 1985 | 1-Nov | | 17,769,220 | 67 | | 5409.43 | 0.00 | 0 | 0 | 0 |
| 1986 | 4-Nov | | 11,938,190 | 73 | | 5563.15 | 0.00 | 1,685,480 | 0 | 0 |
| 1987 | 20-Nov | | 4,452,760 | 76 | | 5199.15 | 0.00 | 0 | 0 | 0 |
| 1988 | 15-Nov | | 14,974,915 | 78 | | 5037.36 | 0.00 | | | |
| 1989 | 31-Oct | | 22,483,730 | 75 | | 5161.26 | 0.00 | 5,929,011 | 0 | 0 |
| 1990 | 24-Oct | | 10,717,320 | 77 | | 5290.15 | 0.00 | 0 | 0 | 0 |

| Table 2-19. Summary statistics of Nimbus Hatchery operations from 1956-1999 (Cont). | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Egg Production (Fecundity) | | | | | | | | | | |
| YEAR | DATE FIRST EGGS TAKEN | INITIAL HOLDING TIME (DAYS) | TOTAL EGG COUNT | AVERAGE EYED EGG SIZE (#/OZ) | PRODUCTION QUOTA (EGGS KEPT) | EGGS PER SPAWNED FEMALE | % EGGS TO REACH EYE | NUMBER OF CHINOOK SALMON PLANTED IN THE AMERICAN RIVER | | |
| | | | | | | | | FINGERLINGS | SMOLTS | YEARLINGS |
| 1991 | 7-Nov | | 15,220,840 | 76 | | 4644.29 | 0.00 | 0 | 0 | 0 |
| 1992 | 16-Nov | | 11,496,400 | 70 | | 5357.90 | 0.00 | | | |
| 1993 | 9-Nov | | 17,949,882 | 79 | | 5014.89 | 0.00 | 0 | 0 | 0 |
| 1994 | 7-Nov | | 18,924,534 | 71 | | 5006.72 | 0.00 | 0 | 0 | 0 |
| 1995 | 6-Nov | | 11,679,195 | 74 | | 5528.19 | 0.00 | 0 | 0 | 0 |
| 1996 | 24-Oct | | 13,852,372 | 74 | | 5165.58 | 0.00 | 0 | 0 | 0 |
| 1997 | 4-Nov | | 10,233,677 | 77 | | 4524.09 | 0.00 | 0 | 0 | 0 |
| 1998 | 16-Oct | | 12,055,059 | | | 3407.01 | | 0 | 0 | 0 |
| 1999 | 3-Nov | 0 | 7,874,238 | 94 | | 4407.91 | 0.00 | 0 | 0 | 0 |

| Table 2-19. Summary statistics of Nimbus Hatchery operations from 1956-1999 (Cont). | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | Juvenile Production | | | |
| Year | Fry Count | Juveniles Produced | Wire Tagged or Clipped? | Average Planting Size | Planting Dates | % Eggs to Juvenile | Planting Locations |
| | | | | | | | |
| 1956 | | 162,930 | no | 1.9/oz | May/July/August | 6.75 | |
| 1957 | | 68,265 | no | 1.6/oz | | | |
| 1958 | | 225,120 | no | 67/lb | 2/19/59 | 1.69 | American River |
| 1959 | | 20,590,954 | | | Jan-June | 51.76 | |
| 1960 | | 14,893,823 | | | Jan-June | 54.85 | American River |
| 1961 | | 18,422,559 | no | | Jan-June | 40.27 | American River |
| 1962 | | 13,081,056 | | | Jan-June | 76.80 | American River |
| 1963 | | | | | | | |
| 1964 | | 15,363,588 | | | Feb-June | 33.74 | American River |
| 1965 | | 24,153,583 | | | Jan-June | 58.34 | American River |
| 1966 | | 18,522,875 | | | Jan-June | 66.92 | American River |
| 1967 | | 5,301,685 | | | Feb-June | 62.49 | American River |
| 1968 | | 3,582,969 | | | | 26.26 | American River Hatchery, American River Mouth, Sacramento River/Rio Vista |
| 1969 | | 3,442,655 | | | Feb-June | 49.05 | American River Hatchery, American River Mouth, Sacramento River/Rio Vista |
| 1970 | | 11,145,287 | | | Feb-May | 71.08 | American River Hatchery, American River Mouth, Sacramento River/Rio Vista |
| 1971 | | 4,503,495 | | | April-June | 21.94 | American River Hatchery, American River Mouth, Sacramento River/Rio Vista |
| 1972 | | 4,562,760 | | | March-June | 31.17 | American River Hatchery, American River Mouth, Sacramento River/Rio Vista |
| 1973 | | 245,705 | | | Jan-June | 1.84 | Sacramento River-Rio Vista |
| 1974 | | | | | | | |
| 1975 | | 5,380,110 | | | Dec-June | 28.83 | Hatchery, Sac River-Rio Visa, Sac River-Garcia Bend, Sac River-Clarksburg |
| 1976 | | | | | | | |
| 1977 | | | | | | | |
| 1978 | | 6,937,154 | | | Jan-June | 46.63 | Hatchery, Rio Vista |
| 1979 | | | | | | | |
| 1980 | | 16,542,676 | No | | Dec-June | 51.26 | Hatchery, Bear River, Pittsburg, Maritime Academy, Benecia |
| 1981 | | 9,942,409 | | | Dec-June | 41.74 | Hatchery, Cosumnes River, Doty Ravine Creek, Bear River, Auburn Ravine Creek, Coon Creek, Rio Vista |
| 1982 | | 8,174,153 | | | Jan-June | 69.55 | American River, Vallejo, Maritime Academy, Benecia, Auburn Ravine Creek, Bear River, Cache Creek, Calaveras River, Cosumnes River, Coon Creek, Dry Creek, Duty Creek, Duty Creek Ravine, Mokelumne River |
| 1983 | | 5,596,467 | T | | March-June | 84.71 | |
| 1984 | | 17,488,220 | | | Jan-June | 95.84 | Hatchery, Maritime Academy |
| 1985 | | 9,251,860 | T | | Jan-June | 52.07 | Foot of ladder, Garcia Bend, Mare Island, Maritime Academy |
| 1986 | | 7,925,325 | T | | Jan-June | 66.39 | Garcia Bend, Discovery Park, Benecia Boat Ramp |
| 1987 | | 5,161,370 | T | | March-June | 115.91 | Foot of ladder, Cosumnes River, Discovery Park, Benecia |
| 1988 | | 7,412,966 | | | | | Discovery Park, Garcia Bend, Miller Park, Benecia, Mare Island |
| 1989 | | 10,528,261 | T | | Jan-June | 46.83 | |

| Table 2-19. Summary statistics of Nimbus Hatchery operations from 1956-1999 (Cont). | | | | | | | |
|---|---|---|---|---|---|---|---|
| Juvenile Production | | | | | | | |
| Year | Fry Count | Juveniles Produced | Wire Tagged or Clipped? | Average Planting Size | Planting Dates | % Eggs to Juvenile | Planting Locations |
| 1990 | | 7,872,855 | No | | Jan-June | 73.46 | American River, Auburn Ravine, Bear River, Coon Creek, Cosumnes River, Dry Creek, Maritime Academy, Benecia |
| 1991 | | 10,775,652 | No | | Jan-June | 70.80 | Secret Ravine Creek, Auburn Ravine Creek, Garcia Bend, Miller Park, Cosumnes River, Coon Creek, Dry Creek, Rio Vista, Benecia |
| 1992 | | 7,936,390 | No | | Feb-June | 69.03 | Miller Park, Auburn Ravine, Coon Creek, Miller Park, Dry Creek, Bear River, Cosumnes River, Garcia Bend, Benecia |
| 1993 | | 8,687,700 | No | | Jan-June | 48.40 | Auburn Ravine Creek, Coon Creek, Dry Creek, Miner's Ravine Creek, Cosumnes River, Miller Park, Secret River Creek, Rio Vista |
| 1994 | | 9,661,443 | No | | | 51.05 | Miller Park, Cosumnes River, Secret Ravine Creek, Miner's Ravine Creek, Dry Creek, Auburn Ravine Creek, Coon Creek, Wickland Oil, Benecia, Unocal |
| 1995 | | 8,753,751 | No | | Jan-June | 74.95 | |
| 1996 | | 9,631,076 | No | | Jan-June | 69.53 | Miners Ravine Creek, Secret Ravine Creek, Coon Creek, Dry Creek, Auburn Ravine Creek, Cosumnes Creek, Miller Park, Wickland Oil, Unocal, Benecia |
| 1997 | | 6,010,404 | No | | | 58.73 | Miller Park, Secret Ravine Creek, Miners Ravine Creek, Dry Creek, Auburn Ravine Creek, Coon Creek, Garcia Bend, Wickland Oil, Benecia |
| 1998 | | 5,871,398 | | | | 48.70 | |
| 1999 | 4,613,954 | 3,851,700 | | 55.7/lb | May-June | 48.92 | Benecia and Wickland |

#### Timing of planting

The hatchery begins spawning chinook salmon in the late fall of each year. Because fall-run juvenile chinook salmon emigrate within six months of hatching, the hatchery will plant smolts and juveniles during the course of the coming year, concluding usually by the summer. For fall-run chinook salmon, release dates for smolts are projected for April 15 through July 31 with the goal of 60 fish/lb, and January through February for fingerlings of size 1500/lb.

#### Location of planting

Fingerling juvenile fall-run chinook salmon are planted in appropriate tributary streams identified by Regional Fisheries Management and approved by the Chief, Central Valley Bay-Delta Branch. Planting locations are constrained to downstream of the lower American River.

#### Tagging

Nimbus Hatchery juvenile fall-run chinook salmon are not currently being tracked by adipose clips and coded wire tagging (West, pers. comm., 2000). Coded wire tags of salmon entering the hatchery from other hatcheries are recorded.

### Fecundity and Fertilization

Fecundity is a measure of the number of eggs each female produces. Hatchery operators keep limited data on the number of eggs per female by estimating the size (by weight) of eggs each year for each lot and using that egg per ounce value to estimate the total eggs for the lot.

This process is repeated at the eyed stage. The lot egg counts can then be summed to give total eggs for the year. The total females spawned can then be used to estimate eggs per female and eyed eggs per female or a measure of percent fertilization. Estimated percent fertilization at the hatchery and average daily maximum water temperatures are presented in **Figure 2-38**. A fecundity summary from 1956 to 2000 appears in **Figure 2-39**.

#### Fry and Juveniles

Very little data concerning initial fry production are contained in the hatchery reports. Fry counts would allow a comparison of fertilized eggs to fry production and to juveniles or smolts planted. In 1999, where those data are given, 4.6 million fry were produced from 7.9 million green eggs and 4.7 million eyed eggs, yielding 3.9 million juveniles for planting.

### Temperature/Disease/Handling

The Nimbus Hatchery has one of the highest incidence of fish disease relative to other hatcheries in the state (Modin, CDFG, pers. comm., 2001). Viruses, bacteria, protozoan and metazoan parasites, and fungus all have been sources of disease in salmon and steelhead at the Nimbus Hatchery. The majority of these pathogens can be controlled at the hatchery through prophylactic and targeted treatment. Two sources are responsible for the majority of these pathogens: adult spawning fish, and source water from Lake Natoma.

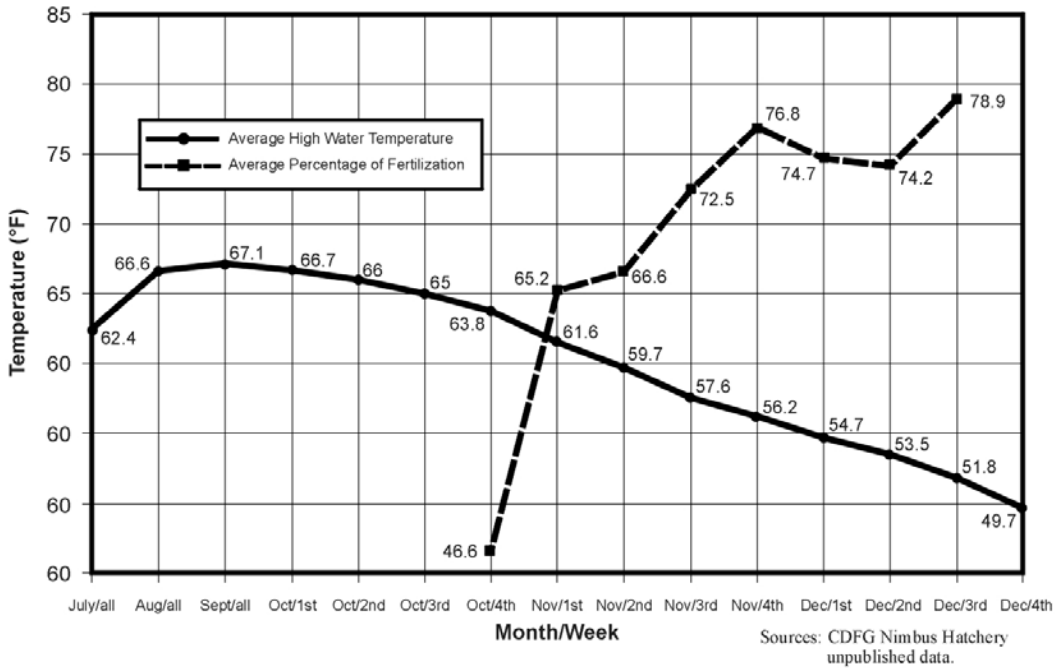


**Figure 2-38. Average daily maximum water temperature recorded at the Nimbus Hatchery and average percent fertilization of fall-run chinook salmon eggs from 1986/87 through 1996/97.**

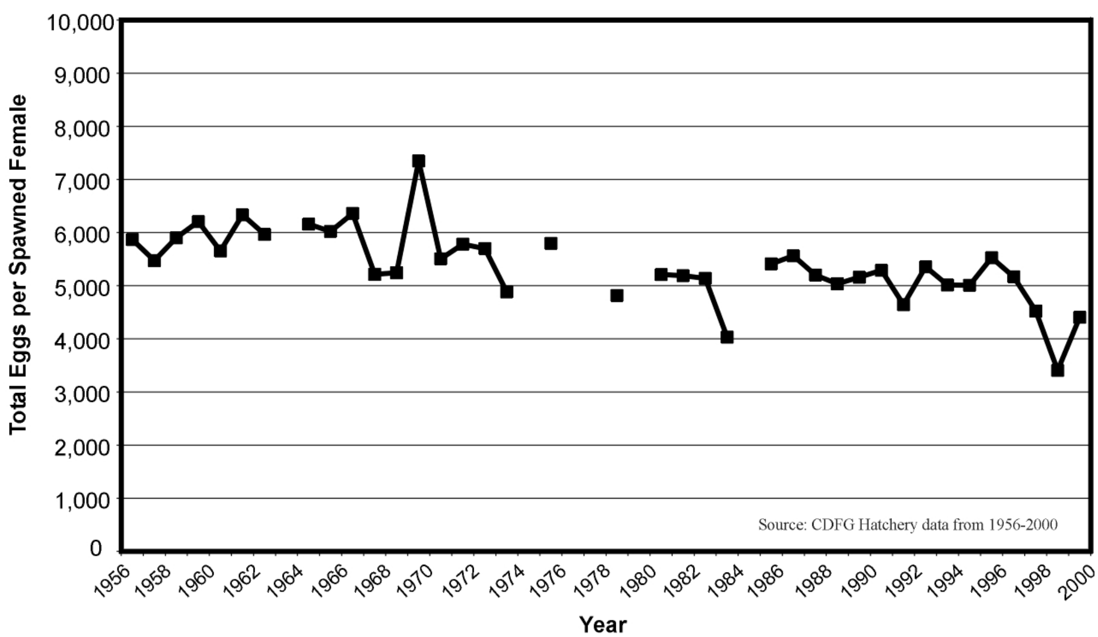


**Figure 2-39. Total eggs per spawned fall-run chinook salmon female at the Nimbus Hatchery on the lower American River, 1956 to 2000.**

Early Nimbus Hatchery annual reports indicate that disease outbreaks were frequent, and at times, of considerable proportion. *Flavobacterium columnare*, responsible for columnaris disease, is one of the most common and persistent warmwater bacteria affecting fish at the Nimbus Hatchery and in the American River (Hinze 1959a; Hinze 1959b; Hinze 1962; Cox, CDFG, pers. comm., 2001). Hinze (1959b) noted that very light infections occurred when water temperatures were below 52ºF, whereas more severe infections occurred at higher temperatures. At the Nimbus Hatchery, outbreaks of columnaris, gill bacteria, enteric red mouth disease, *Ichthyopthirius*, and proliferative kidney disease (PKD) are all associated with increasing temperatures (Ducey 1988, 1990; Modin, CDFG, pers. comm., 2001; Cox, CDFG, pers. comm., 2001).

Improvements in handling methods and temperature control at the Nimbus Hatchery has significantly reduced handling stress and disease outbreaks. Improved methods of disease treatment and prophylactic vaccination (i.e., iodophor, penicillin, vaccines) have also reduced impacts associated with elevated water temperatures (Veek, CDFG, pers. comm., 2000). During the winter of 1961/62, a shutter device was constructed at Folsom Dam to allow water to be released into the river and hatchery from variable lake elevations. Hinze (1964) reports that due to the improved water temperatures, over 80 percent of the eggs taken in the 1962 brood reached swim-up size; almost 20 percent better than the best results obtained prior to 1962. The Nimbus Hatchery also has avoided disease impacts at warmer temperatures by releasing fish into the wild by May and June, before elevated water temperatures take effect (Modin, CDFG, pers. comm., 2001).

Warmwater (i.e. above 60ºF) has been reported to exacerbate the impact of most pathogen-induced diseases (Ordal and Pacha 1963). Groberg et al. (1978) investigated the relationship between temperature and the level of impact a disease imposes. Groberg et al. (1978) injected chinook salmon and steelhead juveniles with *Aeromonas salmonicida* at various holding temperatures from 39.0 to 68.9ºF. A strong and significant relationship was found in both salmonids between water temperature and the mean interval between infection and death. This study demonstrated that higher temperatures accelerate the progress of infection by *A. salmonicida,* while lower temperatures retard it. It also confirmed that water temperatures must be 54.9F or above before a serious epizootic of furunculosis would occur (Groberg et al. 1978).

There are a host of coldwater (i.e., below 60ºF) pathogens that can have severe impacts on hatchery and wild fish populations. Coldwater diseases encountered at the Nimbus Hatchery include bacterial coldwater disease, bacterial kidney disease, and a host of external parasite infections. In the 1958/59 brood year, a columnaris-like bacterium heavily impacted both steelhead and chinook salmon throughout the year with little diminishment during the period of cooler water (Hinze 1961). Nimbus Hatchery managers have found that coldwater diseases are more difficult to treat than warmwater diseases because the immune systems of rearing salmonids are less active at low temperatures (Modin, CDFG, pers. comm. 2001).

Another coldwater disease which has caused significant mortalities in Nimbus Hatchery salmonids is the "Sacramento River Chinook Disease" or infectious *Hematopoitic Necrosis* (IHN). IHN claimed 17 percent of the 1967/68 brood, over 93 percent of the 1973/74, 34 percent of the 1975/76 brood and 15 percent of the 1982/83 brood (Jochimsen 1970, 1976, 1978, 1983). IHN can be vertically transmitted to eggs and larvae through ovarian and seminal fluids. The IHN virus is known to be carried by female chinook from the American River and passed on to their young, or even other females, when placed in contact (Jochimsen 1967). Often, adult fall-run chinook salmon comprising the latter portions of the spawning run test positive for the disease, while fish comprising the early fractions are not found to have the virus (Cox, CDFG, pers. comm., 2001). Hinze (1965) found that as the season progressed from winter to spring and temperatures increased up to 60ºF, incidence of IHN in juvenile fish at the Nimbus Hatchery decreased. A study conducted at the Nimbus Hatchery the following year, however, found no difference in incidence between fry hatched from incubation at constant 55ºF to swim-up, and those whose incubation temperatures were raised to 60ºF and 61ºF during late incubation stages (Jochimsen 1967).

In a histological study of American River chinook salmon and steelhead juveniles, fish were sampled from February 26 through June 7, 1991 at four sites: below Business I-80 Bridge, at H street, at the Gristmill Dam Recreation Area, and above the Old Fair Oaks bridge (Okihiro and Hinton 1992). The primary problem identified for chinook salmon was a disease caused by a myxosporidian parasite, *Ceratomyxa shasta,* which became active in the spring. Because *Ceratomyxa shasta* is passed between fish by an intermediate non-fish host that exists in the Sacramento River and is known not to exist in the American River, infected fish from the Sacramento River were likely a part of the samples collected in the study, particularly in the lower and middle sites (Okihiro and Hinton 1992; Cox, CDFG, pers. comm., 2001). Nonetheless, Okihiro and Hinton (1992) concluded that fish in the lower sampling stations of the lower American River appear to be significantly affected by biologic pathogens, and possibly by xenobiotic compounds.

The incidence of disease in the wild is expected to be somewhat less than that found under confined hatchery conditions due to reduced cross-contamination, reduced stress, and increased genetic diversity. Because temperatures in the lower American River in the summer and fall can approach 70ºF, disease impacts to rearing salmonids during this period may be significant, particularly in the lower reaches.

### Genetic Diversity

Annual egg allotment for fall-run chinook salmon presently is distributed throughout the duration of the spawining run, in proportion to historic temporal distribution of the runs. Maintaining genetic diversity by distributing the egg allotment throughout the spawining run takes precedence over meeting numeric production goals. The 8 million egg take goal will thus be achieved through a graduated egg take, according to historic run timing.

Identifying the genetic makeup of broodstocks in propagation programs is necessary to avoid admixture and hybridization among spawning runs, and to preserve genetic diversity within each spawning run. Genetic markers are useful for confirming parentage and relatedness in hatchery-bred fish and for verifying models of hatchery impacts on the genetic diversity of naturally spawning stocks. Hatchery practices play an important role in maintaining the run identity, population size, and genetic diversity of fall-run chinook salmon populations present in the lower American River.

A genetic study conducted on Central Valley chinook salmon by Banks et al. (2000) found five distinct subpopulations congruent with the winter, spring, fall, and late-fall spawning runs that have long been recognized. The study found that despite spatial and temporal overlap of chinook salmon spawning runs in the Central Valley, there was no evidence showing hybridization among runs. Nevertheless, artificial hybridization in hatcheries could pose a risk to conservation of chinook salmon diversity in the Central Valley (Banks et al. 2000).

Attributed to the temporal overlap of spring and fall runs on Battle Creek, significant linkage disequilibrium was found in fall-run stock samples collected at the Coleman Hatchery suggesting admixture and possible hybridization between the runs. To reduce this potential in the American River, Nimbus Hatchery spawning adults would need to be typed prior to breeding. Methods developed by Banks et al. (2000) are being used to selectively breed winter run but cannot be used to identify fall, spring, and late-fall runs due to their close relation; although estimating run contribution to mixed samples is possible. For fall-run chinook salmon, Banks et al. (2000) found that samples from 13 different geographic locations in the Central Valley were homogeneous, indicating the existence of only one distinct fall-run subpopulation.

The American River is home to one of the largest fall-run chinook salmon population in the Central Valley. According to preliminary data from CDFG's Central Valley Salmon and Steelhead Harvest Monitoring Project, a significant number adult chinook salmon are being captured throughout the summer period from June through September in years 1998-2000 (Brown 2001). Most of them are of a size consistent with the length distribution for 2-year old fall-run chinook salmon (i.e., $\leq$78 cm). Many of these fish, particularly those captured in September, have turned dark in color, a sign of spawning maturation.

Coded wire tagged fish were recovered as part of the Harvest Monitoring Project in 1998 and 1999. The coded wire tags recovered were traced to their hatchery of origin using tag codes obtained from CDFG in Healdsburg (Erickson 2001), and the Pacific States Marine Fisheries Commission website (PSMFC 2001). Of the 25 chinook salmon captured in the American River, the majority (23) were Feather River Hatchery fall-run chinook salmon stock. One tag was traced to a Merced River spring-run stock, and another to the Coleman Fish Hatchery late fall-run stock. The presence of tagged fish, however, does not necessarily explain the origin of untagged fish nor the potential for those fish to be native to the American River.

In the spawning escapement survey conducted in the late-summer, fall, and winter of 1992/93, the CDFG's Stream Evaluation Program discovered a bimodal population temporal distribution of carcasses. The first peak occurred before the survey began, but the end of the earlier run was evident through the end of October. Coded wire tag analysis of some of these fish indicated that they were primarily Feather River spring-run. Others were from the Mokelumne River Hatchery, Coleman Fish hatchery and the Nimbus Fish Hatchery (Snider et. al. 1993). Early (August-September) chinook salmon runs were previously noted in creel censuses and coded-wire-tag evaluations.

It is unlikely that American River spring-run chinook salmon could continue to inhabit the lower American River. Under current and recent past Nimbus Hatchery practices, spring-run are altogether selected against for propagation. The hatchery usually does not accept salmon for spawning until early to mid-November. In addition, conditions during the summer in the lower American River are inhospitable for adult chinook salmon holding over to spawn.

The American River may be dependent on Nimbus Hatchery propagation of fall-run chinook salmon to sustain and support continued growth of the run. A potential concern of Nimbus

Hatchery's supplementation is that it may have diluted the gene pool of the naturally spawning populations with the offspring of a few individuals. Hedrick et al. (1995, 2000a, 2000b) used a demographic population genetics model from Ryman and Laikre (1991) to evaluate the potential genetic impact of the Coleman National Fish Hatchery propagation of winter-run chinook salmon on the effective size of that run in the Sacramento River. They found that the impact of hatchery supplementation on genetic diversity was mediated through the effects on the effective size of the natural population.

In the mathematically ideal population, there are equal numbers of both sexes, adults mate at random, and variance in number of offspring per adult is binomial or Poisson (Hedgcock et al. 2000). In actual populations, the sexes may not be in equal numbers, mating may not be at random, or the variance in offspring number may be larger than binomial or Poisson. For hatchery-supplemented populations, the total effective population size, $N_e$, depends on the effective sizes of the hatchery and wild components of the population, $N_{eh}$ and $N_w$ respectively, and on the relative proportion of hatchery origin fish. For naturally spawning supplemented populations, the ratio of effective spawning population $N_e$ to the total population size N, $N_e/N$ is assumed to have a lower bound of 0.10 and an upper bound of 0.33. Preliminary estimates of the ratio of effective hatchery population $N_{eh}$ to the number of adult fish taken by the hatchery ($N_h$) for the Nimbus Hatchery in recent years yields a value much greater than 0.33. The $N_{eh}/N_h$ ratio contributes to the $N_e/N$ ratio, counter-balancing genetic diversity dilution.

### Osmoregulatory pre-adaptation

The Nimbus Hatchery does not pre-condition juveniles taken to brackish or saltwater for the transfer to a different osmotic media. Fish are known to have increased stress and subsequent increased mortality when forced to adapt to saline waters too rapidly. In addition, increases in predation likely occur, especially in the smaller fish transferred to saltwater in the late winter months. Fish transferred in early summer have an additional stress. The difference in temperature between downstream (i.e., Benicia) and the upper portions of the lower American can exceed 59°F. According to the literature, 65mm is about the minimum size at which juvenile chinook salmon can tolerate seawater. Though these larger juveniles at this stage are more resilient to temperature shock, the combination of saline and temperature shock certainly has the potential to detrimentally affect the planted population.

### Hatchery Contribution to Spawning Populations

Due to the lack of a constant fractional marking program for Central Valley hatcheries, direct determination of the hatchery-reared fish contribution to the total Lower American River spawning population is impossible. However, methods exist to make indirect estimations of hatchery and natural contributions to the spawning population. One method, developed by Dettman and Kelly (1987), uses a model based on statistical regression analysis to estimate the contribution of hatchery populations from the Nimbus and Feather River Hatcheries to the spawning escapement of chinook salmon in the lower American River. The basis for this model was hatchery coded wire tagging conducted between 1978 and 1984. They estimated hatchery contribution to the spawning escapement in the lower American River of 85% for the period of 1977 to 1984. A high hatchery contribution is expected due to adverse natural environment conditions and the hatchery practices implemented to ensure high hatchery population survival.

Since construction and operation of the Nimbus Hatchery began in 1955, lower American River chinook salmon runs have generally increased. Hatchery practices implemented to increase survival of the adult population have contributed to this increase. Experiments by CDFG revealed that salmon survival depended directly on the size, season, and location of the planted fish (Jochimsen 1970). Beginning in 1967, these experiments led to new hatchery practices, including rearing fish to a large fingerling or smolt stage and releasing them in the late spring or summer downstream of Rio Vista in San Pablo Bay and San Francisco Bay. Also, "surplus" fry and small fingerlings were planted directly in the lower American River.

Dettman and Kelly (1987) concluded that, because of the increased likelihood of hatchery-reared fish to stray, a significant number of Nimbus Hatchery-reared fish planted below Rio Vista stray away from the American River (approximately 32% compared with approximately 8% for those planted directly in the American River). Likewise, some Feather River Hatchery-reared fish stray to the American River (approximately 12% of all hatchery-reared fish returning to spawn in the lower American River). These straying populations were taken into account when estimating the total hatchery contribution to spawning populations.

Since the hatchery tagging experiments from 1978 to 1984, no constant marking programs have been implemented in Central Valley hatcheries. The result is a lack of sufficient data to directly determine the current contribution of hatchery-reared fish to the total lower American River spawning population. Therefore, there is no data to substantiate an estimate of the current contribution of hatchery-reared fish to the lower American River spawning population.

### 2.2.3. STEELHEAD

Restoration of California's anadromous fish populations is mandated by *The Salmon, Steelhead Trout, and Anadromous Fisheries Program Act of 1988* (SB 2261) which states that it is the policy of the State to significantly increase the natural production of salmon and steelhead by the end of the last century. SB 2261 directs CDFG to develop a program that strives to double naturally spawning anadromous fish populations by the year 2000. The AFRP of the CFPIA has the similar goal of doubling the natural production of anadromous fish (including steelhead), as previously discussed.

According to USFWS (1995), insufficient data are available to estimate natural production of steelhead in the Central Valley, including the lower American River, other than upstream of Red Bluff Division Dam (RBDD). The AFRP restoration goal for steelhead spawning upstream of RBDD is 13,000 fish per year (USFWS 1995).

Natural production of steelhead in the American River will continue to be limited due to inaccessibility of the headwaters. The proportion of hatchery origin fish spawning in the river remains uncertain. It is known, however, that the vast majority of the steelhead returning to the hatchery is of hatchery origin

Steelhead is the anadromous form of rainbow trout. Adult steelhead migrate through the Sacramento River system beginning in August and continue through March. Adult steelhead return to spawning grounds in the upper Sacramento River and tributaries (including the lower American River). Steelhead also are produced at the Coleman Fish Hatchery on Battle Creek, the Nimbus Hatchery on the American River, and the Feather River Hatchery on the Feather River

(Reynolds et al. 1990). Spawning generally occurs from January through April. Juvenile steelhead rear in their natal streams for 1 to 2 years before emigrating from the river. Emigration of 1- to 2-year-old fish generally has been reported to occur from April through June (Reynolds et al., 1990), although primarily from February through April in the Central Valley (Snider and Titus 2000).

Adult steelhead immigration into the lower American River typically begins in November and continues into April. The steelhead spawning immigration generally peaks during January (CDFG 1986; CDFG, unpublished data).

Spawning usually begins during late December and may extend through March, but can range from November through April (CDFG 1986; CDFG, unpublished data). Optimal spawning temperatures are believed to be similar to those reported for fall-run chinook salmon. Unlike chinook salmon, not all steelhead die after spawning. Those that do not die return to the ocean after spawning, and may return to spawn again in future years. The egg and fry incubation lifestage for steelhead in the lower American River typically extends from December into May.

Fry emergence from the gravel generally begins in March and may extend into June, with peak emergence occurring during April (CDFG 1986; Snider and Titus 1996; CDFG, unpublished data). Optimal egg and fry incubation temperatures are believed to be similar to those reported for fall-run chinook salmon. As with chinook salmon, it is believed that temperatures up to about 65°F are suitable for steelhead rearing, with each degree increase between about 65°F and the upper lethal limit of 75°F being increasingly less suitable and thermally more stressful (Bovee and Milhous 1978). The primary period of steelhead emigration from the lower American River is believed to occur from March through June (Castleberry et al. 1991). A generalized depiction of the temporal occurrence of the various lifestages of steelhead in the lower American River, is presented in **Figure 2-40**. As with fall-run chinook salmon, the entire lower American river is utilized by steelhead for one or more portions of their lifecycle.

#### 2.2.3.1. HATCHERY IMPORTATIONS

As stated in the June 7, 2000 *Federal Register* listing of Northern California Steelhead ESU as threatened, there are two reproductive ecotypes of steelhead; stream maturing “summer steelhead” and ocean maturing “winter steelhead”. Summer steelhead enter fresh water in a sexually immature condition and require several months to mature and spawn. Winter steelhead enter fresh water with well developed gonads and spawn shortly after river entry.

The surviving steelhead run since the destruction of the fish passage facilities at the old Folsom Dam and the construction of Folsom and Nimbus dams was likely the “early” winter, fall-run, or the winter-run, because summer temperatures in the lower American River are not conducive for summer-run or spring-run steelhead survival. These run classifications are primarily based on behavioral and physiological differences, and do not reflect genetic or taxonomic relationships (Allendorf 1975; Allendorf and Utter 1979; Behnke 1992). The degree of genetic similarity is mostly a reflection of geographical relationships, not migration timing. All steelhead populations in California are *Oncorhynchus mykiss irideus* (Behnke 1992). *O. m. irideus* is distributed along coastal rivers and streams from California to Alaska and consists of both summer-run and winter-run steelhead populations.

**Figure 2-40. Steelhead spatial and temporal distribution on the lower American River.**

CDFG has traditionally grouped steelhead into seasonal runs according to their peak migration period - in California, there are well-defined winter, spring, and fall runs. This classification is useful in describing actual run timing, but leads to confusion when it is used to further categorize steelhead populations. Seasonal classifications do not reflect stock characteristics, spawning strategies, and run overlap between summer and winter steelhead. Also, a seasonal run may be comprised of both summer and winter steelhead. For example, spring-run steelhead in the Eel River system could be considered summer steelhead, because they hold-over and do not spawn until the following winter. Spring-run steelhead entering southern California streams in spring and early summer are mature and spawn immediately, and thus would be considered winter steelhead. Thus, run timing is a characteristic of a particular stock but, by itself, does not constitute "race" (McEwan and Jackson 1996).

It is not known whether the native American River runs of steelhead have maintained any phenotypic purity, nor is it known whether genetically pure American River steelhead progeny persist. Another uncertainty is to what extent, if any, the "Nimbus strain" steelhead are genetic hybrids. In over 40 years of transplanting non-indigenous steelhead to the lower American River, a genetically distinct Nimbus strain of steelhead may have "evolved" (i.e., locally adapted). E.B. Taylor (1991) suggests that local adaptation may be evident in as little as a few generations.

A review of the planting history of the lower American River steelhead provides insight to the lifestage needs and behavioral characteristics of these fish. For example, in recent years the Nimbus Hatchery practice has been to return to the river steelhead that attempted to ascend the fish ladder before December, in order to reduce interference with peak runs of fall-run chinook salmon occurring in November. The procedure has changed, however. Currently, the Nimbus Hatchery operates the fish ladder continuously through the fall and winter, as long as fish with viable eggs are willing to ascend the ladder (West, CDFG, pers. comm., 2000).

Nimbus Hatchery has attempted to propagate four runs of steelhead since 1955. For the initial brood year, winter-run steelhead eggs were imported from Coleman and Snow Mountain Fish Hatcheries to establish lower American River runs. Attempts to establish brood stock using native American River steelhead (primarily spring/summer-run steelhead) were hampered by low numbers. In response to continued low number of returning adults in 1957, Nimbus Hatchery continued importing Snow Mountain Hatchery eggs from the Eel River. This practice continued until 1962. The first returns of adult fish from this stock occurred in 1959. In 1960, these fish began to return in greater numbers. By 1963, the run had developed to such an extent that importation to augment the hatchery take was no longer needed. In 1963, approximately 200 spawners were transferred to the Mokelumne River Fish Installation.

Attempts to establish summer and fall-runs from non-indigenous sources resulted in poor returns to the lower American River. Summer-run steelhead eggs were imported from the Skamania Hatchery on the Wahougal River, Washington in 1969, 1970, 1973, and 1974, and from the Roaring River Hatchery on the Siletz River, Oregon in 1971 (Meyer 1985). These fish were raised at Nimbus Hatchery and planted in the American and Sacramento rivers in an attempt to establish a summer-run fishery on the lower American River. This program was terminated in 1976 because of low returns and the fact that most of the adults did not begin to ascend the river until July or August (the same time as the early fall-run migrants), thus negating perceived angling benefits (Meyer 1985).

To enhance the early migrant steelhead fishery on the lower American River, adult fall-run steelhead were trapped in the Sacramento River in 1972-73 and spawned at Nimbus Hatchery. The progeny of these fish were released into the lower American River as sub-yearlings and yearlings. Information is not available as to return rates or angler harvest, and this program was not continued in subsequent years.

Because of low returns to the hatchery of all runs in 1978, steelhead eggs were imported from the Mad River Hatchery (also founded with winter-run Eel River stock) and raised at the Nimbus Hatchery. These fish were planted as yearlings.

In 1979 and 1980, another attempt was made to establish a summer-run on the lower American River. Eggs were imported from the Skamania Hatchery on the Washougal River, Washington, hatched at the Silverado Field Operations Base in Yountville, and raised at the Nimbus Hatchery. These fish were released into the Sacramento River in 1980 and 1981 as yearlings.

In 1980 and 1981, fingerlings and yearlings obtained from the Coleman National Fish Hatchery on Battle Creek were released in the American and Sacramento rivers.

In 1983, approximately 100,000 steelhead eggs were imported from Warm Spring Hatchery on the Russian River. Sixty-six thousand yearling were raised and planted at Rio Vista.

In 1988 and 1989, approximately 235,000 steelhead eggs were imported from Warm Springs Hatchery on the Russian River. Yearlings raised from these eggs were planted in the Clarksburg vicinity of the Sacramento River.

Initially, there was an attempt to maintain the different races, but over time all returns to the Nimbus Hatchery have been combined (Reavis 1991). The existing run of steelhead in the lower American River closely resembles (in morphology and behavior) the Eel River winter-run strain. Steelhead in the lower American River may have experienced some introgression due to hybridization with the Washougal strain, which arrived at the hatchery at the same time (McEwan and Nelson 1991). The result of these importations suggests that steelhead in the lower American River are fish from the Nimbus Hatchery program, which is currently rearing a nonindigenous winter steelhead stock.

The destruction of the old Folsom Dam fish ladder in 1950, the construction of Folsom Dam, and the introduction of exotic strains of steelhead may have caused the extirpation of the native American River summer-run steelhead population. The existing run (referred to as the Nimbus strain) most closely resembles, in morphology and behavior, the Eel River strain. However, a run of smaller-sized steelhead reportedly appears in the river in spring. These fish are possibly representatives of the native Central Valley fall-run steelhead strain (McEwan and Nelson 1991).

According to creel surveys conducted by Brown (2001) since April of 1998, adult steelhead begin appearing in the lower American River, both in upper and middle reaches of the river as early as May and June. Non-adipose clipped steelhead dominate catches through September in 1999 and 2000, while clipped fish dominate after early October through December in these two years. This trend is likely distorted in favor of recording catches of clipped fish since California Fishing Regulations do not allow anglers to keep non-clipped steelhead, and most anglers do not take the time to record data on fish they cannot keep (Brown, CDFG, pers. comm. 2001). The presence of clipped steelhead in the summer and fall of 1999 and the size range of fish found (i.e., 30 to 40cm), indicate an occurrence of 2- and near 3-year olds. Few fish captured in the summer and fall periods in the American River exceeded 55cm. The presence of non-clipped fish during the summer and fall in 1999 and 2000 may indicate remnant populations of an indigenous Central Valley summer-run steelhead. It will take more years of data and genetic typing of year round adult samples to determine the potential presence of genetically native fish in the American River.

#### 2.2.3.2. POPULATION STATUS AND TRENDS

There are no comprehensive estimates available for current annual run size of American River steelhead. Staley (1976) conducted mark-and-recapture estimates for 1971-1972 and 1973-1974 providing the only estimates in relatively recent years of lower American River steelhead run size. Carcass surveys, a method utilized to estimate salmon spawning populations, are not very useful for assessing steelhead spawning populations because steelhead do not necessarily die after spawning, and spawning typically occurs when stream flows are high due to winter storms. Since the hatchery began operation in 1995, it provides the best available measure of steelhead run size. Hatchery counts, however, are inconsistent because lower American River spawning steelhead were often denied access to the hatchery ponds for a portion of their spawning season (November-December). Hatchery counts can be an indication of run size, but should be used with caution because the entire hatchery escapement is not always counted (McEwan and Jackson 1996). Summary data for steelhead at Nimbus Hatchery are provided in **Table 2-20**.

Because of limited rearing habitat and heavy angling mortality, Gerstung (1985) estimated that natural production contributed less than 5% to spawning escapement. Results of a fin marking experiment lead Staley (1976) to conclude that the hatchery was producing the bulk of the run. However, sampling conducted by CDFG since 1992 has found abundant juvenile steelhead annually in the lower American River (Snider, CDFG, pers. comm., 2001). With the exception of an emergency release in January 1997 due to flooding, juvenile steelhead have not been planted in the lower American River since 1989, indicating that the fish observed by CDFG are naturally produced (Snider, CDFG, pers. comm., 2001).

Hatchery maintained runs of steelhead have declined since the late 1960s and early 1970s (**Figure 2-41**). The estimated steelhead run size in the American River in 1971-72 and 1973-74 was 19,583 and 12,274, respectively (Staley 1976). Staley (1976) estimated the steelhead harvest rate for the American River to be 27% for these two seasons. Assuming the harvest rate is the same, run sizes of 305, 1,462, and 255 are estimated to have occurred for the 90/91 through 92/93 seasons, respectively, based on the escapement into the hatchery (McEwan and Jackson 1996). These estimates do not include steelhead adults that are less than 20 inches in length (Staley (1976)) considered all rainbow trout greater than 14 inches to be steelhead; Nimbus Hatchery counts include only rainbow trout greater than 20 inches). However, few steelhead less than 20 inches long are observed at the hatchery. Correcting for this bias, or if there is currently a harvest rate greater than 27%, will not appreciably change the current estimates; the present run size is still considerably less than it was in the early 1970s (McEwan and Jackson 1996).

**Table 2-20. Summary statistics of Nimbus Hatchery operations for steelhead from 1956-1999.**

| Steelhead Hatchery Statistics (Run Data) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BROODYEAR | TOTAL ADULTS (SWAM UP LADDER) | DATE WEIR INSTALLED | DATE KEPT | DATE FIRST FISH TAKEN | DATE LAST FISH TAKEN | TOTAL MALES | %MALE SPAWNED | TOTAL FEMALES | %FEMALES OF TOTAL | %FEMALE SPAWNED | TAGGED NIMBUS STOCK | OTHER TAGGED HATCHERY STOCK | DATE FIRST EGGS TAKEN |
| 1955 | 110 | | | | | | | | | | | | |
| 1956 | 115 | 11-Sep | | 1-Feb | 26-Jun | 41 | | 48 | 42 | | | | |
| 1957 | 51 | 13-Sep | late Dec | 2-Jan | | 33 | | 18 | 35 | 11 | | | |
| 1958 | 102 | 18-Aug | 8-Jan | 8-Jan | 23-Apr | 65 | | 37 | 36 | 28 | | | 2/3/59 |
| 1959 | 778 | 22-Sep | 11-Jan | 11-Jan | 8-May | 354 | | 424 | 54 | 53 | | | 1/13/60 |
| 1960 | 316 | 31-Aug | 11-Jan | 11-Jan | 16-Apr | 150 | | 166 | 53 | 76 | | | 1/25/61 |
| 1961 | 137 | 5-Sep | 5-Jan | 5-Jan | 16-Apr | 86 | | 51 | 37 | 70 | | | |
| 1962 | 2,141 | 22-Aug | 13-Dec | 1-Oct | 1-Apr | 1,226 | | 915 | 43 | 84 | | | |
| 1963 | 1,216 | | | | | | | | | | | | |
| 1964 | 778 | 26-Aug | 28-Dec | 1-Nov | | 502 | | 276 | 35 | 69 | 653 | | |
| 1965 | 874 | 1-Oct | | | | 374 | | 500 | 57 | 68 | | | |
| 1966 | 642 | 20-Aug | 23-Dec | 1-Nov | 3-Apr | 370 | | 272 | 42 | | | | |
| 1967 | 1,183 | 22-Aug | 27-Dec | 27-Dec | | | | | | | 1624 | | |
| 1968 | 3,066 | 10-Aug | 16-Dec | 1-Nov | | 1,617 | | 1,449 | 47 | | | | |
| 1969 | 1,734 | 26-Aug | 30-Dec | 15-Nov | | 1,088 | | 646 | 37 | 57 | 1184 | | 12/29/69 |
| 1970 | 3,033 | 19-Aug | 1-Nov | 1-Nov | | 1,547 | 13 | 1,486 | 49 | 31 | 75 | 4 | 1/5/71 |
| 1971 | 2,256 | 15-Aug | 1-Oct | 1-Oct | 23-Feb | 1,148 | 17 | 1,108 | 49 | 54 | 367 | 16 | |
| 1972 | 2,506 | 11-Aug | 1-Oct | 1-Oct | 6-Mar | 1,220 | 7 | 1,286 | 51 | 26 | 157 | 140 | 12/5/72 |
| 1973 | 3,157 | 24-Aug | 1-Oct | 1-Oct | 9-Apr | 1,895 | 10 | 1,262 | 40 | 19 | 90 | 290 | |
| 1974 | | | | | | | | | | | | | |
| 1975 | 3,181 | 3-Sep | 3-Sep | 3-Sep | 25-Feb | 1,538 | 14 | 1,643 | 52 | 18 | 23 | 1,309 | 12/16/75 |
| 1976 | | | | | | | | | | | | | |
| 1977 | | | | | | | | | | | | | |
| 1978 | 680 | 1-Sep | 10-Nov | 10-Nov | 29-Jan | 333 | 40 | 347 | 51 | 74 | 13 | | |
| 1979 | | | | | | | | | | | | | |
| 1980 | 836 | 3-Sep | 16-Oct | 16-Oct | 22-Jan | 481 | 18 | 340 | 41 | 57 | 10 | | |
| 1981 | 3,190 | 26-Aug | 29-Oct | 29-Oct | 18-Feb | 1,684 | 9 | 1,506 | 47 | 19 | 156 | | 12/22/81 |
| 1982 | 1,003 | 28-Aug | 13-Dec | 13-Dec | 17-Mar | 570 | 42 | 433 | 43 | 71 | | | |
| 1983 | 5,155 | 5-Oct | 21-Oct | 21-Oct | 9-Feb | 2,373 | 8 | 2,782 | 54 | 10 | 219 | | 12/1/83 |
| 1984 | 910 | 13-Sep | 26-Oct | 26-Oct | 4-Feb | 456 | 45 | 454 | 50 | 45 | | | |
| 1985 | 1,193 | 11-Sep | 22-Dec | 22-Dec | | 729 | 26 | 464 | 39 | 47 | | | 12/24/85 |
| 1986 | 1,431 | 30-Sep | 30-Nov | 30-Nov | | 750 | 33 | 681 | 48 | 32 | 1431 | | 1/6/86 |
| 1987 | | 15-Sep | 4-Jan | 30-Nov | | | | | | | | | 1/4/87 |
| 1988 | 289 | | | | | | | | | | | | 1/3/88 |
| 1989 | 594 | 20-Sep | 19-Dec | 19-Dec | 2-Mar | 328 | 68 | 266 | 45 | 71 | | | 12/19/89 |
| 1990 | 228 | 16-Sep | 9-Jan | 9-Jan | 8-Mar | 154 | 52 | 74 | 32 | 86 | | | 1/9/90 |
| 1991 | 1,383 | 24-Sep | 30-Dec | 30-Dec | 2-Mar | 785 | 56 | 597 | 43 | 71 | | | 12/30/91 |
| 1992 | 241 | 29-Sep | 4-Jan | 4-Jan | 22-Feb | 133 | 63 | 108 | 45 | 79 | | | 1/4/92 |
| 1993 | 504 | 28-Sep | 5-Jan | 5-Jan | 10-Mar | 246 | | 214 | 42 | | | | 1/5/93 |
| 1994 | 3,805 | 20-Sep | | | | | | | 0 | | | | 12/12/94 |
| 1995 | 2,360 | 20-Sep | 13-Dec | 13-Dec | 7-Mar | 1,206 | 44 | 1,154 | 49 | 20 | | | 12/13/95 |
| 1996 | 1,353 | 18-Sep | 18-Dec | 18-Dec | 6-Mar | 728 | 41 | 619 | 46 | 34 | | | 12/18/96 |
| 1997 | 649 | 23-Sep | | | | | | | 0 | | | | 12/15/97 |
| 1998 | 649 | 9-Sep | | 15-Dec | 24-Mar | 621 | 68 | 494 | 76 | 79 | | | 12/15/99 |
| 1999 | 1,131 | 18-Sep | 13-Dec | 13-Dec | 29-Mar | 620 | 89 | 511 | 45 | 89 | | | 12/13/99 |

| Table 2-20. Summary statistics of Nimbus Hatchery operations for steelhead from 1956-1999 (cont.). | | | | | |
|---|---|---|---|---|---|
| Egg Production (Fecundity) | | | | | |
| YEAR | NIMBUS GREEN EGG COUNT | AVERAGE EYED EGG SIZE | IMPORTED EGG COUNT | EGGS PER SPAWNED FEMALE | EGGS TO REACH EYE |
| 1955 | | | 483,305 | | |
| 1956 | 198,029 | | 1,077,153 | 4126 | 184,768 |
| 1957 | 34,000 | | 1,113,466 | 17172 | |
| 1958 | 54,581 | | 1,137,520 | 5268 | |
| 1959 | 1,189,200 | | 223,920 | 5292 | |
| 1960 | 481,200 | | 0 | 3814 | |
| 1961 | 145,000 | | 446,111 | 4062 | |
| 1962 | 2,818,000 | | 0 | 3666 | |
| 1963 | | | 0 | | |
| 1964 | 663,150 | | 785,000 | 3482 | |
| 1965 | 1,716,840 | | 0 | 5050 | |
| 1966 | | | 0 | | |
| 1967 | 2,511,180 | | 0 | | |
| 1968 | 1,768,790 | | 194,000 | | |
| 1969 | 1,892,720 | | 87,300 | 5140 | |
| 1970 | 2,423,635 | | 128,561 | 5261 | |
| 1971 | 3,479,545 | | 0 | 5816 | |
| 1972 | 1,921,965 | | 0 | 5748 | |
| 1973 | 1,496,995 | | 0 | 6243 | |
| 1974 | | | 0 | | |
| 1975 | 1,780,480 | | 0 | 6020 | |
| 1976 | | | 0 | | |
| 1977 | | | 626,000 | | |
| 1978 | 1,022,524 | | 0 | 3982 | |
| 1979 | 1,000,000 | | 400,000 | | |
| 1980 | 1,316,140 | | 0 | 6791 | |
| 1981 | 1,817,910 | | 0 | 6353 | |
| 1982 | 1,586,324 | | 104,500 | 5160 | |
| 1983 | 2,002,525 | | 0 | 7198 | |
| 1984 | 1,268,100 | | 0 | 6207 | |
| 1985 | 1,440,770 | 190 | 0 | 6607 | 1,111,205 |
| 1986 | 1,482,880 | 195 | 0 | 6805 | 1,313,490 |
| 1987 | 1,647,090 | 202 | 0 | | 1,420,120 |
| 1988 | 942,965 | 194 | 500,000 | | 702,860 |
| 1989 | 1,267,172 | 199 | 235,296 | 6710 | 968,893 |
| 1990 | 307,600 | 210 | 0 | 4833 | 235,975 |
| 1991 | 2,492,425 | 194 | 0 | 5880 | 1,774,530 |
| 1992 | 514,065 | 208 | 0 | 6025 | 360,061 |
| 1993 | 1,127,245 | 213 | 0 | | 760,859 |
| 1994 | 2,765,999 | 213 | 0 | | 1,776,420 |
| 1995 | 1,570,404 | 220 | 0 | 6804 | 1,203,527 |
| 1996 | 1,245,195 | 209 | 0 | 5917 | 997,948 |
| 1997 | 709,534 | 221 | 0 | | 553,206 |
| 1998 | 2,080,534 | | 0 | 5331 | |
| 1999 | 2,636,954 | 245 | 0 | 5798 | 2,230,240 |

**Table 2-20. Summary statistics of Nimbus Hatchery operations for steelhead from 1956-1999 (Cont.).**

| Juvenile Production | | | | | | |
|---|---|---|---|---|---|---|
| **Year** | **Fry Count** | **Juveniles Produced** | **Wire Tagged or Clipped?** | **Average Planting Size** | | **Planting Locations** |
| 1956 | | 228,758 | | 41.09 | | American/Mokelumne |
| 1957 | | 17,108 | | | | |
| 1958 | | 821,485 | | | 9/58 - 12/58 | |
| 1959 | | 460,628 | | 6,540 lbs. | 7/59-1/60 | |
| 1960 | | 14,472 | | 8.4 lbs. | 22433 | |
| 1961 | | 5,372 | | | June | |
| 1962 | | 1,127,886 | | 86 fish per oz | April-June | American River |
| 1963 | | | | | | |
| 1964 | | 438,956 | | | April-June | American River |
| 1965 | | | | | | |
| 1966 | | 304,545 | | | July-June | Hatchery, Clarksburg |
| 1967 | | | | | | |
| 1968 | | 522,420 | No | | | Hatchery |
| 1969 | | 828,543 | | | August-June | Hatchery, Clarksburg, Sherman Island, Rio Vista, Watt Avenue |
| 1970 | | 740,070 | | | September-March | Clarksburg, Miller Park |
| 1971 | | 907,835 | | | Oct-March | Amer. River Fish Ladder, Amer. River Near Hatchery, Miller Park, Clarksburg, Discovery Park |
| 1972 | | 872,355 | | | August-March | American River near Pacific Coast Aggregates Co., Hatchery, Clarksburg, Miller Park |
| 1973 | | 531,062 | C | | July-March | Hatchery, Fair Oaks Bridge, Clarksburg, Miller Park, Garcia Bend |
| 1974 | | | | | | |
| 1975 | | 574,948 | | | August-March | Sailor Bar, Garcia Bend, Sunrise |
| 1976 | | | | | | |
| 1977 | | | | | | |
| 1978 | | 428,858 | C, T | | Sept-April | Garcia Bend, Rio Vista |
| 1979 | | | | | | |
| 1980 | | 639,841 | T | | July-March | American River, Rio Vista, Carquinez Strait |
| 1981 | | 715,181 | T | | May-April | American River, Rio Vista, Vallejo |
| 1982 | | 841,894 | C, T | | July-March | American River, Rio Vista, Maritime Academy |
| 1983 | | 765,742 | No | | Nov-June | Benecia, Rio Vista, Nimbus Ladder |
| 1984 | | 829,055 | | | July-March | Ladder, Rio Vista |
| 1985 | | 716,090 | | | Jan-June | Rio Vista, Ladder |
| 1986 | | 932,753 | No | | October-April | Garcia Bend, Benecia, Foot of Ladder |
| 1987 | | 510,205 | | | | |
| 1988 | | 463,815 | | | | |
| 1989 | | 442,820 | No | | Jan-June | Clarksburg, Garcia Bend, Foot of ladder |
| 1990 | | 278,760 | No | | Jan-March | Clarksburg, Garcia Bend |
| 1991 | | 377,810 | No | | Jan-Feb | Clarksburg, Garcia Bend |
| 1992 | | 484,900 | | | July | Mokelumne River Hatchery, Garcia Bend |
| 1993 | | 381,640 | | | January | Garcia Bend, Clarksburg |
| 1994 | | 1,158,932 | | | | |
| 1995 | | 320,125 | | | January-February | Garcia Bend |
| 1996 | | 647,923 | | | April-January | Garcia Bend, Miller Park, American River |
| 1997 | | | | | | |
| 1998 | | | | | | |
| 1999 | | | | | January-February | Garcia Bend, Sandy Beach |

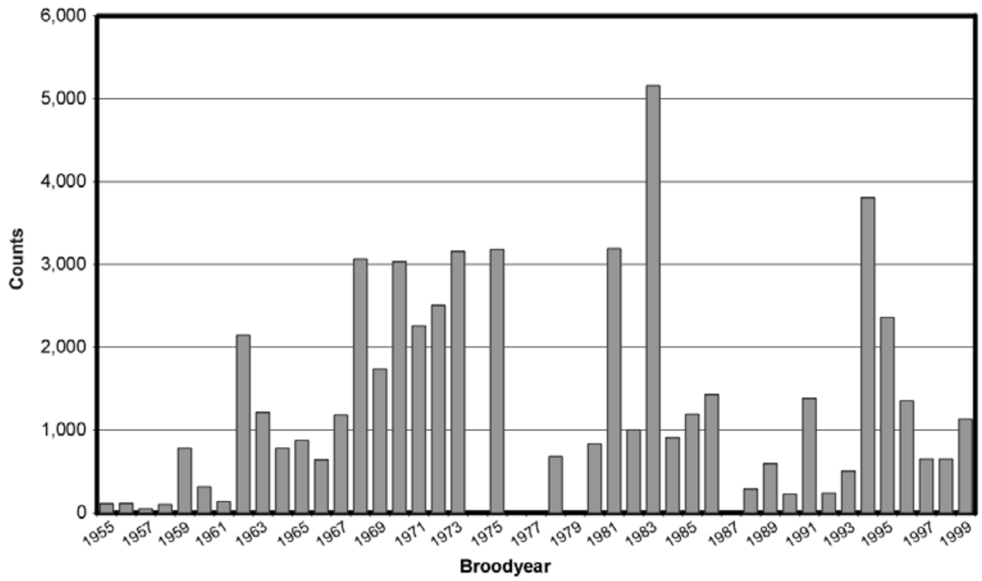


**Figure 2-41. Total number of steelhead adults entering the Nimbus Hatchery from 1955-1999.**

Water temperature in the lower American River probably does not affect adults returning to the river or the Nimbus Hatchery. The NMFS (2000) biological opinion on the impact of CVP and SWP operations on the federally threatened Central Valley steelhead states that predicted temperatures in the lower American River are within the range of reported preferred migrating temperatures (46ºF to 52ºF) from December through March.

### 2.2.3.3. INSTREAM SPAWNING AND INCUBATION

Redd counts were conducted for steelhead in the lower American River in only one year (1991/1992) (Snider and McEwan 1992). In that study, it was reported that steelhead redds were typically too small to recognize in the aerial photographs, leaving less efficient ground surveys to provide most steelhead redd data. For example, only 3 of 66 steelhead redds identified by ground surveys in 1991 were seen in the aerial photographs. As such, the 1992 steelhead redd survey was not nearly as comprehensive as the fall-run chinook salmon redd survey. Furthermore, poor visibility associated with the heavy rains in February limited the field surveys to January and March. According to CDFG, however, the data do provide insight into the timing and distribution of steelhead redds (Snider and McEwan 1992).

In 1992, the lower American River Technical Advisory Committee reviewed the 1991/92 redd survey study program and recommended restricting the sampling to fall-run chinook salmon. The Committee stated that the aerial photographic survey method was not effective for steelhead because of the smaller size of the redds, bad weather, increased turbidity and decreased visibility during the steelhead spawning period (Beak Consultants 1992).

Natural spawning reportedly takes place from December through April, with fry usually emerging in April and May sometimes through June, depending on water temperature (Gerstung 1985). In the 1991/92 steelhead redd survey, six redds were observed on January 2, indicating that steelhead spawning likely began in December (Snider and McEwan 1992).

In the 1991/92 steelhead redd survey, most redds were observed in the uppermost portion (RM 22) of the lower American River, although some redds were observed as far downstream as RM 6 (**Figure 2-42**). Habitat type electivity estimates indicated that spawning steelhead preferred flatwater glides, followed by bar complex runs and riffles (Snider and McEwan 1992). That survey found that steelhead spawning began in December and extended into March.

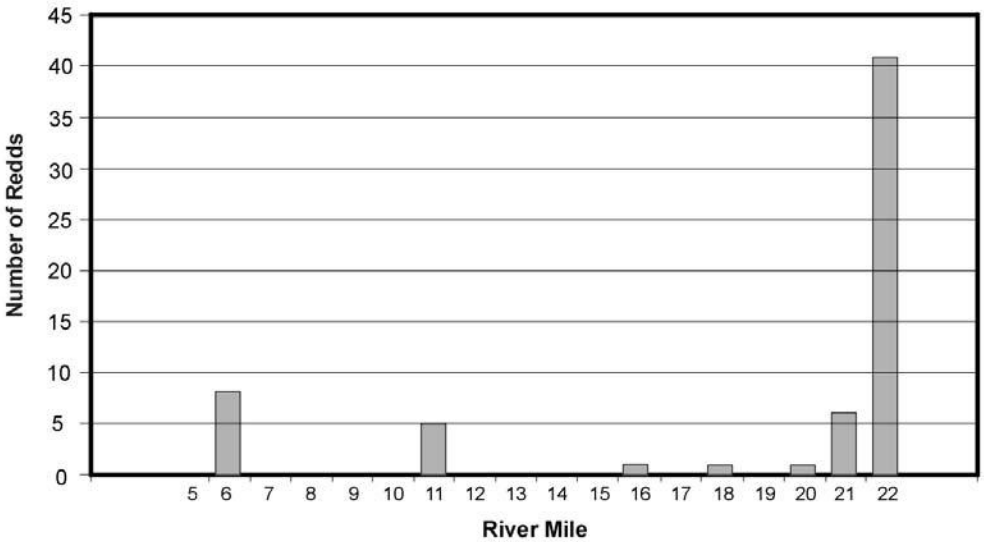


**Figure 2-42. Steelhead redd counts versus river mile in the lower American River, 1992.**

Preferred or optimal water temperatures for various lifestages of steelhead are reported in the literature (Bell 1986; Bovee 1987; Reiser and Bjornn 1979; McEwan and Nelson 1991). Reported optimal spawning temperatures fall in the range from 39ºF to 52ºF. Optimal temperatures for incubation and emergence also has been reported to be between 48º and 52ºF (McEwan and Nelson 1991). The NMFS (2000) biological opinion on the impact of CVP and SWP operations on the federally threatened Central Valley steelhead states that typical temperatures from Nimbus Dam to the mouth of the American River are within the range of preferred spawning, incubation, and emergence temperatures in December through March, and that cooler temperatures during these months are likely to slow the development of incubating eggs and pre-emergent fry resulting in a longer time until emergence.

Based on results of emigration and community surveys conducted on the lower American River, fry emergence usually occurs in April and May and can extend through June. Castleberry et al. (1991) captured steelhead trout as small as 21 mm in late April from the Sunrise site, and in early May from both the Sunrise and H Street sites. These observations further suggest that steelhead trout fry emerged from redds during a 45-day interval extending from early April through early May.

Egg size data are not collected from in-river spawning in the lower American River, but an annual trend in average egg size (at the eyed stage) from the Nimbus Hatchery exhibits a clear trend of increasing egg size in recent years (1985-1999) (**Figure 2-43**). See the discussion for fall-run chinook salmon regarding potential ramifications of egg size.

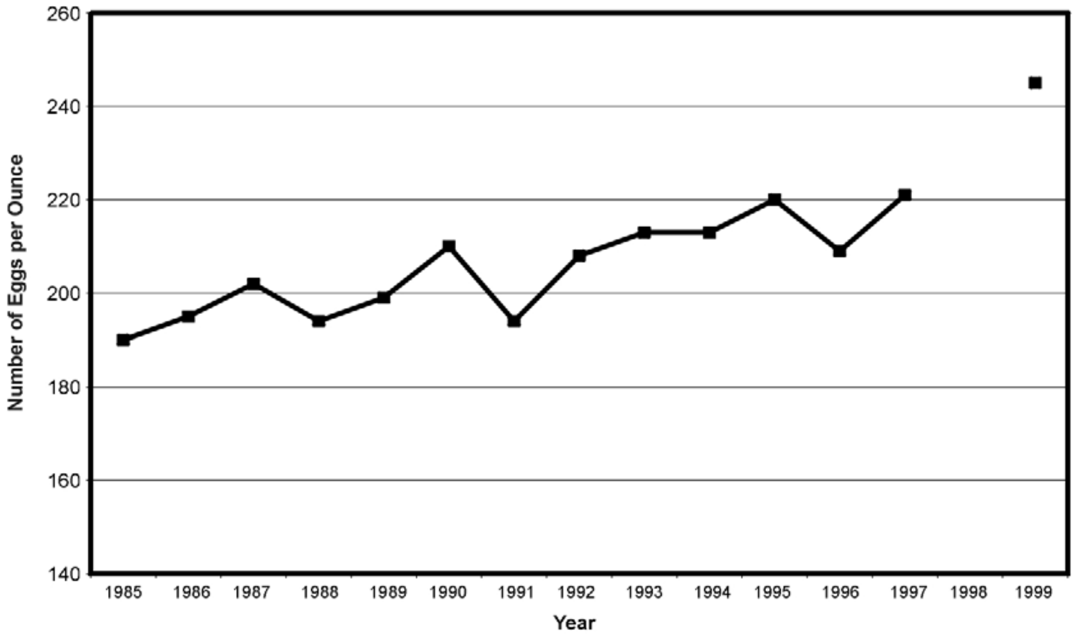


**Figure 2-43. Trend in steelhead egg size collected at the Nimbus Hatchery, 1985-1999.**

### 2.2.3.4. JUVENILE REARING AND EMIGRATION

#### Rearing

Newly emerged fry typically move to quiet, shallow water areas associated with the stream margin (Royal 1972; Barnhart 1986). Emergence can peak from mid-March through June. Rotary screw trap catches of young-of-the-year steelhead can extend into September (Snider and Titus 1995; Snider et al. 1997; Snider et al. 1998; Snider and Titus 2000; Brown and Moyle 1991; Snider and McEwan 1993; Snider and Keenan 1994; CDFG 2000b; Snider and Titus 1996). As juveniles, they move to riffles which are optimum feeding locations. To maintain natural rearing habitat, suitable conditions must be maintained year round.

From 1992 through 1999, CDFG has been conducting seining surveys and rotary screw trapping surveys to define the temporal and spatial distribution of steelhead and other fish in the lower American River. CDFG has produced fish community survey reports through 1995. In addition, steelhead captured by seining are reported for 1996/97 in Snider and Titus (2000). The following discussion is based upon these sources of information. For more detailed description of results and data, see Snider and McEwan (1993), Snider and McEwan (1994), Snider and Titus (1996), and Snider and Titus (2000), and CDFG unpublished data. Comparison of results from the two gear types, rotary screw traps and seines, results indicate that the rotary screw traps represent the temporal distribution of migration (emigration for yearlings, in-river migration for YOY), but does not appear to adequately reflect the relative abundance of yearling migrants (Snider and Titus 2000).

Typically three lifestages of steelhead appear in rotary screw traps and seining surveys: young-of-year, yearling (both in-river produced and hatchery produced) and adults. Hatchery planted steelhead can be distinguished from in-river reared steelhead by wear on the fins, or by scale analysis.

In general, juvenile steelhead usually appear in the seine samples during April, increase in abundance through April and/or May, and decrease thereafter. Juvenile steelhead continue to be present in relatively low numbers in the summer months, primarily at upstream locations. Seine results for 1993 illustrate these distributions (**Figure 2-44**). Overall, higher numbers of juvenile steelhead are typically captured at upstream areas for a given sampling period. Steelhead fry are more abundant in upstream areas primarily due to proximity to spawning location (Snider, CDFG, pers. comm., 2001). As the year progresses, the proportional abundance of juvenile steelhead becomes more uniform throughout the river (Snider, CDFG, pers. comm., 2001).

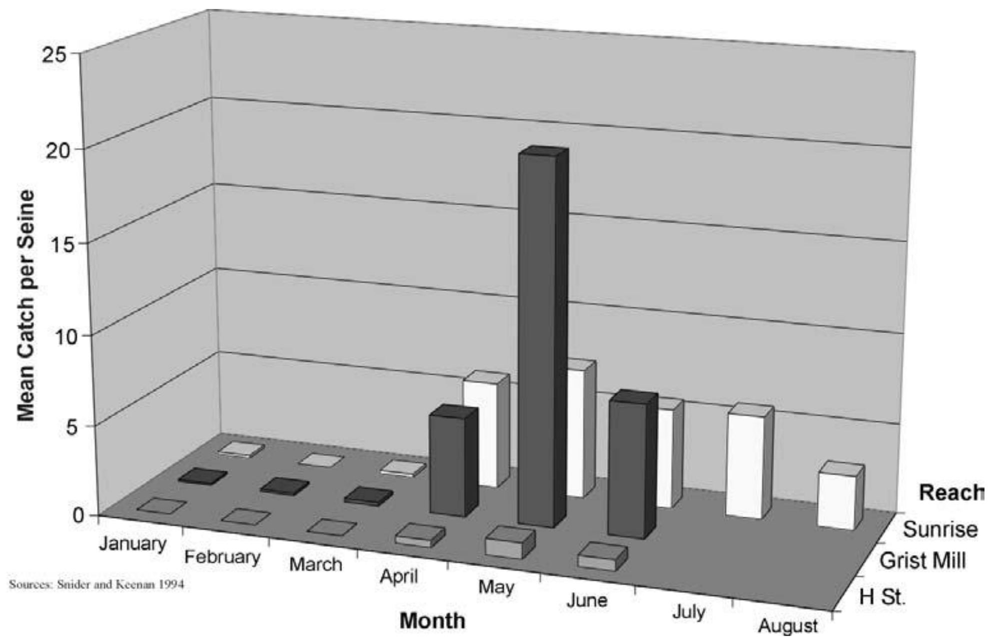


**Figure 2-44. Monthly mean steelhead catch per seine at Sunrise, Gristmill, and H Street, 1993.**

Young-of-the-year (YOY) steelhead begin appearing in rotary screw traps at the earliest in mid-January (1997), but typically in mid-March. Steelhead YOY, however, begin appearing in seine surveys as early as early February, but typically before mid-March, suggesting that emergence and emigration are not coincident (Snider and Titus 1995; Snider et al. 1997; Snider et al. 1998; Snider and Titus 2000; Brown and Moyle 1991; Snider and McEwan 1993; Snider and Keenan 1994; CDFG 2000b; Snider and Titus 1996). Juvenile steelhead fish length generally increases from winter through summer. **Figure 2-45** illustrates this general increase in size throughout the season.

Yearling-sized individuals captured early in the season (i.e., winter to early spring) strongly suggest some over-summer survival, but evidence is inconclusive as to the origin of these fish. Furthermore, the presence of apparent young-of-the-year steelhead in October samples indicates some capability to survive summer conditions, increasing the likelihood of survival to smolt.

Steelhead may spend summers outside of the lower American River and return during the fall (Snider and McEwan 1993).

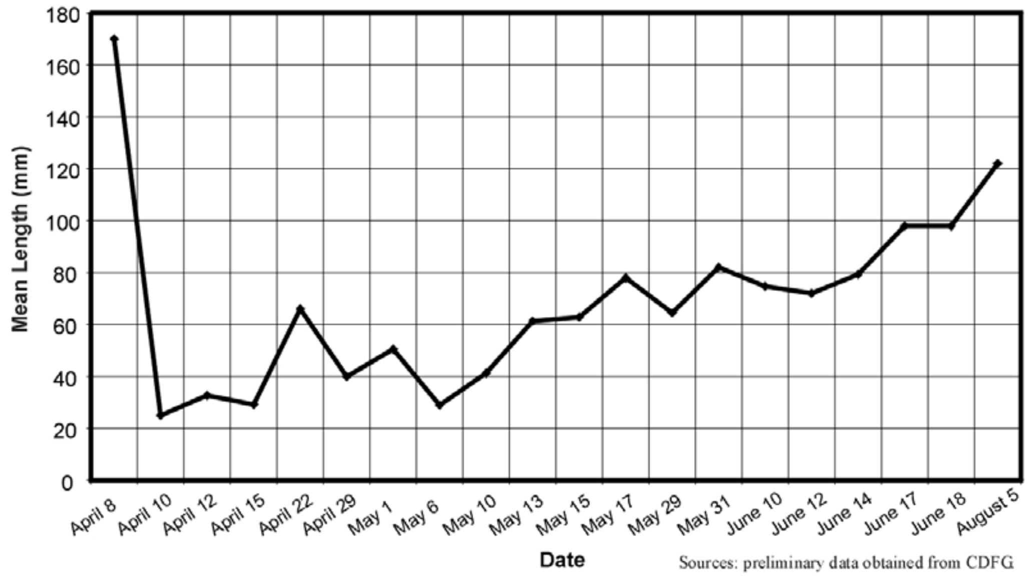


**Figure 2-45. Size distribution of juvenile steelhead captured by seining in the lower American River during 1991.**

Reaches included in the community surveys were:

| REACH | RIVER MILE | DESCRIPTION |
|---|---|---|
| 1 | 0 to 5 | Sacramento River to Paradise Beach |
| 2 | 5 to 9 | Paradise Beach to Watt Avenue |
| 3 | 9 to 16.5 | Watt Avenue to Ancil Hoffman/ Rossmoor |
| 4 | 16.5 to 22.5 | Ancil Hoffman to Hazel Avenue |

Rearing steelhead are not typically found in Reach 2. Reach 3 and 4 typically dominate the steelhead catch throughout the survey period (Brown and Moyle 1991; Snider and Keenan 1994; DFG 2000b; Snider and Titus 1996). Larger fish typically inhabit fast-water areas such as riffles, and smaller fish are generally found in pools and glides. The majority of emergent fry are collected in glides (Brown and Moyle 1991; Snider and Keenan 1994; DFG 2000b; Snider and Titus 1996).

By late summer, young-of-the-year steelhead are distributed throughout the lower american River and exhibit fidelity (Titus, CDFG, pers. comm., 2001). Limited mark and recapture evaluations of juvenile steelhead collected by seining in the lower American River since 1996 indicate that juveniles tend to occupy specific habitats throughout the summer (Titus, CDFG, pers. comm., 2001). Yearling steelhead are found in bar complex and side channel areas characterized by habitat complexity in the form of velocity shelters, hydraulic roughness elements, and other forms of cover (Snider, CDFG, pers. comm., 2001; Titus, CDFG, pers. comm., 2001)

## Temperature Conditions

Several documents report preferred or optimal water temperatures for various lifestages of steelhead (Bell 1986; Bovee 1987; Reiser and Bjornn 1979). Optimal temperatures for fry and juvenile rearing are reported to be between 45 and 60ºF (McEwan and Nelson 1991).

Temperatures during the winter and spring months are consistently below 60ºF in the lower American River. These temperatures are not likely to adversely affect rearing and emigrating juvenile steelhead during the period of December through March. Water temperature is a primary factor reported to affect growth and survival of fishes in the lower American River (Leidy et al. 1987). In 1995, for example Snider and Titus (1996) found that smaller average fish size in Reach 4 of their community survey indicated that development rates were lower and emergence later due to temperature differences. In general, a more pronounced longitudinal temperature gradient on the lower American River in the spring may be responsible for slower emergence in upstream locations relative to downstream locations (Snider and Titus 1996).

The environmental factor probably most limiting to natural production of steelhead in the lower American River is high water temperatures during the summer and fall (Snider and Gerstung 1986). Water temperatures exceed 60ºF in the lower American River during summer, especially during July through September, when mean daily water temperatures can exceed 70ºF.

Cech and Myrick (1999) recently conducted a laboratory thermal tolerance study on juvenile Nimbus strain steelhead showing that juveniles exhibited a higher level of temperature-independence of growth, oxygen consumption, food consumption, and thermal preference than has been previously reported for other steelhead strains over the range of 51.8-66.2ºF. Nimbus steelhead swimming performance and thermal tolerance generally increased with increasing temperatures. Nimbus steelhead used in this study preferred temperatures between 62.6ºF and 68ºF, irrespective of ration level or rearing temperature. Nimbus steelhead preferred higher temperatures than the 44.6ºF to 60.1ºF range reported as optimal for California steelhead (McEwan and Jackson 1996; McEwan and Nelson 1991; Zedonis and Newcomb 1997).

The lack of any kind of ration effect on thermal preference is interesting, as other studies have reported that fish may behaviorally thermoregulate and seek lower temperatures when rations were restricted to decrease their maintenance metabolic costs (Hughes 1998; Konecki et al. 1995; Reynolds and Casterlin 1978). It is likely that the difference between the two ration levels was not sufficient to elicit such a response in the Nimbus steelhead (Cech and Myrick 1999). However, reduced ration levels from 100%, to 82% to 92% of full ration did result in reduced growth rates, swimming performance, and oxygen consumption rates.

The preferred thermal range for Nimbus steelhead was found to be 63ºF to 68ºF; thus, their metabolic rates near that temperature range are likely to show thermal-independence (Taylor and others 1997). An ecological advantage of this temperature-insensitivity in respiration is that Central Valley steelhead can move to warmer water to take advantage of the higher growth and, possible, activity rates without incurring a significant maintenance metabolic cost, providing sufficient food is available (Cech and Myrick 1999).

## Flow Conditions

Rapid flow fluctuations result in stranding of substantial numbers of juvenile steelhead and salmon that are rearing in the river. When flows increase, juvenile salmonids not ready to emigrate will move to the littoral areas of the stream to avoid the high velocities in the main channel and to take advantage of the newly formed habitat. When flows suddenly decrease, many of these fish become trapped in isolated pools and backwaters.

Preliminary results of CDFG's fish stranding study for the lower American River indicate that the aquatic habitat most affected by changes in flow below 4,000 cfs tends to be low profile banks and mid-channel bars. A few isolated ponds may be created on these low profile banks and mid-channel bars by reductions in flow from 4,000 cfs to 1,750 cfs. Low profile bars are sensitive to small decreases in stage that can de-water or partially de-water the slopes of the bars.

Flows during the 1998 stranding survey were relatively high (**Figure 2-46**). Reductions in flows that occurred resulted in the stranding of juvenile steelhead at various locations in the lower American River. Most stranding occurred at the most upstream locations, perhaps reflecting increased initial abundance.

Stranding of juvenile steelhead frequently was observed at instream locations. A significant off-channel stranding event was observed at the upstream location during July.

## Angling

Substantial numbers of rainbow trout are caught in the lower American River each year. Perhaps a primary source of "rainbow trout" in the lower American River actually is steelhead yearlings which have failed to emigrate, although this is not documented.

Staley (1976) conducted intensive creel censuses during the 1971-1972 and 1973-1974 steelhead sport fishing seasons. He estimated that anglers fished 150,508 hours and caught 5,369 steelhead during the 1971-1972 season. (Stanley considered any rainbow trout greater than 35.6 cm fork length to be a steelhead.) During the 1973-1974 season the estimated catch was 3,265 steelhead. Staley (1976) estimated the harvest rates for steelhead to be in the mid-20 percentile. Gerstung (1985) estimated that 2,000 to 5,000 rainbow trout were caught each year from the lower American River. Creel censuses by Meyer (1981-1986) during the sport fishing season estimated the steelhead harvest from 3,158 to 4,614.

Previously conducted tagging studies indicate that approximately 50% of yearling steelhead released in the lower American River were harvested as juveniles, while those released in the lower Sacramento River are harvested as juveniles at rates of less than 6% (Staley 1976).

## Emigration

Although annual emigration surveys have been conducted in the lower American River by CDFG since 1992, the rotary screw traps are not particularly efficient at capturing juvenile steelhead. Total catch for juvenile steelhead ranged from 30 steelhead in the 1994/95 and 1992 surveys, to 152 steelhead in the 1995 survey.

**Figure 2-46. Number of juvenile steelhead stranded at Sunrise, Gristmill, H Street, and SP Bridge on the lower American River 1998, and flow at Fair Oaks (USGS Gage 11446500).**

Results from a seining survey conducted concurrent with the 1994/95 screw trap survey demonstrated the screw trap's inability to capture the majority of steelhead juveniles. Substantially more young-of-the-year steelhead were captured by seining than were caught by the screw traps (1,231 v. 27 fish), suggesting that few steelhead, if any, actively emigrate as young-of-the-year (Snider et al. 1997b), or that the traps did not catch them.

Yearling steelhead of hatchery origin were captured in two of the five emigration surveys reviewed (1993/94 and 1996/97). In the 1993/94 survey, hatchery yearlings represented 33% of the total yearlings trapped, and 50% of the total yearlings trapped in the 1996/97 survey. Yearling steelhead of hatchery origin were identified by the presence of fin erosion, whereas non-hatchery origin steelhead were without fin erosion (Snider and Titus 2000).

Yearling steelhead first appear in the screw traps in the lower American River typically in early December, and were found in the traps through March. Young-of-the-year steelhead typically begin appearing in the screw traps in March, and continue through the end of the survey period in the late summer or fall.

Juvenile steelhead in the Central Valley typically emigrate as yearlings (Schaffter 1980). Most steelhead emigrants enter the Delta between February and June, although emigrants also have been observed entering the Delta in the fall. Steelhead appear to rear in the Delta for short periods (Baracco 1980; Pickard et al. 1982; Snider and Titus 1995).

Winter flows may affect the efficiency of rotary screw trap capture of juvenile steelhead. Snider and Titus (2000) suggest that high flows in late 1996 and early 1997 may have resulted in the capture of emergent fry in 1997.

#### 2.2.3.5. NIMBUS HATCHERY OPERATIONS

**Trapping**

The ladder is operated continuously through the fall and winter, as long as fish with viable eggs are ascending. Live steelhead that have contributed to the egg taking or fertilization are returned to the lower American River. Also, steelhead that are not ready to spawn may be returned to the river alive (West, CDFG, pers. comm., 2000).

**Egg Taking**

Up to 800,000 steelhead eggs are taken representing the full spectrum of the run. Some or all of each pooled lot of eggs are retained according to a predetermined schedule of weekly egg taking needs.

If it becomes apparent by late January that the Mokelumne River Hatchery is able to take enough steelhead eggs to reach mitigation goals, then up to 250,000 steelhead eggs may be taken at the Nimbus Hatchery for transfer to the Mokelumne River Hatchery. Eggs or fingerling steelhead transferred to the Mokelumne River Hatchery will be taken from all the available lots of eggs or fingerlings at the Nimbus Hatchery (from Nimbus Hatchery Operational Plans, 1999).

## Mitigation

The goal is to rear 430,000 steelhead to yearlings and release them from January through February in the Sacramento River below Discovery Park. All steelhead to be released will be marked with an adipose fin clip or coded-wire tag, as appropriate (from Nimbus Hatchery Operational Plans, 1999).

## 2.2.4. SACRAMENTO SPLITTAIL

In addition to fall-run chinook salmon and steelhead, species of primary management concern for the lower American River include Sacramento splittail, American shad, and striped bass. A general depiction of lifestage periodicity for these three fish species is presented in **Figure 2-47**.

### 2.2.4.1. BACKGROUND

A proposed rule to list the Sacramento splittail as threatened under the federal Endangered Species Act (ESA) was published in the *Federal Register* (59 FR 862) on January 6, 1994. The proposed rule issued by the USFWS described splittail as primarily threatened by large diversions from the Sacramento and San Joaquin rivers, prolonged drought, loss of shallow-water habitat, introduced aquatic species, and agricultural and industrial chemicals (59 FR 862). On February 8, 1999 (FR 64 5963), the USFWS published its final rule, listing splittail as threatened under the federal ESA. The USFWS has not designated, or proposed, critical habitat for splittail.

Little information regarding Sacramento splittail (*Pogonichthys macrolepidotus*) occurrence, abundance, or habitat utilization is available specifically for the lower American River. Pertinent information on splittail specific to the lower American River includes:

- Observations during fish community surveys (Hanson et al. 1991; Brown et al. 1992; Snider and McEwan 1993; Snider and Keenan 1994; Snider and Titus 1996; Snider et al. 1998; Snider and Titus 2000); and

- Flow – potential spawning habitat availability assessment (SWRI 1999a).

This *Baseline Report* presents a summary of information obtained from the literature, incorporating information specific to the lower American River to the extent available, including excerpts taken directly from SWRI (1999a).

### 2.2.4.2. POPULATION TRENDS

Adult splittail are relatively long-lived (up to 8-10 years) and have high fecundity. These life history traits favor maintaining long-term population levels, despite reduced juvenile production in one or more individual years. The results of numerous annual surveys (e.g., IEP summer townet, fall mid-water trawl, and Delta outflow/San Francisco Bay; USFWS IEP beach seine, Chipps Island trawl; University of California, Davis Suisun March survey, IEP Bay Study midwater and otter trawls; and the CVP and SWP salvage counts) have been used to characterize splittail population trends, and relate them to environmental conditions. Considerable uncertainty exists with regard to the effectiveness with which many of the ongoing fish surveys sample adult and juvenile splittail, and whether trends derived from these surveys reflect actual population trends. Utilizing data from all surveys, as is being done by the CDFG's Bay-Delta Branch (CDFG 1999a), maximizes the ability to accurately describe recent and long-term population trends, and to relate these trends to environmental conditions throughout the system.

**Figure 2-47. American shad, splittail, and striped bass temporal and spatial distribution on the lower American River.**

The population abundance of splittail is highly variable, and year-class abundance varies greatly. Low year-class success occurred throughout the 1987-1992 drought years. Age-0 abundance declined in the estuary during the 6-year drought and typically declines in dry years (Sommer et al. 1997).

In 1998, high flows and consistent floodplain inundation resulted in record or near record age-0 splittail abundance for abundance indices calculated to date. High abundance was supported by age-0 recruitment from the San Joaquin, Sacramento, Cosumnes, Napa and Petaluma rivers, the Sutter and Yolo bypasses, Suisun Marsh, the Delta, and numerous small tributaries. For the fourth year in a row, significant numbers of age-0 splittail were produced in the San Joaquin River and its tributaries. Floodplain inundation appears to provide the best explanation for increased abundance in high outflow years (CDFG 1999a).

The long-term indices (e.g., those based on IEP's summer townet and fall midwater trawl surveys) exhibited several peak abundances associated with high outflow (i.e., wet) years, including 1978, 1982-83, 1986, 1995, and 1998. However, this relationship is not exhibited to the same degree across all surveys sites or for all high outflow years. Most of the indices rebounded in 1995 and 1998 from low values associated with the 1987-1992 drought (CDFG 1999a).

Some of the declining trends leading, in part, to the listing of splittail by the USFWS under the federal ESA are attributable to surveys starting at or near a peak abundance period for splittail in the early 1980s and sampling through a low abundance period that coincided with the most recent drought. Reduced age-0 abundance in the Delta was expected as a result of reduced incidence of floodplain inundation during the drought. Reduction in adult abundance from successive years of low age-0 abundance during the drought was not sufficient to inhibit a strong reproductive response when favorable outflows returned in the mid and late 1990s (i.e., 1995 and 1998). In 1995, an extremely wet year, splittail recruitment indices were comparable to or exceeded those of wet years in the 1980s, despite drought conditions in 1987-1992 and 1994, representing 7 out of 8 preceding years. These data indicate that the Bay-Delta splittail population remains capable of producing strong year classes in response to favorable environmental conditions (Sommer et al. 1997; CDFG 1999a).

Low numbers of splittail have been collected in the lower American River. Fish community surveys have been conducted in the lower American River annually from 1991 through 1997 (Brown et al. 1992; Snider and McEwan 1993; Snider and Keenan 1994; Snider and Titus 1996; Snider et al. 1998; Snider and Titus 2000). The fish sampling surveys encompassed the period extending from approximately January through June, when adult and larval splittail would likely be in the river. Splittail have been collected in very low numbers, primarily at downstream locations. The largest number of splittail was collected during June 1991, when 88 of 89 fish were captured at the lowermost sampling station, located downstream of U.S. Interstate Business 80 (RM4) (Brown et al. 1992). All splittail captured in 1991 were young-of-the-year.

Adult and juvenile splittail are difficult to capture using beach seines (a primary sampling methodology used by CDFG in the fish community surveys). Thus, the low numbers of splittail captured may be partially a function of sampling gear efficiency. However, these data do provide insight as to their relative abundance in the lower American River compared to elsewhere in the system where seining surveys also are conducted. Based on available information pertaining to the relative numbers of adult and juvenile splittail captured in the lower American River by various surveys, it can be reasonably concluded that, if splittail spawn in the river, they do so in relatively low numbers.

#### Factors Affecting Splittail Abundance

In addition to flows, food availability, toxic substances, and competition and predation (particularly from striped bass and other introduced species) are among the factors reported to potentially limit splittail abundance. In addition, harvest for food and bait by sport anglers may inhibit recovery of the splittail population (ERPP 1999).

Splittail are predominantly benthic foragers with a limited range of prey types, and they feed opportunistically on the benthic food items available within local habitats. (DWR and USBR 1994). Caywood (1974) analyzed stomach contents of splittail from Miller Park on the Sacramento River in 1973 and 1974 and found the most frequent items included detritus and algae (73 to 81%), earthworms (*Lumbricus* spp.) (40 to 64%) and dipterans (up to 46%) (DWR and USBR 1994). Brown et al. (1992) reported on the stomach contents, including an index of relative importance, for 20 juvenile (mean SL = 29 mm, range 22-36 mm) splittail collected from downstream areas of the lower American River during June 1991. They found that of all identifiable matter, amphipods followed by chironomids had the highest indices of relative importance.

Toxic contaminants, including heavy metals, pesticides, herbicides, and polycyclic aromatic hydrocarbons may affect splittail populations, although no toxicity studies have been conducted to determine the sensitivity of splittail to these contaminants. Contaminants in the sediments are potentially the greatest threat to splittail because they frequently feed in shallow water near the bottom, where there is a greater risk of exposure to urban and agricultural runoff (DWR and USBR 1994).

Splittail abundance trends may also be affected by a number of native and introduced fish and invertebrate species. The exceptionally large number of introduced species are of particular concern as they have extensively modified the ecosystem (DWR and USBR 1994). Known predators of splittail include catfish, striped bass, and sunfish. Increased water transparency may also enhance predation. If predation has a major effect on splittail recruitment, the most probable explanation is that a recently introduced species is responsible. The species most likely to have the greatest effect are inland silverside (introduced in 1975) and the yellowfin and chameleon gobies (introduced in the late 1950s) (DWR and USBR 1994).

Splittail are not harvested commercially, but comprise at least a small recreational fishery. The present status of the recreational fishery is not known. However, Moyle et al. (1995) report that splittail are sometimes used as bait for striped bass. Although recreational harvest could reduce the number of spawners, there is no evidence to suggest that this factor has a major effect on splittail abundance (DWR and USBR 1994).

### 2.2.4.3. GEOGRAPHIC DISTRIBUTION

Adult splittail inhabit the Delta, Suisun Bay, Suisun March, and other parts of Sacramento-San Joaquin estuary. Splittail inhabit the Sacramento River below Red Bluff Diversion Dam and the lower sections of its tributaries, including the Feather and American Rivers (Moyle et al. 1995).

Adult splittail foraging and spawning migrations occur in the Sacramento River every year and in the San Joaquin River during years with high outflow. Changes in the timing, magnitude and duration of high river flows (i.e., floodplain inundation) are believed to affect when and where adults migrate and, thus, their winter-spring distribution and the initial distribution of young-of-the-year splittail (Sommer et al. 1997; CDFG 1999a).

In 1997 and 1998, adult splittail were captured by CDFG as far north as Red Bluff Diversion Dam on the Sacramento River (RM 243). Adult splittail forage and may spawn in tributaries of the Sacramento River upstream of the Feather River. Recent CDFG work has confirmed splittail spawning in the Sutter and Yolo bypasses as well (SWRI 1999a).

Larval splittail were identified from archived plankton samples collected between 1988 and 1994 by the Striped Bass Egg and Larva Survey. Larval splittail were always collected in this survey's most upstream sites (Verona to Grimes, RM 79-125), with the catch per 1,000 $m^3$ of water sampled frequently as high or higher at these sites compared to downstream sites. Sampling at the confluence of the Sacramento and American rivers as a part of this survey during 1992, 1993, and 1994 produced a relatively low catch of larval splittail in 1994, but no larvae in the other two years. Except for years with some (1989, 1992) or substantial (1993) winter/spring outflow, splittail larvae were uncommon in Sacramento River collections downstream of the City of Sacramento. Larvae were not collected in Suisun Bay or in Suisun Marsh except in 1993. Two interpretations are possible for these data: 1) splittail spawn relatively high in the Sacramento River system every year, but downstream dispersal of larvae increases with higher flows; and 2) some splittail are able to spawn in Suisun Bay or Suisun Marsh during high-flow years because of reduced salinity and increased small stream flooding (CDFG 1999a).

The distribution of age-0 splittail based on data from the IEP's Beach Seine Survey was similar to that shown by the plankton survey discussed above, with age-0 splittail always collected at the most upstream sites. Data from the Beach Seine Survey provide evidence of Sacramento River spawning in both high- and low-flow years, and also of extended riverine rearing (CDFG 1999a).

Splittail inhabit the San Joaquin River and the lower portions of some of its tributaries during high outflow years, but are rarely caught in low outflow years. In June of 1998, a joint USFWS/CDFG splittail survey crew collected juvenile splittail from Salt Slough, located near RM 136 of the San Joaquin River. When river flows create suitable spawning habitat, as occurred annually from 1995 through 1998, the San Joaquin River system is used for spawning and can produce substantial numbers of splittail (CDFG 1999a).

In recent years, juvenile and adult splittail were documented to use both the Sacramento and San Joaquin river systems extensively during the winter and spring months. Summer through fall distribution of adult splittail is primarily limited to tidal fresh and brackish waters of the Delta, Suisun Bay, and Suisun, Napa and Petaluma marshes. However, data collected in recent years by CDFG and others suggest that some fish of all age groups remain in the Sacramento River year-round. At the western edge of their known range, splittail continue to inhabit the Petaluma River and Marsh as they did previous to and during the 1987-1992 drought. Use of the Napa Marsh appears to vary with freshwater outflow. Use of Suisun Marsh also varies with outflow, but to a lesser degree than use of Napa Marsh (CDFG 1999a).

As previously stated, in the lower American River, relatively few splittail have been collected. Of those collected, most have been captured at downstream locations.

### 2.2.4.4. General Life History and Habitat Utilization

Splittail are relatively large members of the minnow family, achieving lengths of up to nearly 16 inches (Moyle 1976). Splittail are endemic to the Sacramento-San Joaquin Delta estuary and to the lower reaches of the Sacramento and San Joaquin rivers (Sommer et al. 1997). Historically, splittail inhabited Central Valley lowland rivers and lakes (Moyle 1976). Adult splittail primarily inhabit the Delta, Suisun Bay, Suisun Marsh, and other parts of Sacramento-San Joaquin estuary. Splittail are also known to inhabit the Sacramento River below Red Bluff Diversion Dam and the lower sections of its tributaries, including the Feather and American rivers (Moyle et al. 1995).

Splittail are relatively long-lived (up to 8-10 years) and generally become reproductively mature at age-2. Prior to spawning, adult splittail apparently migrate upstream into freshwater areas primarily during January through April (Meng and Moyle 1995). The precise timing and location of spawning varies among years, and the timing and magnitude of winter and spring runoff may play a substantial role in determining the temporal and spatial distribution of spawning in any one year (Daniels and Moyle 1983). Increasing water temperature and photoperiod, which occur with the onset of spring and summer, appear to trigger spawning activity in the Sacramento-San Joaquin Delta (Daniels and Moyle 1983). Spawning has been reported to occur January through July (Wang 1986), March and May (Caywood 1974), early March to mid-May (Daniels and Moyle 1983), and February through April (Moyle et al. 1995). The timing of their upstream movements and spawning corresponds to the historically high-flow period associated with snowmelt and runoff each spring.

Splittail have been reported to spawn in the lower reaches of rivers (Caywood 1974), dead-end sloughs (Moyle 1976), and in larger sloughs (Wang 1986). Splittail spawning habitat has been reported to include flooded riparian vegetation and emergent aquatic plants such as tules (*Scirpus* sp.) (Caywood 1974; Wang 1986). Riverbanks, bars, and sloughs lined with “willows and weeds” have also been reported to provide spawning and rearing habitat for splittail (Meng and Moyle 1995).

Splittail larvae are believed to develop and grow in shallow, highly vegetated areas close to the spawning areas, but move into deeper water as they mature (Caywood 1974; Wang 1986). Juvenile splittail migrate (or are washed) downstream to Suisun Bay (Caywood 1974; Wang 1986). Numbers of age-0 splittail collected at Delta pumping plant fish salvage facilities peaked between May and August, indicating that their downstream migration occurs during the spring and summer months (Meng and Moyle 1995). However, some juvenile splittail apparently rear in upstream habitats for up to a year before migrating downstream (R. Baxter, pers. comm., 1997).

Splittail are typically found in slow moving sections of rivers and sloughs. In the Delta and Suisun Marsh, splittail congregate in shallow water habitats in dead-end sloughs with an abundance of emergent vegetation (Meng and Moyle 1995). Studies from Suisun Marsh indicate that splittail are found in small dead-end sloughs fed by freshwater streams and in the larger sloughs such as Montezuma and Suisun (Daniels and Moyle 1983; Meng 1994; Moyle et al. 1986). Juveniles and adults utilize shallow edgewater areas lined by emergent aquatic vegetation (USFWS 1994). Submerged vegetation provides abundant food sources and cover to escape from predators. Shallow, seasonally flooded vegetation is also apparently the preferred spawning habitat of adult splittail (Caywood 1974; Daniels and Moyle 1983; Moyle1976; Moyle et al. 1986; Wang 1986). Collections of mature adult and young-of-the-year splittail from the temporarily flooded Sutter Bypass in February and March 1993 supports evidence that seasonally inundated, vegetated floodplains are used as spawning and rearing habitat (Jones and Stokes 1993). Floodplain inundation is a significant element required to maintain strong year classes (Sommer et al. 1997). It is likely that reproductive success of this species is tied to the timing and duration of flooding of the Yolo and Sutter bypasses and to flooding of riparian zones along the major rivers of the Central Valley (ERPP 1999).

### 2.2.4.5. LOWER AMERICAN RIVER HABITAT AVAILABILITY

SWRI (1999a) examined the relationships between flows and potential splittail spawning habitat availability, and the potential effects of flow fluctuations on splittail in the lower American River. A preliminary examination of aerial photographs indicated that potential splittail spawning habitat may exist in the lower American River, particularly in the reach below Gristmill (RM 12). The 11-mile reach of river between Nimbus Dam and Gristmill was not included in the assessment due to its relatively high gradient and relative paucity of potentially suitable backwater habitats (SWRI 1999a). Although potential splittail spawning habitat is believed to exist between RM 5 and the river's confluence with the Sacramento River (RM 0), stage (i.e., elevation) in this reach of the river is largely influenced by the water surface elevation of the Sacramento River. Hence, the relative amount of inundated riparian habitat in this reach would be controlled not only by lower American River flows, but mostly by Sacramento River stage.

For the reach of the lower American River between RM 5 and RM 12, flooding frequency and inundation of riparian vegetation is a function of instream flows and resultant river stage or elevation. Moreover, this reach contains an abundance of low-lying, backwater habitats with riparian vegetation that may provide potential spawning and rearing habitat, when inundated by sufficiently high river flows. SWRI (1999a) restricted the study area to the reach of the river between RM 8 (just upstream of Howe Avenue) and RM 9 (just downstream of Watt Avenue). This 1-mile reach was selected as the study area because it: 1) was identified to contain backwater habitats most likely to provide potential splittail spawning habitat; and 2) represents a segment of the river to serve as an "index" for the availability of such habitat between RM 5 and RM 12.

Aerial photographs were used as base maps for delineating riparian habitat types and the water's edge at different flow rates, and were digitized using ArcCAD software. A digital base map of the study area delineating riparian habitat types was created, and became the standard electronic base map for calculating the area inundated at each river flow evaluated. The transparent overlays delineating the water's edge for each of the five flow rates evaluated were digitized using the same coordinate system, thereby creating a "shoreline contour" file for the study area.

The amount of riparian habitat inundated in acres (dependent variable) was regressed against flow in cfs (independent variable). Because the study area is located 14-15 miles downstream of Nimbus Dam, a lag time of 12 hours was used to estimate earlier releases from Nimbus Dam that corresponded to flows through the study area at the times that field measurements were made. Field measurements indicated that total amount of riparian vegetation inundated in the study area ranged from 2.4 acres at a river flow of 4,540 cfs to 35.8 acres at a river flow of 22,570 cfs (**Appendix C**).

The simple linear regression analysis performed identified a positive, statistically significant ($r^2$=0.99; P<0.001) relationship between flow and the total acreage of riparian vegetation inundated within the study area. This relationship is defined by the equation:

$$\text{Habitat} = (0.001874 \times Q) - 6.4585$$

Where: Habitat = the total amount of riparian vegetation inundated within the study area (acres); and

Q = flow within the study area (cfs)

The x-intercept of the linear regression line occurs at 3,456 cfs, which indicates that zero acres of riparian habitat are inundated within the study area at river flows of approximately 3,456 cfs or less. For river flows between 3,456 cfs and 22,571 cfs, the total acreage of riparian vegetation inundated within the study area increased by approximately 1.9 acres for each 1,000 cfs increase in flow. Field observations determined that the first 2.4 acres of riparian vegetation inundated primarily occurred within a narrow strip along the riverbank. This inundation zone was noted as being very shallow (i.e., generally <2 ft deep) and, therefore, unlikely to provide suitable potential habitat for splittail. Based on this observation, more than 2.4 acres of inundated vegetation must be present within the study area before potentially suitable splittail spawning habitat would be available.

#### Spawning Opportunities

Splittail are reported to spawn at water temperatures between 9-20°C (48-68°F) (Wang 1986). Water temperatures would typically be within this range in the lower American River throughout the February through May period, annually. Also, based on finding eggs in female splittail to be in several size stages of development, Wang (1986) reported that splittail *"...may have a prolonged spawning season*", rather than the majority of spawning occurring within a 2-3 week period like many other fish species. Considered together, the above information suggest that the relative success of annual spawning is not dictated by physical conditions during a short window of time between February and May, but rather the availability of suitable conditions throughout this four-month period of the year (SWRI 1999a).

Because splittail spawn in shallow, vegetated areas, the length of time that such habitats remain inundated is critical to spawning success. Areas of inundated riparian vegetation potentially suitable for splittail spawning would need to be inundated for some period of time (e.g., several days to a week) to attract adult splittail to the area for spawning. Splittail eggs have been documented to require approximately 7 days to hatch at 15.5°C (59.9°F) and 3-5 days at 18.5°C (65.3°F) (IEP 1994). Additionally, swim bladder inflation is believed to occur about 5-7 days post hatch, with swim-up completed at 7 days post hatch (IEP 1994).

Hence, in order for an inundated area of riparian habitat to provide splittail with a "potential spawning opportunity", it must remain inundated for a sufficiently long period of time to allow adult splittail to be attracted to the area and spawning, egg incubation/hatching, and larval swim bladder inflation and swim-up to occur. Completion of these events would result in fry capable of moving passively or actively with receding waters, thereby having the potential to avoid stranding and dewatering as water levels decrease.

At water temperatures that typically exist within the lower American River throughout the February through May period (8-19°C (46-66°F)), the estimated length of time of inundation required within the study area would be about 2-4 weeks, with the shorter end of this range applicable during April and May when water temperatures are higher. Areas inundated for substantially shorter periods of time (e.g., a few days to a week) may attract adults to spawn in the area, only to have the eggs or early larval stages stranded and dewatered when flows are reduced. Thus, inundation of riparian vegetation for such short periods of time would not be expected to provide splittail with an opportunity to successfully produce swim-up fry capable of reaching the river's mainstem.

Based on the splittail life history characteristics discussed above, a "potential spawning opportunity" was defined to occur within the study area if inundated riparian vegetation potentially suitable for spawning (i.e., >2.4 acres) was continuously available for a minimum of 3 weeks during February and March, and a minimum of two weeks during April and May. The current flood control diagram for Folsom Reservoir went into effect in early 1995. SWRI (1999a) utilized daily flow data from 1995 through 1998 for their assessment, the results of which are presented in **Table 2-21**.

**Table 2-21. Number of days that riparian vegetation potentially suitable for splittail spawning (i.e., >2.4 acres) would be inundated within the study area (RM 8-9 of the lower American River) (SWRI 1999a).**

| Month | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|
| February | 14 | 25 | 18 | 27 |
| March | 31 | 11 | 3 | 16 |
| April | 30 | 16 | 0 | 30 |
| May | 31 | 20 | 0 | 31 |

A daily assessment of flows under the four years evaluated (i.e., 1995-1998) showed that multiple potential spawning opportunities occurred within the study area during the February through May period in each year except 1997. In 1997, no potential spawning opportunity occurred. The daily flow assessment performed for the period February through May of 1995-1998 showed that adverse flow fluctuations (those that could strand and dewater splittail eggs and larvae) would occur less often during February, March, and April under the current flood control diagram than under the previous diagram. Also, the potential for successful splittail spawning within the study area is not believed to be limited by the amount of inundated riparian vegetation present as much as it is by the presence/absence of such habitat (i.e., potential spawning opportunities in this habitat) and adverse flow fluctuations (SWRI 1999a).

### 2.2.5. AMERICAN SHAD

#### 2.2.5.1. BACKGROUND

American shad (*Alosa sapidissima*), a non-native species, was first introduced into California in 1871, when approximately 10,000 fry were transported from New York state and released in the Sacramento River near Tehama (Painter et al. 1978). The introduced American shad rapidly became abundant, and by 1879 a commercial shad fishery had developed in California. Annual commercial catches of American shad regularly exceeded 1 million pounds from 1900 through 1945, with the largest annual catch of 5,675,509 pounds recorded in 1917 (Painter et al. 1978). Commercial catches rarely exceeded 1 million pounds after 1945, and legislative action in 1957 terminated the commercial fishery (Painter et al. 1978) in favor of the rapidly developing sport fishery (Moyle 1976).

Most of the information regarding the distribution, abundance, and factors affecting American shad in the Central Valley was developed in the 1970s. Between 1975 and 1978, CDFG, supported in part by USFWS, conducted field surveys using angling, gill net, and bump net methods to collect age and reproduction history data, as well as creel census surveys, during May and June each year on American shad populations in the Sacramento River system (including the lower American River). These studies served as the basis for several reports (Meinz 1978; Painter et al. 1978; Meinz 1981; Wixom 1981).

In recent years (1994-1999), American shad have been captured in the lower American River during CDFG's emigration surveys using rotary screw traps (Snider and Titus 1995; Snider et al. 1997a; Snider et al. 1998; Snider and Titus 2000; CDFG 2000).

This *Baseline Report* presents a summary of American shad information obtained from the literature, particularly as it pertains to the lower American River. More extensive discussion can be found in the above-referenced reports.

#### 2.2.5.2. POPULATION TRENDS

No specific estimates are available regarding annual run size of American shad in the Sacramento River system, including the lower American River. Because no consistent data to estimate the adult component of the American shad population are available, the USFWS used juvenile abundance in the IEP's fall midwater trawl (MWT) as an index of production. The AFRP production target for American shad in the Central Valley is a juvenile (MWT ) index of abundance of 4,258. This value is double the mean juvenile shad abundance from 1967-1988 for the Central Valley (USFWS 1995). No abundance estimates or production goals are provided specifically for the lower American River.

#### 2.2.5.3. GENERAL LIFE HISTORY AND HABITAT UTILIZATION

An anadromous fish species, American shad migrate from the ocean to freshwater to spawn. Adults returning from the ocean begin passing through the Sacramento-San Joaquin Delta in late March or April, increase substantially in numbers through April and peak during May in the Sacramento River at Clarksburg (CDFG 1987). Historically, American shad spawned throughout Delta tidal fresh waters upstream into both the Sacramento and San Joaquin rivers, but spawning has apparently declined in the San Joaquin system, leaving the north Delta and Sacramento River system upstream from Hood the primary spawning areas (CDFG 1987).

Adult American shad enter the lower American River beginning in April and may continue through the first week of July (Snider and Gerstung 1986), with peak spawning migration occurring from mid-May through June (CDFG 1987). Water temperature is apparently the most important factor influencing the time of spawning. American shad are reported to spawn at water temperatures ranging from about 46.4ºF to 78.8ºF (Walburg and Nichols 1967), although most spawning apparently occurs after water temperatures reach about 54ºF (Massman 1952; Leim 1924). Optimum water temperatures for American shad spawning have not yet been determined for the American River. However, optimum water temperatures for American shad spawning in the Feather River were reported to range from 60 to 70ºF (Painter et al. 1978).

As broadcast spawners, female American shad deposit eggs near the surface of open waters, where they are fertilized by one or more males (Walburg and Nichols 1967). The semibouyant eggs drift with the current and gradually sink toward the bottom (Painter et al. 1978). Eggs generally hatch in 4 to 6 days at water temperatures from 59 to 64.4ºF (Walburg and Nichols 1967). However, most of the eggs spawned in the lower American River probably do not hatch until they have drifted downriver and entered the Sacramento River (Kelley et al. 1985a; Snider and Gerstung 1986).

#### Rearing Habitat

Previous reports have suggested that juvenile American shad do not utilize the lower American River as rearing habitat for extended periods, and that the lower American River did not serve as a season-long nursery area for juvenile shad (Meinz 1979; Painter et al. 1978; Kelley et al. 1985b). This suggestion apparently was based on CDFG seine surveys conducted for juvenile shad in the lower American River weekly from July through November 1977, and from mid-July through mid-September 1978. Only 98 juvenile American shad were collected, all from the mouth of the river, suggesting that juvenile American shad do not rear in the lower American River (Kelley et al. 1985b).

By contrast, recent collections of juvenile American shad by CDFG suggests that juvenile American shad may rear in the lower American River for relatively extended periods. Emigration surveys conducted by CDFG from 1994-1999 (Snider and Titus 1995; Snider et al. 1997; Snider et al. 1998; Snider and Titus 2000; CDFG 2000) utilizing a rotary screw trap indicate that juvenile American shad rearing occurs at least as far upstream as Watt Avenue (RM 9) well into November and even into December, subsequent to spawning the previous spring (**Figure 2-48** and **Figure 2-49**). CDFG's community surveys, primarily based on seining, generally do not capture American shad. Only in 1995 were a few shad captured, although one juvenile was captured as late as January (Snider and Titus 1996).

**Figure 2-48. Catch distribution of American shad caught by screw trap during the lower American River emigration survey, 1993-1996.**

**Figure 2-49. Catch distribution of American shad caught by screw trap during the lower American River emigration survey, 1996-1999.**

### Flow Considerations

The relative volume of flow influences the size and location of American shad spawning runs in the Sacramento River and tributaries (Snider and Gerstung 1986). Unlike chinook salmon, not all American shad die after spawning. However, American shad spawning migrations are comprised mostly of first-time spawners, referred to as “virgin” fish (Wixom 1981). Over the four years of study, virgins made up 67% of the males and 72% of the females sampled (Painter et al. 1978). For American River shad specifically, the gill net-caught adult shad results show that 88% of the males and 90% of the females were virgin.

Virgin fish have been reported to distribute themselves relative to the proportions of flow in the tributaries and the mainstem of the Sacramento River (Painter et al. 1978). For example, the American, Feather, and Yuba rivers experienced drastically reduced flows during the drought years of 1976 and 1977, while the Sacramento River remained relatively high. In these years, a substantially lower percentage of virgin fish were found in these tributaries as compared to other years. In addition, for the years 1975 through 1978, the percentage of virgin spawners in the run was positively correlated with the relative volume of flow in the tributaries as compared to the Sacramento River. The coefficients of correlation exceeded 0.99 on all rivers except the Feather, where many juvenile shad are reared through their first summer and become imprinted during that period. The results support the hypothesis that the relative size of shad run in the Sacramento tributaries is controlled by the relative flows in those rivers (Kelley et al. 1985b).

Kelley et al. (1985b) compared estimated lower American River shad catches in 1969 (Hooper 1970) and in 1976, 1977, and 1978 (Meinz 1981) with the relationship between American and Sacramento River flow during May and June of those years. In 1969 and 1978, when American River flows were 18 and 19 percent of the Sacramento flows, catches were much higher than in 1976 and 1977 when American River flow was 10.5 and 5.4 percent of the Sacramento River. No total catch estimates have been made since 1978, so further evaluations of these potential relationships have not been made (Kelley et al. 1985b).

Given that virgin fish often comprise a majority of the spawners, the number of American shad spawning in the lower American River would be expected to vary as flows in the lower American River change relative to flows in the Sacramento River. Based on the finding that during the four years when catch data were collected by CDFG, May and June mean flows ranging from 520 to 1,277 cfs resulted in poor catches compared to two years when mean monthly flows ranged from 3,338 to 7,797 cfs, Kelley et al. (1985b) recommended flows of 2,000 or greater from mid-May through June for American shad attraction. Snider and Gerstung (1986) recommended flow levels of 3,000 to 4,000 cfs in the American River during May and June as sufficient attraction flows to sustain the American shad fishery in the lower American River. Painter et al. (1978) recommended that to…”*Maintain a normal distribution of adult shad to tributaries in the watershed, the May/June flow of the American River should be not less than 10% of the Sacramento River at Sacramento*.”

## 2.2.6. STRIPED BASS

### 2.2.6.1. BACKGROUND

Striped bass (*Morone saxalilis)* was introduced into California when two shipments totaling 432 fish were planted in the Sacramento-San Joaquin Estuary in 1879 and 1882 (Moyle 1976). The species rapidly became abundant and provided the basis for a commercial fishery by 1888. Commercial landings exceeded 1.2 million pounds by 1899 (Skinner 1962).

Striped bass remains an important anadromous sport fish with high recreational value. It also plays an important role as a top predator in the Bay-Delta and its watershed (ERPP 1999).

Limited information is available on striped bass in the lower American River. Very few individuals have been captured by electrofishing, gill netting, seining, or rotary screw trapping.

The USFWS conducted Standard Fishing Method (SFM) surveys throughout the year on a significant stretch of the lower American River from December 1976 through 1980 (DeHaven 1977, 1978, 1979, 1980). Those surveys provide information about the presence and distribution of striped bass both temporally and spatially. The studies provide only limited abundance and lifestage characteristic data, however, due to bias (selectivity) inherent in the SFM methodology. In addition, inconsistent sampling due to: (1) annual closure of the upper reach of the river for salmon spawning; (2) pressure from other anglers; and (3) interference from rafters, limit result comparability from reach to reach, season to season, and year to year (DeHaven 1978).

### 2.2.6.2. POPULATION TRENDS

The AFRP production target for striped bass in the Central Valley is 2,500,000 adults, approximately double the 1967-1991 average estimated abundance of adult striped bass in the Central Valley (USFWS 1995). Abundance and goals specific to the American River are not provided by the AFRP.

Tag and recapture data have been collected on the lower American River for striped bass from 1976 through 1980. DeHaven (1977) reports, however, that one obstacle to estimating population size for the American River is that no creel census data are available from anglers. In addition, USFWS tagging and recapture efforts are potentially biased due to the use of the SFM method and also due to influences from emigration and immigration. In addition, DeHaven (1980) states that over the years he "…*gradually began to catch this species consistently in the American River…during most months of the year*." This statement implies that a change in angling success, or catch per unit effort, may have been attributable to improved technique and experience, rather than changes in fish abundance.

### 2.2.6.3. GENERAL LIFE HISTORY AND HABITAT UTILIZATION

The timing of adult striped bass spawning migration is variable. Some fish migrate upstream from September to November from San Francisco Bay to San Pablo Bay through Carquinez Strait and into Suisun and Grizzly bays. These early fish overwinter in the Sacramento-San Joaquin Delta and remain there until spring, when they disperse throughout the Sacramento River, the San Joaquin River and the Sacramento-San Joaquin Delta to spawn. Other fish overwinter in salt water and begin migrating upstream in March. After spawning, most striped bass adults return to brackish or salt water (Chadwick 1967).

Two major spawning areas and a number of minor spawning areas are used by striped bass in California. The two principle areas are in the Sacramento River between Sacramento and Colusa, and in the western Delta in the San Joaquin River between Antioch and Venice Island. Spawning begins when water temperatures exceed 60ºF and peaks between 63 and 68ºF. Spawning in the Sacramento-San Joaquin Delta and in the San Joaquin River usually precedes spawning in the Sacramento River by approximately two weeks because of lower water temperatures in the Sacramento River. In general, the spawning period may range from about mid-April to mid-June.

Adult striped bass are present in the lower American River throughout the year (DeHaven 1977), with peak abundance occurring during the summer months (DeHaven 1977, 1978, 1979 1980; CDFG 1971; Snider and McEwan 1993). Snider et al. (1998) found 17 striped bass in their rotary screw traps between October 1995 through September 1996. All of the striped bass were found in the summer period (May through August) suggesting an increase in abundance during that period. The majority of these fish caught were yearling, and the remainder were divided between YOY and subadult. A spring "run" into the river may occur from the lower Sacramento River and Delta and may be a function of cool-water habitat and an abundance of juvenile prey fish (Jones and Stokes 1998).

No studies have definitively determined whether striped bass spawn in the lower American River (CDFG 1971; CDFG 1986). However, the scarcity of sexually ripe adults among sport-caught fish indicates that minimal, if any, spawning occurs in the lower American River, and that adult fish that enter the river probably spawned elsewhere, or not at all (DeHaven 1977, 1978). The majority of Sacramento River spawning occurs in the lower Sacramento River, downstream of RM 140 (USFWS 1988).

Catch rates in the tidal reach of the lower American River reported in DeHaven (1977, 1978, 1979, 1980), seem to indicate an upstream movement of striped bass from winter and spring, to summer and fall, possibly peaking in late summer. The immigrating fish captured in the SFM surveys from 1977 through 1980 are dominated by juvenile and subadult.

DeHaven (1979) found, based on age distribution of the 1979 striped bass catch, that the large immigration of bass which occurred during the late-summer through early-fall period in 1978 was probably largely made up of the 1976 and 1977 year-classes which were hatched during the drought. In all years of the SFM surveys reviewed (1976-1980), the predominant age classes of fish caught were aged 2 and 3, but a few 13 and 14 year-old fish were also caught.

Major food items found in striped bass stomach contents by DeHaven (1977, 1978) include crayfish, unidentified ammocoete, tule perch, golden shiner, and other unidentified fishes. In DeHaven (1979), chinook salmon also made up a significant part of the striped bass diet.

### Rearing Habitat

The lower American River apparently is a nursery area for young striped bass (CDFG 1971, 1986). Numerous schools of 5 to 8-inch-long fish have been reported in the river during the summer months (CDFG 1971). In addition, juvenile and sub-adult fish have been reported to be abundant in the lower American River during the fall (DeHaven 1977).

Electrofishing conducted during a CDFG fish community survey in February through July 1992, captured 28 striped bass, 23 of which were caught in the downstream reaches of the river (near SP Bridge and H Street) (Snider and McEwan 1993). Size distribution of those captured indicates that the majority were adult (>25cm). Striped bass were not documented in CDFG's seining conducted in 1996 and 1997 (Snider et al. 1998; Snider and Titus 2000).

Optimal water temperatures for juvenile striped bass rearing range from approximately 61ºF to 71ºF (USFWS 1988). DeHaven (1977) reports that high temperatures (September averages of 72 to 79C from upper to lower reaches in lower American River) in the summer of 1977 may have caused reduced catchability, emigration from the river, or a concentration of fish in the upper reach. This behavioral observation may indicate that striped bass exhibit a preference for water temperatures below 72ºF.

### Flow Considerations

The number of striped bass entering the lower American River during the summer is believed to vary with flow levels and food production (CDFG 1986). Year-class strength of striped bass in the Delta has been correlated with survival and growth during the first 60 days after hatching (USFWS 1988). The abundance of young striped bass was, in turn, positively correlated with freshwater outflow from the Delta, and negatively correlated with the percentage of Delta inflow diverted from Delta channels during spring and early summer by the SWP and CVP (USFWS 1988). Immigrations into the lower American River were later in 1978 than in 1977, which was attributed by DeHaven (1978) to much higher flows and lower water temperatures prevailing in 1978 as compared to 1977.

Snider and Gerstung (1986) suggested that flows of 1,500 cfs at the mouth during May and June would be sufficient to maintain the striped bass fishery in the lower American River. However, these investigators reported that, in any given year, the population level of striped bass in the Delta was probably the greatest factor determining the relative number of striped bass occurring in the lower American River.

## 2.2.7. OTHER FISH SPECIES

### 2.2.7.1. BACKGROUND

One of the initial efforts to address the fish fauna, including non-salmonids, of the American River Basin was conducted by Gerstung (1971) for CDFG. Gerstung (1971) reported on the fish and wildlife resources of the American River to be affected by the Auburn Dam and Reservoir and the Folsom South Canal, including a comprehensive list of fish species occupying the lower American River.

Hanson et al. (1991) conducted an investigation of the aquatic resources and an evaluation of sampling methodologies throughout the lower American River. Day and nighttime electrofishing, beach seining, diver observations, gill netting, and fyke netting methods were used in pilot surveys. The results provide some limited information regarding the aquatic resources present during 1991. The electrofishing surveys were limited in that sampling and capture efficiency varied between species and sampling areas, but the technique was useful when used in combination with other sampling techniques to characterize the species composition and general geographic distribution. Beach seining using 50 foot seines was effective in capturing fish over a wide range of sizes. Limitations associated with the beach seine include the limits on the areas that can be sampled, variable effectiveness at different flows, net avoidance by larger individuals, and problems with snags. Diver observations could not quantify relative abundance due to influences from flow, and were not recommended for inclusion as part of the routine lower American River fisheries sampling program. The gill nets were plagued with sampling problems but were somewhat effective at capturing adult squawfish and suckers, although the incidence of damage and mortality to the fish was high.

Brown et al. (1992) conducted the first comprehensive community survey since Gerstung (1971). The survey extended from March 6 to June 19, 1991. Beach seine, electrofishing, and dip net methods were used in an attempt to sample every habitat type on a weekly basis at four sites along the lower American River: Southern Pacific Bridge, H Street Bridge, Gristmill, and Sunrise Bridge.

In 1992, CDFG continued the fish community survey of the lower American River initiated in 1991 by Brown et al. (1992). CDFG began conducting routine fish community surveys shortly after Hanson et al. (1991) and Brown et al. (1992) identified methodologies to accomplish fish surveys. CDFG surveys began in 1992, and seining results have been reported through 1997 (Snider and McEwan 1993; Snider and Keenan 1994; Snider and Titus 1996; Snider and Titus 2000; CDFG 2000). The objective of the fish community surveys was to determine trends in spatial and temporal distribution of species composition. Those reports, however, apparently express caution about the efficacy of using the fish community data to provide a basis for relative abundance comparisons due to the variable efficiency of seining.

CDFG also has conducted annual emigration surveys using rotary screw traps from 1992 to the present. However, the rotary screw trap is stationary and selectively captures downstream swimming fish in the Watt Avenue area, and thereby is not intended to provide additional information regarding habitat utilization (Snider 1992; Snider and Titus 1995; Snider et al. 1997;

Snider et al. 1998; Snider and Titus 2000; CDFG 2000). Results of the aforementioned studies form the basis of the following discussions.

### 2.2.7.2. SPECIES COMPOSITION, ABUNDANCE, AND DISTRIBUTION

#### Species Composition

The lower American River supports a rich fish fauna, but the abundance of individual species appears to be low (Brown et al. 1992). Of the 42 species that do or did occupy the river, 19 are considered numerous or common in certain portions of the stream, 9 are considered present or occasional, 14 are considered as few, uncommon or rare, and 1 is now extinct (see Table 3-1) (Gerstung 1971; Jackson 1992).

The first comprehensive list of fish species known to occur in the lower American River was compiled by Gerstung (1971). In addition to the species reported by Gerstung (1971), surveys of the fish community in the lower American River in recent years have documented the presence of fish species not previously reported.

Threespine stickleback and wakasagi were not identified by Gerstung (1971) but were found by Brown et al. (1992). Hanson et al. (1991) found crappie/sunfish and catfish not reported by Gerstung (1971) or Brown et al. (1992). Snider and McEwan (1993) found that their study's species composition corresponded well with the list presented in Gerstung (1971), although several additional species were identified including warmouth, logperch, Mississippi silverside, and river lamprey.

Of the fish species listed in Table 3-1, 22 are believed to be non-anadromous species native to the lower American River. Fall-run chinook salmon, steelhead, and splittail are of particular management importance and were discussed in previous sections.

#### Relative Abundance

Among the various surveys conducted in recent years, a few native, non-salmonid species have been most abundant including Sacramento sucker, Sacramento pikeminnow, and sculpins (prickly and riffle). Brown et al. (1992) reported that these three species (with sculpins considered to be one species) were collected in more than 10% of the samples. Sculpins subsequently identified by Brown et al. (1992) were found to be dominated by prickly sculpins, indicating that they were the predominant species. The percentage of the total number of fish caught during the intensive fish surveys represented by native species is presented in **Table 2-22**.

Hanson et al. (1991), electrofishing the lower American River in mid April and mid May 1971, found 17 fish species, the most abundant non-salmonid native fish species being the Sacramento sucker, Sacramento pikeminnow, and the tule perch.

Twenty-eight different fish species were represented in the 1992 seining and electrofishing surveys reported by Snider and McEwan (1993). Sacramento sucker was the most abundant species, followed in abundance by tule perch and Sacramento pikeminnow. In the CDFG fish community surveys conducted using seines, Sacramento sucker, Sacramento pikeminnow and sculpins generally dominated the catch, followed in abundance by tule perch and hardhead (Snider and Keenan 1994; Snider and Titus 1996; CDFG memorandum, Titus 1994a). Hardhead and pacific lamprey are frequently captured in the CDFG emigration surveys using rotary screw traps.

**Table 2-22. Relative abundance of native fish species captured during intensive fish surveys from March 6 through June 19, 1991 (from Brown et al. 1992).**

| Species (common name) | Percent of all fish captured |
|---|---|
| Sacramento sucker | 44.5 |
| Sacramento pikeminnow | 6.4 |
| tule perch | 2.4 |
| sculpins (prickly and riffle0 | 2.3 |
| Pacific lamprey | 1.6 |
| hardhead | <0.1 |
| hitch | <0.1 |
| threespine stickleback | <0.1 |

## Distribution

### Temporal Distribution

Snider and Keenan (1994) and Snider and Titus (1996) found that three native fish species were collected in every month of the study period (January through June): chinook salmon, Sacramento pikeminnow, and Sacramento sucker.

Snider and McEwan (1993) captured juvenile, subadult, and adult Sacramento pikeminnow every month with juvenile numbers gradually increasing between February and July, and subadult numbers increasing substantially beginning in May. Young-of-the-year pikeminnow appeared in the catch starting in June. Snider and Titus (1996) found that juvenile-sized fish were relatively abundant in seine catches in January (214 fish) and June (1,126 fish), with only 17 or fewer fish caught during the intervening months. Adult pikeminnow were only collected during January and June. Catches of pikeminnow exceeding 1,000 fish per hectare occurred only during short periods in April and June (Brown et al. 1992).

Brown et al. (1992) reported that the abundance of Sacramento sucker increased, and the average length decreased from March 6 to June 19, 1991. Beginning May 20, fish abundance exceeded 1,000 fish per hectare through the end of the study at the Gristmill and H Street locations. By May 27, high catches were observed at the downstream location (SP Bridge), although high catches were not observed upstream (Sunrise) until June 10. Larval suckers were captured as early as April 1, primarily at the SP Bridge location, and young-of-the-year first appeared May 6. A few spawning adults were present throughout the study period.

Snider and Titus (1996) reported high juvenile Sacramento sucker catches in January and June, with substantially fewer suckers reported in intervening months. The abundance of juvenile suckers, increased throughout the study period. Young-of-the-year initially occurred in the catch in April, and were relatively abundant through July. Adult suckers were collected during every month but June.

Sculpins showed little variability in abundance through the sampling period March 6 to June 19, 1991 (Brown et al.1992). Sculpin egg masses were sporadically captured along with fish during April and May indicating the presence of spawning.

In Brown et al. (1992), larval hardhead were first found in late May. Hardhead were captured as early as November in CDFG emigration surveys using rotary screw traps (Snider et al. 1997; Snider and Titus 2000).

Pacific lamprey ammocoetes and subadults were periodically collected from late November 1993 through early July during the 1993/94 emigration survey (Snider and Titus 1995). Subadults exhibited peak abundance during late may, and the peak catch of adults occurred during late April. In the 1994/95 survey, ammocoetes appeared in the trap nearly every week from November 1994 through September 15, 1995, with peaks at the end of February and middle of May. In 1995/96, ammocoete lamprey appear first in October 1995, with peaks in April 1996. In 1996/97, ammocoete lamprey first appeared in October 1996 and continued to be present until mid-June 1997, with peak catch occurring during mid-February 1997 (Snider et al. 1997; Snider et al. 1998; Snider and Titus 2000).

### Spatial Distribution

Surveys conducted in the lower American River indicate that, in general, species richness increases in a downstream direction, although the relative abundance of the most common species is highest in upstream locations. Brown et al. (1992) found that the most species (20) were captured in seine surveys at the lowermost (SP Bridge) site, and the fewest species (11) were captured at the uppermost (Sunrise) site. CDFG fish community survey results generally confirm those reported by Brown et al. (1992) regarding the general longitudinal distribution in that species richness decreased moving upstream, while relative abundance of the more common species appeared to increase moving upstream. For example, Snider and McEwan (1993) reported that the greatest species richness occurred in the SP Bridge reach (27 species), followed by the H Street (23 species), Gristmill (22 species) and Sunrise (13 species) reaches. According to Snider and McEwan (1993), the largest catches were made in the Sunrise reach consisting primarily of chinook salmon, sucker, pikeminnow, and steelhead.

Brown et al. (1992) found that Sacramento pikeminnow were usually most abundant at the uppermost (Sunrise) site, and did not exhibit preference for any particular habitat at that site. At the H Street site, bar complex pools yielded the highest catches, whereas flatwater pools yielded the highest catches at the Gristmill site (Brown et al. 1992).

Hanson et al. (1991) found that Sacramento pikeminnow were present at all sampling locations, although the greatest numbers were collected at the Fair Oaks-Sunrise area and the Business 80 locations. They were found in greatest numbers within the Sunrise flatwater glide, and within the Business 80 flatwater pool habitats.

Snider and McEwan (1993) found that juvenile and subadult pikeminnow consistently appeared in every reach throughout the study, although relative abundance varied substantially between reaches. Adjusted density (catch/hectare) ranged from zero in the SP Bridge reach (March) and the Sunrise reach (March, April, and may) to 2,530 fish/hectare in the H Street reach in June. Snider and McEwan (1993) reported that juvenile and subadult pikeminnow abundance increased in the slower habitats throughout the season. They noted that the catches in glide and backwater habitats increased coincidentally with increases in flow, and speculated this could be due to fish concentrating in the slower habitat types, or it could reflect differences in capture efficiency between habitat types.

Sacramento sucker spawning activity was observed at the head of riffles in both April and May at Sunrise and Gristmill sites (Brown et al. 1992). Suckers did not seem to consistently favor any particular habitat type, but were found wherever there was slow-moving water. At Gristmill, the number of large catches decreased from bar complex run (5), to bar complex riffle (4), to flatwater glide (3), to flatwater pool (2). At the Sunrise site, flatwater glide was clearly a favored habitat with 11 of the largest catches.

Snider and McEwan (1993) found that suckers generally appeared in every reach. Juvenile suckers appeared evenly distributed in all habitat types. Young-of-year suckers first appeared in the slow water habitat types, predominantly pools and backwaters, but distributed to the other habitats, including riffles, after peak abundance in May.

Sculpins (prickly and riffle) were found to more commonly occur, and to be more abundant, at upstream sites rather than downstream sites (Brown et al. 1992). High densities of sculpins in upstream areas were primarily due to large numbers of sculpins collected in riffle habitats. Sculpins were found to be positively correlated with larger substrate and high water velocities, and negatively correlated with average water depth and temperature. When riffle habitat was available at a general sampling location, it was always the habitat yielding the highest catches (Brown et al. 1992).

# 3.0 HYDROLOGY: RIVER FLOWS AND WATER TEMPERATURES

## 3.1. HISTORIC OVERVIEW

### 3.1.1. ANNUAL HYDROLOGY

Historically, the greater Sacramento River Basin has experienced highly variable annual water availabilities and associated river flows. Distinct periods of water availability, categorized by water-year type, represent in-basin water conditions ranging from "critical" to "wet". The periodicity of wet and dry periods for the Sacramento River Basin appears to approximate 14 years.

The American River is the second largest tributary to the Sacramento River, with a mean annual runoff of 2.7 million acre-feet. Total storage in the numerous reservoirs within the American River Basin represents 75% of the mean annual runoff, or about 2.2 million acre-feet. Folsom Reservoir, with a capacity of about 974,000 acre-feet, represents the largest impoundment on the American River. Since its construction in 1955, Folsom Dam and Reservoir has changed the hydrologic regime in the lower American River.

Folsom Reservoir provides flood control functions and water storage. It captures runoff during the winter rainy season and throughout the spring precipitation-snowmelt period. The resulting river flows in the lower American River have not been as extreme, on the average, as they were prior to construction of the dam (i.e., before February 1955). Mean monthly averages of pre- and post-1955 streamflows in the lower American River (measured at the Fair Oaks U.S. Geological Survey stream gage) are illustrated in **Figure 3-1**.

As shown in Figure 3-1, the post-1955 seasonal flow regime has produced higher flows during the early-July to February period, relative to the pre-1955 flow regime. Alternatively, it has generated reduced flows during the February through June period, relative to the pre-1955 flow regime. From these historically averaged mean monthly flow patterns, it is evident that through the construction of Folsom and Nimbus dams, the distribution of flows over the entire year has been altered, relative to the unimpaired flow regime (i.e., pre-Folsom Dam condition).

**Appendix D** shows annual mean daily flows for the lower American River (measured at the Fair Oaks gauge) in 10-year increments from 1904 through 1998. These hydrographs exhibit the seasonal and annual variability of the American River. In general, the hydrographs reveal that peak flows occur during the winter or early-spring months, corresponding to the rainy season and snowmelt period for the American River watershed. The magnitude of peak flows also varies and is dependent upon precipitation pattern and extent, duration, intensity, basin antecedent moisture, and snowpack characteristics. The recession limbs decrease rapidly with the onset of summer.

**Figure 3-1. Historic periods of mean monthly American River flows at Fair Oaks.**

### 3.1.2. SEASONAL HYDROLOGY

As shown in Appendix D, although representative of only two years of data (1954 and 1955), illustrates both the variability that can occur within a year, and the influence of Folsom Dam and Reservoir on downstream flows. For example, in 1954 the peak flow event occurred in early March and approximated 36,000 cfs. The peak flow event was preceded during that year by two earlier storm events as illustrated by the smaller distinct hydrograph peaks. During the remainder of the spring and early summer months, the hydrograph exhibits elevated flows that gradually diminish along the recession limb, reaching baseflow conditions by July. During this period, two distinct storm events (i.e., hydrograph peaks) are noticeable. Watershed snowmelt coupled with rainstorms likely contributed to this portion of the hydrograph. The 1955 hydrograph, by comparison, is distinguishable by its lack of a defined annual flow peak. Initial storage of water in Folsom Reservoir occurred in 1955. Moreover, 1955 was relatively dry, small rain events occurred over the winter, and snowpack accumulations in the upper watershed did not provide significant runoff.

## 3.2. FACTORS CURRENTLY AFFECTING FLOW AND WATER TEMPERATURE

Flow in the lower American River results from the complex interaction between hydrologic conditions, operational constraints, and decisions and actions to protect environmental resources. This section of the *Baseline Report* describes the framework within which these decisions about flows in the American River and other streams are made. The process's complexity and time sensitive nature must be emphasized. Although annual operations plans are developed for the Central Valley project, which includes Folsom Dam and Reservoir, daily operations (and flows) may be dramatically affected by measures to protect endangered and threatened fish. The 2001 initiation of CALFED's Environmental Water Account (EWA) will likely increase uncertainty in daily operations and, therefore, the ability to provide stable (and predictable) flows in the lower American River.

Integrated operation of the Central Valley project and State Water Project influence flows in the lower American River. The Central Valley Project (CVP) is the largest surface water storage and delivery system in the state, with a geographic scope covering 35 of California's 58 counties. The State Water Project (SWP) includes facilities to capture and store water north of the Delta, on the Feather River, and to deliver water to service areas in the Feather River Basin, the San Francisco Bay area, the San Joaquin Valley's Tulare Basin, and southern California.

### 3.2.1. CENTRAL VALLEY PROJECT (CVP) FACILITIES

The CVP includes 20 reservoirs, with a combined storage capacity of approximately 11 million acre-feet; 8 powerplants and 2 pumping-generating plants, with a combined capacity of approximately 2 million kilowatts; 2 pumping plants; and approximately 500 miles of major canals and aqueducts.

Organizationally, a variety of divisions and units manages and operates CVP facilities. The nine divisions of the CVP include: (1) American River Division; (2) Delta Division; (3) East Side

Division; (4) Friant Division; (5) Sacramento River Division; (6) San Felipe Division; (7) Shasta Division; (8) Trinity River Division; and (9) West San Joaquin Division. Most of the distribution and drainage systems constructed by Reclamation, however, have been transferred to the local irrigation and water districts for operation and maintenance (O&M), including some small storage reservoirs and pumping plants.

CVP facilities can also be grouped into two systems. The Northern CVP System comprises the CVP divisions north of the Delta including the Trinity, Shasta, Sacramento River, and American River divisions. Facilities in CVP divisions south of the Delta include the Delta, West San Joaquin, and San Felipe Divisions, and are collectively known as the Southern CVP System. Both the East Side and Friant divisions are operated independently of the remainder of the CVP due to the nature of their water supplies and service areas.

Facilities are operated and maintained by local field offices, with operations overseen by the Central Valley Operations Coordinating Office (CVOCO) in Sacramento. The CVOCO is responsible for recommending CVP operating policy, developing annual operating plans, coordinating CVP operations with the SWP and other entities, establishing CVP-wide standards and procedures, and making day-to-day operating decisions.

### 3.2.2. STATE WATER PROJECT (SWP) FACILITIES

The SWP operates four reservoirs in the Feather River Basin. Three relatively small reservoirs in the upper Feather River Basin in Plumas County include Lake Davis, Frenchman Lake, and Antelope Lake. These reservoirs are operated for recreational, fish and wildlife, and local water supply purposes. The SWP also operates Lake Oroville, the second largest reservoir in California with a storage capacity of approximately 3.5 million acre-feet. Lake Oroville is used to conserve and regulate the flows of the Feather River for subsequent release to the Delta.

In the Delta, the North Bay Aqueduct, completed in mid-1980s, diverts water from the north Delta near Cache Slough. Ending at the Napa Turnout Reservoir in southern Napa County, the aqueduct conveys water for SWP entitlements and provides conveyance capacity for the City of Vallejo. It also serves various agricultural and municipal service areas in Napa and Solano counties, including Solano Irrigation District, and the cities of Fairfield and Vallejo. In the southern portion of the Delta, the Banks Delta Pumping Plant lifts water into the California Aqueduct from the Clifton Court Forebay. The California Aqueduct is the state's largest and longest water conveyance system, beginning at the Banks Delta Pumping Plant and extending to Lake Perris, south of Riverside in southern California.

### 3.2.3. CENTRAL VALLEY PROJECT OPERATIONS

Decisions related to the operation of the CVP consider a diverse range of project-wide, regional, and site-specific factors. In formulating operational decisions, criteria related to reservoir operations, downstream hydrologic and environmental conditions, and water rights in the Delta must be evaluated.

#### 3.2.3.1. RESERVOIR OPERATING CRITERIA

Factors that influence the operation of CVP reservoirs include inflow, release requirements for fisheries, flood control requirements, carryover storage objectives, water-related recreational activities, power production capabilities, coldwater reserves, and pumping costs. Operational decisions must balance conditions not only a specific reservoir, but also conditions at other project reservoirs. The possibility of using multiple water sources to meet certain requirements provides operational flexibility and yet, at the same time, adds complexity to operational decision-making. For example, storage space south of the Delta that can only be filled with water exported from the Delta is a major operational consideration involving the geographic distribution of water in storage.

##### Flood Control

The Corps is responsible for determining flood control operational requirements at most CVP reservoirs. If CVP reservoir storage exceeds Corps requirements, water must be released as defined in the Corps' flood control manuals. These manuals require lower reservoir storage levels in the fall in anticipation of winter rains and snowmelt runoff from higher elevations. To avoid excess releases at the end of the summer, Reclamation often schedules releases in excess of minimum flow requirements over the course of the summer. This practice generally results in end-of-water-year reservoir storage levels at, or below flood control thresholds (i.e., defined by flood control diagrams) so that empty space is made available to regulate reservoir inflows.

##### Carryover Storage

CVP reservoirs are operated in consideration of the need to protect future water supplies in the event of dry conditions. Carryover storage at the end of September forms an initial basis for the following year's operating conditions and is an integral part of the process of allocating CVP water supplies. Carryover objectives consider a variety of factors including but not limited to flood protection, dam safety criteria, existing water demands, forecasted water supply availability, volume of coldwater the reservoirs, power production requirements, and drought risk.

##### Recreation

CVP reservoirs provide optimal recreational activities including water-related activities when full, or nearly full. CVP operations attempt to achieve reservoir levels during the prime recreation seasons (i.e., Memorial Day weekend through Labor Day) that receive maximum number of recreational users.

##### Coldwater Reserves

Release of coldwater from project reservoirs may be needed to protect fish spawning and rearing in the streams below the reservoirs. The volume of coldwater in individual reservoirs varies with the time of year, geographic location, water depth, and degree and strength of temperature stratification. Temperature stratification is more common and persistent in large reservoirs than in smaller reservoirs. Stratification typically occurs in the summer and fall, being generally absent in winter and spring. CVP operations attempt to preserve coldwater pools in Trinity Dam and Trinity Reservoir, as well as Shasta and Folsom reservoirs, to benefit downstream fish resources notably chinook salmon and steelhead in the Trinity, Sacramento, and American rivers.

#### Power Production

To maximize the opportunity for power production, reservoir storage levels should be at the highest levels allowable to make best use of hydraulic head. Although energy production increases during end-of-summer releases to achieve empty space flood storage targets, electrical capacity is reduced due to decreasing hydraulic head. For most efficient energy purposes, releases should not exceed the capacities of CVP powerplants. Operators attempt to pass all reservoir releases through the powerplants, however such releases often exceed powerplant capacities during flood operations.

### 3.2.3.2. STREAMFLOW CRITERIA

Flow criteria below reservoirs to protect fish resources and to protect against the impacts of high flows on channels, levees and areas subject to flooding. Federal law (the Defense Appropriation Act of 1993 and the Water Resources Development Act of 1999) requires that the Corps and USBR use improved weather forecasting capability to help ensure that reservoir releases are made in anticipation of incoming flows to CVP reservoirs.

Instream flow requirements are also established and maintained as part of specific in-river thresholds for certain rivers and are discussed later.

#### Fish Resources

River reaches below CVP-operated dams commonly support resident and anadromous fish communities. While resident fish are affected by reservoir release fluctuations, the anadromous fish (e.g., chinook salmon and steelhead) are usually more sensitive to such fluctuations. Maintaining favorable water conditions in these river reaches for protected species is a major CVP operational requirement.

CVP operators attempt to establish and maintain reservoir releases to sustain spawning and incubation of salmonids and other fish.. Reduced releases can dewater spawning redds and strand rearing juveniles. Additionally, if initial releases are too low, subsequent large flow increases may cause channel scour and loss of redds. CVP operations are coordinated to best anticipate and minimize extreme flow fluctuations during spawning and incubation.

Following hatching and rearing, emigrating juveniles can be assisted by increased releases from both CVP and non-CVP reservoirs. The USBR coordinates reservoir operation with CDFG and USFWS to schedule releases that generate “pulse” flows to assist downstream fish migration. These pulse flows may also help reduce predation and minimize entrainment at the Delta pumping plants.

#### Coldwater Pool Conservation

In 1990 the SWRCB established water temperature criteria for the Sacramento River between Keswick Dam and the Red Bluff Diversion Dam. The Regional Water Quality Control Board (RWQCB) set water temperature criteria between Lewiston Dam and the confluence of the North Fork of the Trinity River. Coldwater conservation in reservoirs is particularly important during water-short years. During these times, water temperatures in the reservoirs become higher as reservoir storage levels decrease and surface waters warm. Flows below the reservoirs become lower as reservoir releases drop and, depending on the time of the year, stream water temperature can increase

In 1993, NMFS issued a long-term Biological Opinion on the winter-run chinook salmon. The opinion includes flow and water temperature requirements in the Sacramento River below Keswick Dam. Typically, CVP operations meet the Sacramento River temperature criteria by releasing a combination of coldwater from Shasta and Whiskeytown reservoirs.

#### Flood Control

CVP reservoir releases for flood control consider public safety, including concerns for downstream levee stability. Flood control releases are typically accomplished through a series of stepped increases defined by such factors as powerplant capacity, potential for minor flooding. bank erosion, and channel hydraulic capacity. Flood releases are targeted at the lowest levels that satisfy requirements for increasing available storage, while minimizing downstream impacts. After the flood threat passes, reservoir releases are reduced according to Corps guidelines.

### 3.2.3.3. Regulatory Obligations and Agreements

The CVP has been historically managed and operated under several regulatory obligations and agreements. Prior to the passage of the CVPIA in 1992, SWRCB Decisions 1422 and 1485, and the Coordinated Operations Agreement (COA) were the primary guidelines for the manner with which the CVP was operated. Since the passage of the CVPIA, several additional initiatives have been implemented within the CVP. The various regulatory obligations and agreements affecting CVP operation are described below.

#### SWRCB Decision 1422

SWRCB Decision 1422 comprises the original Board Decision in 1973 along with an associated Board Order (SWRCB Order 83-3) issued in 1983. Under this decision, operational criteria for New Melones Reservoir were identified together with provisions for water quality conditions on the San Joaquin River at Vernalis. Additionally, D-1422 allowed USBR to appropriate water in New Melones Reservoir for purposes of irrigation, municipal and industrial uses, fish and wildlife enhancement, flood control, and maintenance of water quality conditions on the Stanislaus River.

#### SWRCB Decision 1485

SWRCB Decision 1485 was adopted in 1978 to protect beneficial uses in the Delta and delineate responsibilities for the two primary exporters from the Delta the CVP and SWP.

#### Coordinated Operations Agreement (COA)

The Coordinated Operations Agreement (COA) describes CVP and SWP responsibilities for meeting D-1485 requirements. Details of the COA are provided below under Section 3.2.6.1, Integrated Systems Operations (Coordinated Operations Agreement (COA)).

### Winter-Run Chinook Salmon Biological Opinion

In 1992 NMFS issued a one-year Biological Opinion containing conditions necessary to avoid jeopardy to the Sacramento River winter-run chinook salmon by CVP/SWP operation. In 1993 NMFS issued a long-term biological opinion for this same species to address modifications to the long-term CVP operational plan and SWP operations.

Under this biological opinion, from October 1 through March 31 Reclamation is required to maintain a minimum flow of 3,250 cfs in the Sacramento River below Keswick Dam. This minimum flow provides safe rearing and downstream migration of the winter-run chinook salmon and helps avoid juvenile stranding. During droughts, NMFS must reconsider these minimum flows on a case-by-case basis in light of human health and safety concerns.

Additionally, under this biological opinion, from late June through mid August, USBR attempts to maintain daily average water temperatures in the Sacramento River at no more than 56°F from Keswick Dam to above Red Bluff (i.e., within the winter-run chinook salmon spawning grounds). Operational and environmental conditions vary and the precise river location and timing of this temperature requirement is calculated by USBR.

The biological opinion requires that the gates at the Red Bluff Diversion Dam be open from September 15 through May 14. Consequently, diversions to the Tehama-Colusa Canal during this time would be reduced. In 1996, however, the SWRCB issued a water rights order requiring the release of up to 38,293 acre-feet annually from Black Butte Reservoir for rediversion through the constant head orifice to the Tehama-Colusa Canal during the periods April to May 15 and from September 15 to October 29.

In the Delta, the biological opinion USBR requires that the Delta Cross Channel (DCC) gates be closed position from February 1 through April 30 to reduce the number of emigrating juvenile winter-run chinook salmon that enter the interior channels. The opinion also includes provisions to limit the number of winter-run chinook taken at the federal and State project intakes in the south Delta. Finally, the opinion provided QWEST (calculated flow towards project pumps) standards.

### Bay-Delta Plan Accord and Water Quality Control Plan

In December 1994, agency and stakeholder representatives signed the Bay-Delta Plan Accord (Delta Accord) was to provide interim water and operational conditions that would remain in place while those and other parties worked towards a long term agreement. The Delta Accord provided for the CVP and SWP to meet the water quality goals in the Bay-Delta.

The SWRCB subsequently adopted the parts of the Delta Accord in their 1995 Draft Water Quality Control Plan (Plan). The Plan includes water quality goals and associated beneficial use objectives and water quality requirements for the Sacramento, Stanislaus, and San Joaquin rivers. The Plan also includes water quality objectives for the reasonable protection of municipal and industrial uses from salinity intrusion. These objectives are year-type based maximum chloride concentration standards for various compliance locations within the Delta.

Fish and wildlife water quality objectives include those for dissolved oxygen, salinity, Delta outflow, river flows, export limits, and Delta Cross Channel gate operation. Delta outflow objectives are for the protection of estuarine habitat for anadromous fish and other estuarine-dependent species. Sacramento and San Joaquin river flow objectives provide attraction and transport flows and suitable instream habitats for various lifestages of aquatic species including delta smelt and chinook salmon.

NMFS issued an amendment to the long-term winter run chinook salmon biological opinion following release of the Plan in 1995. The QWEST requirements in the NMFS biological opinion were converted to export/inflow ratios to give equivalent protection for winter-run chinook salmon.

### Delta Smelt Biological Opinion

With the signing of the Principles for Agreement for the Bay-Delta Plan, the USFWS agreed to initiate immediate reconsultation on the biological opinion it had issued on February 4, 1994. The original opinion addressed the effects of the combined operations of the CVP and SWP on delta smelt for the period February 15, 1994, through February 15, 1995. In that opinion, the USFWS had concluded that the proposed operations of the CVP and SWP would result in jeopardy, therefore, Reasonable and Prudent Alternatives (RPAs) were included in the opinion consisting of specific operational criteria that the CVP and SWP would implement.

On March 6, 1995, the USFWS issued a revised biological opinion for delta smelt. This opinion concludes that proposed long-term combined CVP and SWP operations, as modified by the winter-run chinook salmon biological opinion, the Principles for Agreement, and the Bay-Delta Plan (draft at the time), are not likely to jeopardize the continued existence of the delta smelt or adversely modify its critical habitat. The opinion identifies the water quality standards along with the operational constraints that are to benefit delta smelt.

### Central Valley Project Improvement Act (CVPIA)

On October 30, 1992, Congress passed the Central Valley Project Improvement Act (CVPIA) (Public Law 102-575, Title XXXIV). This statute effectively reauthorized the CVP for a wider range of beneficial uses and interests than originally mandated and that fish and wildlife protection is a project purposes equal with irrigation, power generation, municipal and agricultural water uses. The CVPIA is to address past CVP impacts on fish, wildlife, and associated habitats and to protect, restore, and enhance these resources in both the Central Valley and Trinity River basins. The numerous initiatives under the CVPIA have the ultimate purpose of shifting the current balance among the many competing interests for CVP water.

The CVPIA contains numerous sections and provisions to help improve fish and wildlife and their habitat adversely impacted by construction and operation of the Central Valley Project. Two of these, sections 3406(b)(1), the Anadromous Fish Restoration Program, and 3406(b)(2), specific dedication of CVP yield for fish, wildlife and habitat restoration, are of particular importance to restoration of environmental resources in the lower American River.

#### Anadromous Fish Restoration Program (AFRP)

The goal of the AFRP is to double the natural production of five anadromous species of fish – steelhead, chinook salmon, American shad, striped bass and sturgeon. The doubling is based on average levels of these fish attained during the period 1967 through 1991. Doubling is to be achieved by several methods including obtaining and maintaining life-stage appropriate instream flows, habitat improvements and eliminating or reducing losses through water diversions. Reduction in diversion losses is accomplished through a companion Anadromous Fish Screen Program. The CVPIA provides that extensive monitoring be conducted through a Comprehensive Assessment and Monitoring Program to help determine if AFRP goals are being achieved.

**Dedication of CVPIA yield to Fish and Wildlife**

Section 3406(b)(2) of the CVPIA directs the Secretary of the Interior to:

> "*…dedicate and manage annually 800,000 acre-feet of Central Valley Project Yield for the primary purpose of implementing the fish, wildlife, and habitat restoration purposes and measures authorized by this Title; to assist the State of California in its efforts to protect the waters of the San Francisco Bay/Sacramento-San Joaquin Delta Estuary; and to help to meet such obligations as may be legally imposed upon the Central Valley Project under State or Federal law following the date of enactment of this Title, including but not limited to additional obligations under the Federal Endangered Species Act…*"

Project Yield is defined as the average annual delivery capability of the CVP during the drought period of 1928 through 1934 as it would have been with all facilities and requirements on the date of CVPIA enactment. Furthermore, Section 3406(b)(2) provides that this dedicated quantity be managed pursuant to conditions specified by the USFWS after consultation with USBR and DWR in cooperation with CDFG.

Interpretation of Section 3406(b)(2), specifically, how the 800,000 acre feet may be used and how it should be accounted for has engendered lengthy agency, stakeholder and public debate. In addition, some provisions in the U.S. Department of Interior's (DOI) November 20, 1997 final Administrative Proposal for the Management of Section 3406(b)(2) Water were challenged in federal court. In April 1999, the Court directed DOI to provide an accounting of the compliance with 3406(b)(2) for the period March 1, 1999 through February 28, 2000.

In response to the Court order and comments from the affected community, USBR has calculated CVP yield and allocated the yield by basin. The USFWS has developed a list of actions contributing to the CVPIA goal of doubling production of the targeted anadromous fish. Among these actions is improving flow conditions on several streams, including the lower American River.

### CALFED Bay Delta Program (CALFED)

Representatives of state and federal governments along with urban, agricultural, and environmental interests have participated in the development of the CALFED Bay Delta Program. The program is intended to develop a comprehensive long-term plan designed to restore the ecological health of the Bay Delta and improve water management practices for its many beneficial uses. State and federal agencies holding management and regulatory authority in the Bay Delta provide the necessary policy and oversight direction within the CALFED process. The Framework Agreement, signed in June 1994, establishes the cooperative roles of these state and federal agencies. Three primary areas of focus within the CALFED process include water quality standards, coordination of CVP/SWP operations, and development of long-term solutions to the Bay Delta.

There are several CALFED components that can potentially affect flows in the lower American River. Three of them, the State Federal Water Operations Management Team and associated teams and activities, the Environmental Water Account, and the Environmental Water Program are of particular importance.

The state/federal Water Operations Management Team (WOMT) , the CALFED OPS Group and its associated Data Assessment Team (DAT), No Name Group, and Real-Time monitoring are increasingly involved in making day to day operational decisions. Starting at the data level, a near real time monitoring program collects data on fish abundance and distribution to biologists and operators on the DAT. Although the team focuses on data from the April 1 through June 30 period, timely data also are important from October 1 through the end of March. Team members hold periodic conference calls to determine if fish are becoming susceptible to project operations and to look at operations forecasts. If it appears that proposed operations pose danger to listed species, DAT may request operational changes. Time permitting, requests for significant changes in project operation are brought to CALFED OPS consisting of operators, biologists, and mid-level agency managers and stakeholders for consideration. If agreement can be reached, the changes are made. If CALFED OPS cannot reach agreement, the decision may be forwarded to Agency managers in the Water Management Operations Group for resolution. The No-name Group, which includes operators and stakeholders, provides a forum for stakeholders to express any concerns. When it appears that there are serious fish, water quality or operational concerns, the deliberations may include a series of conference calls and face-to-face meetings. Actions may include changing reservoir releases, Delta flows and Delta pumping.

CALFED is activating the Environmental Water Account (EWA) in the 2001 water year. Under this process, water will be banked and withdrawn as needed to protect environmental resources. Banking may occur as a result of water purchases or project operations resulting in environmental benefits. Review of the results of this first year will provide a better assessment of how the managing the account affects SWP and CVP reservoir and pumping operations.

CALFED's Environmental Water Program is part of its Ecosystem Restoration Program, it also in its initial stages. In this program, water is purchased from willing sellers for environmental enhancement and these purchases are separate from the EWA. Operation of this account can affect stream flows, because the purchased waters are stored and moved through the reservoirs and rivers.

Finally, the resource agencies conditioned approval of CALFED's environmental documents on their ability to achieve protection of listed and sensitive species though meeting several milestones. Meeting these milestones can affect operations, and thus streamflows, below federal and State project reservoirs. The effects of these requirements will not be known for a few years.

### SWRCB Decision 1641

Over the years, the State Water Resources Control Board has issued several decisions affecting water quality and water rights for the Sacramento-San Joaquin estuary. As part of its continuing responsibility to protect beneficial uses in the Delta and Bay, the SWRCB adopted Decision 1641 (D1641) on December 29, 1999 and a revised D1641 on March 15, 2000. The decision and its revision are to allocate flow and operations-related obligations under the 1995 Water Quality Control Plan and are based on more than two months of testimony before the SWRCB and its staff.

With respect to flows in the lower American River, D1641 continues USBR's interim obligation to meet certain flow standards. The Decision also approves, subject to terms and conditions, the DWR/USBR petition for changing points of diversion in the Delta, the USBR petition for change in places and purposes of use for the CVP and, finally, the San Joaquin River Agreement. The San Joaquin River Agreement obligates the USBR and DWR to meet the San Joaquin River's portion of Delta outflow requirements. As part of the CVP, operation of Folsom Dam and Reservoir (and downstream flows) may be modified to meet D1641 flow and operational requirements.

### 3.2.4. STATE WATER PROJECT OPERATIONS

SWP operations are primarily affected by SWRCB D-1485 and instream flow requirements on the Feather River, pumping limitations imposed on the Banks Pumping Plant, Delta smelt and winter-run chinook salmon biological opinions, and CALFED OPS related activities previously described for CVP operations. SWP operations are covered in the opinions through a Section 7 nexus as part of USBR's formal consultation with NMFS and the USFWS.

DWR is presently beginning a process to relicense the Oroville Complex with the Federal Energy Regulatory Commission. This collaborative process has the potential to change reservoir operations. The formal application will be submitted in 2005 in time to obtain a new license in 2007.

#### 3.2.4.1. FEATHER RIVER MINIMUM INSTREAM FLOWS

Minimum fish flow requirements in the Feather River are maintained consistent with a 1993 agreement between the DWR and CDFG. This agreement sets minimum flows in normal years at 1,700 cfs from October through March, and 1,000 cfs from April through September. Lower minimum flows are assigned during dry and critically dry years. Finally, a maximum flow restriction of 2,500 cfs is maintained per the agreement during October and November.

#### 3.2.4.2. LIMITS AT BANKS PUMPING PLANT

The Banks Pumping Plant is operated to meet demands south of the Delta. Pumping capacity at the plant is set at 6,680 cfs during the months of October, November, April, August, and September. Depending on flow in the San Joaquin River at Vernalis, consistent with the Corps' Public Notice criteria dated October 13, 1981, pumping may be increased above the 6,680 cfs. In the spring, pumping is restricted to meet flow and export conditions called for in the Vernalis Adaptive Management Plan.

#### 3.2.4.3. SWP CONTRACTOR DELIVERY ALLOCATIONS

SWP contractors have a total of 4.23 million acre-feet of water per year allocated for delivery in the San Joaquin, Central Coast, San Francisco Bay, and South Coast regions. Approximately 2.5 million acre-feet per year of this amount is designated for the Southern California Transfer Area, nearly 1.36 million acre-feet per year to the San Joaquin Valley, and the remaining 370,000 acre-feet per year to the San Francisco Bay and Central Coast regions, and the Feather River service area.

SWP deliveries are based on criteria established in the Monterey Agreement, which imposes deficiency levels on an equal basis to all SWP contractors (i.e., agricultural and M&I contractors). Generally, the allocation of water supplies for any given year is based on the following variables:

1. forecasted water supplies based on the Sacramento River Index;
2. the amount of carryover storage in Oroville Reservoir and San Luis Reservoir;
3. projected requirement for end-of-year carryover storage; and
4. SWP system delivery capability.

It should be emphasized that conditions as part of the Delta Accord, the Water Quality Control Plan, biological opinions, and climatic conditions and actual demand have resulted in less water being delivered than allocated.

#### 3.2.4.4. FEATHER RIVER SETTLEMENT CONTRACTOR DELIVERY ALLOCATIONS

The Feather River Settlement Contractors are water users who held riparian and senior appropriative rights on the Feather River. The State of California entered into contractual agreements with these existing water rights holders (e.g., water rights settlements) as the SWP was constructed. Most of these agreements establish the water quantities these contractors are permitted to divert under their senior water rights and identify the supplemental SWP supply allocated by the State.

### 3.2.5. INTEGRATED SYSTEM OPERATIONS

Both the CVP and SWP use the Sacramento River and the Delta as common conveyance facilities. Reservoir releases and Delta exports must be coordinated to ensure that each of the projects retains its portion of the shared water and bears its share of joint obligations to protect beneficial uses.

#### 3.2.5.1. COORDINATED OPERATIONS AGREEMENT (COA)

The Coordinated Operations Agreement (COA) between the United States of America (USBR) and the State of California became effective in November 1986. The agreement defines the rights and responsibilities of the CVP and the SWP regarding Sacramento Valley and Delta water needs and provides a mechanism to measure and account for those responsibilities. The COA includes a provision for its periodic review.

The COA has been the mechanism by which the CVP and SWP coordinate operations to meet Delta standards as defined by SWRCB Water Quality Control Plans. The existing COA was adopted in 1986 to implement standards defined by the SWRCB D-1485 standards, which were adopted in 1978. The COA includes many provisions concerning the joint operations of the Delta including methods to ensure that water demands in specific areas other than the Delta and in the Delta are met prior to exporting water to areas south of the Delta. In addition, the provisions include formulas to define how much water the CVP and the SWP can export when the Delta conditions allow exports. As the Bay-Delta planning processes proceeds, portions of the COA will need to be reinterpreted to incorporate new standards.

The COA provides rules for the CVP and the SWP to store water in the Sacramento Valley and to export water from the Delta. The COA also defines responsibility for meeting Delta standards and provides a mechanism for defining the responsibility for actions not explicitly addressed in the COA, such as the NMFS biological opinion for the winter-run chinook salmon and the USFWS biological opinion for delta smelt.

The Delta Accord, Water Quality Control Plan, and daily operational changes associated with the CALFED OPS process, have acted to make it more difficult to implement provisions of the COA. DWR and USBR managers and operators are reviewing the agreement and how to apply it in an operational world far different than envisioned in 1986.

### 3.2.6. OPERATIONS PLANNING

Operations forecasting is performed by CVOCO to determine how the current and anticipated water and power resources available to the CVP can best be used to meet project objectives. Operations forecasting encompasses many processes, including data collection and analysis, review, and intra- and inter-agency communication. It may be conducted seasonally, monthly, weekly, or daily, depending on the existing needs and on the uncertainty of the quantities being forecasted.

#### 3.2.6.1. PROSIM

USBR's PROSIM model provides a monthly simulation of the CVP and SWP water and power operations. It is a "rule-and-demand-driven" computer simulation model that mimics CVP and SWP operations and the hydrologic effects of those operations on the major Central Valley reservoir and river systems. As a linked-node model, PROSIM simulates system operations within the geographical area affected by CVP and SWP facilities.

A network of 67 computation points, or nodes, represents river systems and project facilities within the CVP/SWP. PROSIM uses a mass balance approach to simulate the occurrence, regulation, and movement of water from one node to another. At each node, various physical processes (e.g., surface water inflow or accretion, flow from another node, groundwater accretion or depletion, and diversion) can be simulated or assumed. Operational constraints, such as reservoir size and seasonal storage limits or minimum flow requirements, can be defined for each node.

PROSIM simulates monthly operations of the following water storage and conveyance facilities:

1. Trinity, Whiskeytown, and Shasta/Keswick reservoirs (CVP);
2. Spring Creek and Clear Creek tunnels (CVP);
3. Oroville Reservoir (SWP);
4. Folsom Reservoir and Lake Natoma (CVP);
5. Tracy (CVP), Contra Costa (CVP), and Banks (SWP) pumping plants;
6. San Luis Reservoir (shared by CVP and SWP); and

7. East Branch and West Branch SWP reservoirs.

To varying degrees, PROSIM nodes also define conveyance facilities including the Tehama-Colusa, Corning, Folsom South, Delta-Mendota, and California Aqueduct canals. Other systems tributary to the Delta are modeled separately from PROSIM (e.g., the New Melones/Stanislaus River system and the San Joaquin River) and are incorporated as fixed input to a PROSIM node.

#### 3.2.6.2. PROSIM OPERATION

The model simulates one month of operation at a time, sequentially from one month to the next, and from one year to the next. Each decision that the model makes regarding stream flow regulation is the result of defined operational requirements and constraints (e.g., flood control storage limitations, minimum instream flow requirements, Delta outflow requirements, diversion assumptions) or operational rules (e.g., preference among reservoirs for water releases). Certain decisions, such as the definition of water year type, are triggered once a year, which leads to water delivery allocations and specific instream flow requirements. Other decisions, such as specific Delta outflow requirements, are dynamic from month-to-month. PROSIM output is represented by flow or storage conditions at each node on a mean monthly basis for the 70-year hydrologic period of record (1922-1991).

### 3.2.7. AMERICAN RIVER DIVISION

The American River Division was authorized for construction by the Corps and integrated into the CVP by the American River Basin Development Act of 1949. The American River Division includes the Folsom Unit, Sly Park Unit, and Auburn-Folsom South Unit of the CVP. These facilities conserve water on the American River for flood control, fish and wildlife protection, recreation, protection of the Sacramento-San Joaquin Delta from intrusion of saline ocean water, agricultural water supplies, municipal and industrial (M&I) water supplies, and hydroelectric generation. The Folsom Unit consists of Folsom Dam and Reservoir (975,000 acre-feet capacity), Folsom Powerhouse, Nimbus Dam, Lake Natoma, and Nimbus Powerplant on the American River.

The Sly Park Unit, which provides water from the Cosumnes River to El Dorado Irrigation District (EID) includes Jenkinson Lake formed by Sly Park Dam on Sly Park Creek, a low concrete diversion dam on Camp Creek, and Sly Park Conduit. The Folsom and Sly Park Units were added to the CVP in 1949. In 1965, the Auburn-Folsom South Unit was authorized and includes: County Line Dam, Pumping Plant, and Reservoir; Sugar Pine Dam and Reservoir; Linden and Mormon Island Pumping Plants; Folsom South Canal; and other necessary diversion works, conduits, and appurtenant works for delivery of water supplies to Placer, El Dorado, Sacramento, and San Joaquin counties.

### 3.2.8. FOLSOM DAM AND RESERVOIR

Folsom Dam and Reservoir is a multi-purpose water storage facility located at the confluence of the North Fork American River and South Fork American River, approximately 26 miles from the confluence of the American and Sacramento rivers. Folsom Dam was originally authorized in the Flood Control Act of 1944, and was to be constructed by the Corps. Its original intention was to be primarily for flood control purposes and, therefore, operated by the Corps. The project was re-authorized in an enlarged form by the American River Basin Development Act of 1949; this act called for increasing the project's water supply objective, incorporating Folsom Dam into the CVP, and giving operational control of the facility to USBR.

The dam itself is a concrete gravity structure 340 feet high, 36 feet wide at the crest, and 1,400 feet in length. The spillway crest is situated at 418-ft mean sea level (msl) with the top of the dam at 480.5-ft msl. The maximum storage capacity of the reservoir is 975,000 acre-feet with a minimum active storage of 90,000 acre-feet; this level of storage approximates the minimum power operating pool. The power plant consists of three Francis turbines capable of generating a total of 211,000 kW, with a maximum power discharge of 8,600 cfs.

#### 3.2.8.1. TEMPERATURE CONTROL DEVICE (TCD)

Currently, the existing urban water supply intake at Folsom Dam situated at elevation 317 ft msl provides the only direct conduit from Folsom Reservoir through the dam. Water diverted through this intake supplies the City of Roseville, City of Folsom, Folsom State Prison, and the San Juan Water District (including its wholesale customers; Orangevale Water Company, Citrus Heights Water District, and Fair Oaks Water District). This fixed-location diversion outlet is typically within the reservoir's coldwater pool throughout the period of the year when the reservoir is thermally stratified (i.e., April through November). Consequently, diversion of water from this elevation directly reduces the reservoir's coldwater pool volume, thereby reducing the volume of cold water that is available annually for releases into the lower American River to benefit salmonid fishery resources, and for the Nimbus and American River fish hatcheries.

The proposed temperature control device (TCD) at Folsom Dam is intended to be a vertical structure consisting of openings at various locations and affixed to the dam face at the location of the existing urban water supply intake. Its operation would allow USBR operators to draw from various reservoir elevations through the selection of specific louvers on the TCD.

Folsom Reservoir's coldwater pool is not sufficient to support cold water releases throughout the July-October period annually, which would provide maximum thermal benefits to juvenile steelhead (over-summer) rearing and fall-run chinook salmon immigration, spawning, and incubation, and juvenile steelhead and trout rearing in the hatcheries. Consequently, coldwater pool releases into the lower American River must be allocated in an optimal manner each year.

#### 3.2.8.2. WATER RELEASE SHUTTERS

The intake to the Folsom Dam power plant penstocks has nine water release shutters that can be used to modify the temperature of water releases from the reservoir to improve water temperature conditions in Nimbus Salmon and Steelhead Hatchery and American River Trout Hatchery and for chinook salmon spawning in the river. The original shutter configuration when the 400,000 acre-feet "fixed" flood control storage was in effect in 1994 is referred to as the 1-1-7 configuration. Under this configuration, the top shutter can be opened independently of the others, as can the second shutter. The bottom seven shutters, however, must be opened as one unit. The water release shutters at Folsom Dam were modified from the 1-1-7 configuration to a 3-2-4 configuration as mitigation for the Interim Agreement to improve Reclamation's ability to manage the temperature of water stored in Folsom Reservoir and released to the lower American River.

Water temperatures in the lower American River are, in part, a result of the shutter configuration of Folsom Dam. The position of each of the shutters corresponds to a particular elevation (ft msl), minimum pool access elevation, and reservoir storage. There must be at least approximately 26 ft of water above the shutters to generate enough head for power generation and avoid cavitation. The top two shutters, for example, would become inoperable when the reservoir elevation drops below 402 ft msl (**Table 3-1**).

**Table 3-1. Folsom Dam water release shutters - elevational data.**

| No. of Shutters Down | Top Elevation of Shutter (ft msl) | Minimum Pool Elev. (ft msl) | Reservoir Storage (acre-feet) |
|---|---|---|---|
| 9 | 401 | 428 | 595,930 |
| 8 | 388 | 415 | 487,968 |
| 7 | 375 | 402 | 392,847 |
| 6 | 362 | 389 | 310,734 |
| 5 | 349 | 376 | 240,914 |
| 4 | 336 | 363 | 184,200 |
| 3 | 323 | 350 | 139,493 |
| 2 | 310 | 337 | 104,614 |
| 1 | 297 | 324 | 77,390 |
| Source: USBR, 1994 | | | |

Shutter configurations are constrained by the current structural design of Folsom Dam. Folsom Dam has three semi-circular platforms, each of which supports five gatekeepers. Each of the gatekeepers has three "stems" that are involved with operating the nine water release shutters within each gatekeeper. The stems are physically connected to one or more shutter(s) to facilitate their operation (i.e., lifting or lowering). The structural design constrains shutter reconfiguration to various sized groups or "gangs" of shutters that can be connected to the three operating stems.

#### 3.2.8.3. EXISTING RIVER OUTLETS AND POWER PENSTOCK INTAKES

The existing eight river outlets are 5 feet wide and 9 feet high and have a capacity of approximately 28,000 cfs. The four upper river outlets are located at 275 ft msl and the four lower river outlets are located at 205 ft msl. The power penstock intakes are situated at 307 ft msl.

### 3.2.9. EID TCD

The El Dorado Irrigation District (EID) is proposing to develop and implement its own temperature control device (TCD) at its urban water supply intake on the south shore of Folsom Reservoir. The current intake lies along the reservoir bed as an extended pipeline. Proposed as part of the El Dorado County Water Agency (EDCWA) project to secure its Congressionally authorized new CVP water contract under P.L.101-514, this structure is currently in its design stages. It is anticipated that the final design would involve establishing louver controlled openings at specific points along the intake pipeline that correspond to specific reservoir elevations.

### 3.2.10. NIMBUS DAM

Nimbus Dam is a concrete gravity structure 87 feet high, 28 feet wide, and 1,093 feet in length. The Nimbus Power Plant at the dam's northern end consists of two Kaplan turbines capable of generating a total of 19,900 kW at a maximum power discharge of 5,500 cfs. Nimbus Dam impounds Lake Natoma with a maximum storage capacity of 8,760 acre-feet. In addition to its role as a regulating facility for Folsom Dam releases, the dam also is the diversion location for the Folsom South Canal.

### 3.2.11. FOLSOM SOUTH CANAL

The Folsom South Canal was originally authorized as part of the Auburn-Folsom South Unit of the CVP and was planned to terminate approximately 20 miles southeast of the City of Stockton. At the time of its construction, it was intended to serve industrial, municipal, and irrigation users in Sacramento and San Joaquin counties. The completed portion of Folsom South Canal extends from Nimbus Dam southward about 27 miles towards the Cosumnes River. It was the main water supply conveyance for the Rancho Seco Nuclear Power Plant, while in operation. It has also been a primary conveyance of interest for the East Bay Municipal Utility District (EBMUD) in its efforts to exercise its CVP contract for delivery to its East Bay service area.

### 3.2.12. AMERICAN RIVER DIVISION DEMANDS

Water demands on the American River have been reviewed and evaluated under several recent and continuing projects. The most recent effort has been through the Sacramento Area Water Forum (circa. 1999). Since then, several adjustments and modifications have been made to these demands based on recent updates to specific purveyor needs.

#### 3.2.12.1. SACRAMENTO AREA WATER FORUM

Existing and anticipated future water demands on the American River have been recently reviewed and corroborated in the Sacramento Area Water Forum (Water Forum). Under the Water Forum's charge, a comprehensive package of integrated actions have been developed to achieve it's two co-equal objectives: (1) provide a reliable and safe water supply for the region's economic health and planned development through to the year 2030; and (2) preserve the fishery, wildlife, recreational, and aesthetic values of the lower American River.

The Water Forum signed into effect the Water Forum Agreement (in April 2000), which included seven independent elements. One element, known as the *Increased Surface Water Diversions* element, recognizes that surface water diversions from the lower American River (including Folsom Reservoir) will increase in the future. These additional water supplies will be needed to support economic development and planned urban growth through the year 2030. In **Table 3-2** and **Table 3-3** present the existing (1995) and projected future (2030) water demands of the Water Forum purveyors.

It is envisioned that diversions from the lower American River by purveyors in the region in average and wetter years above H Street would increase from the current level of 216,000 acre-feet annually to about 481,000 acre-feet annually by the year 2030 (see Tables 3-11 and 3-12). With appropriate mitigation, however, it is felt that diversions at these levels could be accomplished without adversely affecting the fishery, wildlife, recreational, and aesthetic values of the lower American River.

In dry years, however, total surface water demands from the lower American River (including Folsom Reservoir) cannot be met without significantly degrading the existing resources of the river. Accordingly, the Water Forum has developed a suite of specific surface water reductions for each purveyor based on purveyor-specific considerations of water entitlement type, needs forecasts, and the potential availability of offsetting alternative water supply sources. Potential actions identified by the Water Forum include conjunctive use of groundwater consistent with established sustainable yield objectives for the groundwater basins; utilizing other surface water supplies; re-operation of Folsom Reservoir; increased water conservation; and water reclamation.

The proposed reductions in diversions from the lower American River, coupled with purveyor-initiated specific actions, would be designed to meet consumer consumptive needs during drier and driest years while minimizing the potential impacts to the river.[1] The second element, therefore, is known as *Actions to Meet Customers' Needs While Reducing Diversion Impacts in Drier Years*. The drier the year, the more the purveyors would limit their American River diversions. In the driest years, purveyors would limit their diversions from the lower American River (including Folsom Reservoir) to "baseline" levels or, the historic maximum quantity of water that they diverted in any one-year through 1995. In many cases, purveyors would continue to meet their customers' needs in drier and driest years through various alternative water supply options such as increased reliance on groundwater pumping.

**Table 3-2. American River existing condition demands.**

| Location | Demand (AF) | Demand Type |
|---|---|---|
| **Upstream of Folsom Reservoir** | | |
| El Dorado Irrigation District | 15,000 | Water Rights |
| Georgetown | 10,000 | Water Rights |
| Placer County Water Agency | 8,500 | Water Rights |
| Total | 33,500 | |
| **Folsom Reservoir -** *Represented by PROSIM Node 14* | | |
| Northridge Water District | 0 | Water Rights |
| City of Folsom | 15,000 | Water Rights |
| Folsom State Prison | 2,000 | Water Rights |
| San Juan Water District (Placer County) | 10,000 | Water Rights |
| San Juan Water District (Sacramento County) | 44,200 | Water Rights/M&I Contract |
| El Dorado County Water Agency | 0 | M&I Contractor |
| El Dorado Irrigation District | 5,000 | M&I Contractor |
| Roseville, City of | 23,000 | M&I Contractor |
| Total | 99,214 | |
| **Folsom South Canal -** *Represented at PROSIM Node 15* | | |
| Southern California Water Co. | 3,500 | Water Rights |
| California Parks and Recreation | 0 | M&I Contract |
| SMUD | 15,000 | Water Rights |
| South Sacramento County Agriculture | 0 | Ag Contractor |
| Losses | 1,000 | |
| Total | 19,500 | |

[1] Drier years: Defined as those years when the projected March through November unimpaired inflow to Folsom Reservoir is less than 950,000 acre-feet. Driest years: Defined as those years when the projected March through November unimpaired inflow to Folsom Reservoir is less than 400,000 acre-feet. Driest years: Defined as those years when the projected March through November unimpaired inflow to Folsom Reservoir is less than 400,000 acre-feet.

| Location | Demand (AF) | Demand Type |
|---|---|---|
| **From Below Nimbus Dam to H Street -** *Represented by PROSIM Node 16* | | |
| Arcade Water District | 2,000 | Water Rights |
| Carmichael Water District | 8,000 | Water Rights |
| Sacramento, City of | 50,000 | Water Rights |
| Total | 60,016 | |
| **American River at I5 -** *Represented at PROSIM Node 16* | | |
| EBMUD | 0 | |
| Total | 0 | |
| **Sacramento River below the American River Confluence -** *Represented by PROSIM Node 17* | | |
| Sacramento, City of | 45,000 | Water Rights |
| Sacramento county Water Agency | 0 | |
| Total | 45,000 | |

**Table 3-3. American River future condition demands.**

| Location | Demand (AF) | Demand Type |
|---|---|---|
| **Upstream of Folsom Reservoir** | | |
| El Dorado Irrigation District | 33,350 | Water Rights |
| Georgetown | 11,200 | Water Rights |
| Placer County Water Agency | 35,500 | Water Rights |
| Total | 80,050 | |
| **Folsom Reservoir -** *Represented by PROSIM Node 14* | | |
| Northridge Water District | 29,000 | Water Rights |
| City of Folsom | 34,000 | Water Rights |
| Folsom State Prison | 2,000 | Water Rights |
| San Juan Water District (Placer County) | 25,000 | Water Rights |
| San Juan Water District (Sac County) | 57,200 | Water Rights/M&I Contract |
| El Dorado County Water Agency | 7,500 | M&I Contractor |
| El Dorado Irrigation District | 7,550 | M&I Contractor |
| Roseville, City of | 54,900 | M&I Contractor |
| Total | 217,150 | |
| **Folsom South Canal** – *Represented at PROSIM Node 15* | | |
| Southern California Water Co. | 5,000 | Water Rights |
| California Parks and Recreation | 5,000 | M&I Contract |
| SMUD | 30,000 | Water Rights |
| South Sacramento Count Agriculture | 35,000 | Ag Contractor |
| Losses | 1,000 | |
| Total | 76,000 | |
| **From Below Nimbus Dam to H Street -** *Represented by PROSIM Node 16* | | |
| Arcade Water District | 11,200 | Water Rights |
| Carmichael Water District | 12,000 | Water Rights |
| Sacramento, City of | 96,300 | Water Rights |
| Total | 119,500 | |
| **American River at I5** – *Represented at PROSIM Node 16* | | |
| EBMUD | 112,000 | M&I Contract |
| | 0 | |
| Total | 112,000 | |
| **Sacramento River below the American River Confluence -** *Represented by PROSIM Node 17* | | |
| Sacramento, City of | 34,300 | Water Rights |
| Sacramento county Water Agency | 45,000 | |
| Total | 79,300 | |

In drier and driest years, further protection would be given the lower American River through the release of replacement water upstream of Folsom Reservoir (also known as "re-operation water”). Under the Water Forum Agreement, the drier the year, the greater the amount of water that would be replaced to the river. In these years, the amount of water replaced would be equivalent to the purveyor’s increased diversions over its baseline. One potential source for this replacement water would be Placer County Water Agency’s Middle Fork Project. Under the Water Forum Agreement, this initial quantity of replacement water could be up to 20,000 acre-feet per year and would apply to the diversions of the City of Roseville and the Placer County Water Agency. Finally, the Water Forum Agreement recognizes that purveyors could meet at least a portion of their water needs by diverting from the Sacramento River, thus avoiding direct effects to the lower American River.

#### 3.2.12.2. DIVERSION AGREEMENTS TO IMPLEMENT THE WATER FORUM AGREEMENT

In order to fully implement the Water Forum Agreement and, more specifically, the proposed surface water diversion provisions including the dry-year reductions, an agreement with Reclamation would be sought with each purveyor through the year 2030. These agreements would acknowledge the water entitlement(s) of the individual purveyor and codify the proposed reductions in deliveries. The agreement could either: (1) reduce the quantity of water that is scheduled for delivery upstream of Nimbus Dam under the purveyor’s CVP contract; (2) reduce the quantity of water that is scheduled for delivery upstream of Nimbus Dam under the purveyor’s water rights; or (3) implement alternative dry year actions. Nothing in the agreement need affect USBR’s authority to determine or apply water shortage provisions pursuant to its water shortage policies. Furthermore, any reductions in deliveries agreed to by the purveyors under these agreements could be credited by USBR to reductions imposed under the water shortage provisions of CVP water service contracts.

### 3.2.13. AMERICAN RIVER DIVISION OPERATIONS—FOLSOM DAM AND RESERVOIR

#### 3.2.13.1. FLOOD CONTROL

Flood control requirements and regulating criteria are specified by the Corps From June 1 through September 30, no flood control restrictions exist. Full flood reservation space is required from November 17 through February 7. From October 1 through November 16 and from April 21 through May 31, reserved storage space for flood control is a function of the date. Beginning February 8 and continuing through April 20, flood reservation space is a function of both date and wetness.

Since 1996, USBR has operated to modified flood control criteria which reserves 400,000 to 670,000 acre-feet of flood control space in Folsom Reservoir and a combination of upstream reservoirs. This flood control plan, which provides additional flood protection for the lower American River, is implemented through an agreement between USBR and the Sacramento Area Flood Control Agency (SAFCA). The terms of the agreement allow some of the empty reservoir space in Hell Hole, Union Valley, and French Meadows to be treated as if it were available in Folsom Reservoir. Although some of the SAFCA release criteria differ from the Corps plan, the criteria generally provide greater flood protection than existing Corps criteria for Folsom Reservoir. Required flood control space may begin to decrease on March 1. Between March 1 and April 20, the rate of filling is a function of available upstream space. As of April 21, the required flood reservation is about 175,000 acre-feet. From April 21 to June 1, the required flood reservation is only a function of the date, with Folsom Reservoir storage allowed to completely fill on June 1.

### 3.2.13.2. Reservoir Storage and Refill

The American River at Folsom Dam has an average annual runoff of about 2,700,000 acre-feet, with the reservoir's storage capacity of 974,000 acre-feet. Flood control is an authorized function of the reservoir, and allowable flood control storage figures are used to determine if refill has occurred. Experience has shown that the desirable carryover storage is about 620,000 acre-feet.

From past analyses, it is estimated that there is an 80 percent chance that the reservoir will refill with 620,000 acre-feet of carryover storage. As the carryover storage is reduced, the ability of the reservoir to refill in a single year is diminished. When carryover storage is reduced to one-half of the reservoir's storage capacity (approximately 487,000 acre-feet), the refill potential has fallen to about 60 percent.

In general, Folsom Reservoir has a high potential for refilling. For example, even when the reservoir is drawn down to 200,000 acre-feet, there is nearly a 50 percent chance that the reservoir will refill.

### 3.2.13.3. American River - Instream Flow Requirements

Instream flow requirements for the lower American River have been set and managed through a variety of standards, court decisions, and voluntary management operations. These are discussed below.

#### D-893

The SWRCB Decision 893 is the current regulatory requirement for the lower American River, and is the minimum operational flow standard for the river. Under D-893, a minimum daily flow of 500 cfs is to be maintained at the mouth of the American River between September 15 and December 31, with a minimum of 250 cfs at all other times.

#### D-1400

In April 1970, the SWRCB issued Decision 1356 (D-1356), granting USBR water rights permits for Auburn Dam. The SWRCB reserved jurisdiction for the purpose of formulating terms and conditions relative to flows to be maintained in the lower American River for recreational purposes, and for the protection and enhancement of fish and wildlife. Such flows were subsequently set by the SWRCB in Decision 1400 (D-1400). The flows in D-1400 were based on the assumption that Auburn Dam would be built. Since Auburn Dam was never built, the D-1400 flows are not legally binding on Reclamation; however, USBR still operates to meet such flows, if water is available (see D-1400 Modified, below).

#### D-1400 (modified)

Prior to the CVPIA, the American River Division facilities were operated to help maintain natural fish production in the American River below Nimbus Dam by maintaining minimum fish flows proposed in D-1400 while also attempting to meet temperature objectives. Over the years, this voluntary operational practice became known as “modified” D-1400. It incorporates minimum flow objectives similar to D-1400 when hydrologic conditions are supportive and limits releases to D-893 minimum fish flow objectives only under very adverse hydrologic conditions. Therefore, minimum flows can range from 250 cfs in months with very low Folsom Reservoir storage to 3,000 cfs in months with high storage and hydrologic projections of ample runoff.

### “Hodge” Criteria

“Hodge” physical solution flows are river flow levels for the lower American River identified by Judge Richard Hodge in the Environmental Defense Fund (EDF) et al. v. EBMUD court decision. These flows condition EBMUD’s potential diversion from Folsom South Canal and were intended to protect public trust values associated with the lower American River. Public trust values considered in the development of the Hodge “physical solution” flows included fishery resources, riparian habitat values, and recreational values. The Hodge physical solution flows are as follows:

| | |
|---|---|
| October 15 through February | 2,000 cfs |
| March through June | 3,000 cfs |
| July through October 14 | 1,750 cfs |

These physical solution flows were considered to represent conservative flows for providing sufficient physical habitat for fishery resources in the lower American River. In addition to these instream flow requirements, the decision also required that an additional 60,000 acre-feet per year be maintained as reserve at the reservoir from mid-October through June for release upon the recommendation of CDFG in consideration of specific fishery requirements.

Hodge physical solution flows do not specifically address water temperature considerations for over-summering juvenile steelhead. Water temperatures associated with the flows set out in the Hodge decision are often detrimental to juvenile steelhead rearing, as well as fall-run chinook salmon spawning and incubation.

### AFRP Flow Objectives

AFRP flow objectives for the American River are intended to decrease water temperatures and increase spawning, incubation, rearing, and emigration habitat for fall-run chinook salmon and steelhead while providing benefits for estuarine species as well. These instream flow objectives are presented in **Table 3-4,** below.

**Table 3-4. Recommended AFRP instream flow regimes for the lower American River.**

| Month | Flow (cfs) for each of four water year types | | | |
|---|---|---|---|---|
| | Wet | Above and Below Normal | Dry/Critical | Critical Relaxation |
| October | 2,500 | 2,000 | 1,750 | 800 |
| November-February | 2,500 | 2,000 | 1,750 | 1,200 |
| March-May | 4,500 | 3,000 | 2,000 | 1,500 |
| June | 4,500 | 3,000 | 2,000 | 500 |
| July | 2,500 | 2,500 | 1,500 | 500 |

| | | | | |
|---|---|---|---|---|
| August | 2,500 | 2,000 | 1,000 | 500 |
| September | 2,500 | 1,500 | 500 | 500 |
| Source: USFWS, 1995 | | | | |

These flow regimes were developed in consideration of water availability (i.e., unimpaired runoff at Fair Oaks) associated with each of the hydrologic, water-year conditions (i.e., wet, normal, dry/critical, and critical relaxation). An objective associated with these flow regimes is for Folsom Reservoir to achieve a target storage of about 610,000 acre-feet by September 30 in order to provide a sufficient volume of water (and coldwater pool) to maintain spawning and incubation (fall and winter) flows.

The recommended flows under the AFRP are considered to be flow objectives flows under each hydrologic condition (water year type). Higher flows are likely to occur during any given month depending on precipitation and runoff. The "dry/critical" flow regime is intended to accommodate a relatively wide range of hydrologic conditions, including all but the most severe drought conditions. Conversely, the "critical relaxation" flow regime is intended for application to hydrologic conditions characterized by the most severe droughts.

For the protection of Central Valley steelhead, USBR proposes to adaptively manage releases and water temperatures in the lower American River with the participation of NMFS through the American River Operations Group. This Operations Group meets monthly to review past operations, evaluate future operations, and develop operational alternatives that optimize conditions for steelhead and fall-run chinook salmon.

### 3.2.13.4. AMERICAN RIVER - FLOW RAMPING CRITERIA

Regarding seasonal fluctuations and ramping of streamflows in the lower American River, USBR proposes to use draft criteria developed by CDFG, which were recently identified in the NMFS draft Biological and Conference Opinion on Central Valley steelhead (as part of the section 7 consultation on the effects of the CVP and SWP on Central Valley steelhead). Under these criteria, USBR shall ramp down releases in the lower American River consistent with the limitations presented in **Table 3-5**. Ramping shall also be limited to night periods (defined as one hour after sunset and one hour before sunrise).

**Table 3-5. Proposed ramping criteria for the lower American River.**

| During any 24 hour period, Nimbus Dam releases should not decrease more than the ranges below (cfs) | Individual decreases in Nimbus Dam releases should not be greater than the values below (cfs) |
|---|---|
| 20,000 to 16,000 | 1,000 to 1,500 |
| 16,000 to 13,000 | 1,000 |
| 13,000 to 11,000 | 500 to 800 |
| 11,000 to 9,500 | 500 |
| 9,500 to 8,000 | 500 |
| 8,000 to 7,000 | 300 to 350 |
| 7,000 to 6,000 | 300 to 350 |
| 6,000 to 5,500 | 250 |
| 5,500 o 5,000 | 250 |
| Below 5,000 up to 500 per 24 hour period. | 50 per hour |
| Source: NMFS 2000. | |

### 3.2.14. AMERICAN RIVER – WATER TEMPERATURE CONTROL

Elevated water temperatures in the lower American River have been recognized as a key factor affecting salmonid stocks that inhabit the river. Temperatures on the American River are influenced by several factors, including the relative temperatures and volume of releases from the limited capacity of the coldwater pool reserve within Folsom Reservoir. The temperature of water released from Folsom Dam is a function of the following: total storage in Folsom Reservoir; depths from which releases are made; the percent of total releases from each reservoir depth; ambient air temperatures and other climatic conditions; tributary accretions and associated water temperatures; and residence time in both Folsom Reservoir in Lake Natoma.

USBR operates the American River Division of the CVP to meet, to the extent possible, the temperature objectives for the Nimbus Salmon and Steelhead Hatchery and the American River Trout Hatchery, while maintaining suitable temperatures for instream salmonids. The interagency American River Operations Group (USBR, USFWS, NMFS, CDFG, Sacramento County, SAFCA, and Save the American River Association) was created in 1996 and assists USBR in the adaptive management of releases and associated water temperature conditions in the lower American River in order to meet the needs of fall-run chinook salmon and steelhead within the river.

Water temperatures along the lower American River are highly influenced by flows released from Folsom and Nimbus dams. Other factors also play an important role in determining water temperatures at any particular location along the lower American River including, water depth, ambient air temperature, direct exposure to sunlight, habitat unit (i.e., run, glide, pool, or riffle), Folsom Dam release temperatures (based partly on shutter configuration), and residence time in Lake Natoma.

A comparison of annual river thermographs and corresponding hydrographs for two relatively recent years (1992 and 1993) representing different water year types is shown in **Figure 3-2** and **Figure 3-3**. Maximum daily air temperatures are also plotted. These two years, as illustrated by the differing y-axis scales, represent examples of dry and above-normal years, respectively. Even between these two different water-year types, mean daily water temperature fluctuations exhibit an inverse relationship with flows during the late-summer and fall months (i.e., as flows decrease, water temperatures increase). The increasing air temperatures typical throughout this time period contribute to this condition. At higher flows and lower air temperatures, this relationship is reversed.

During the coldest part of the year, ambient air temperature becomes an increasingly important factor and drives water temperature down. The sensitivity of water temperature in the river to flow changes can be seen in Figure 3-2. Mid-summer flow releases, with such low base flows, reveal the rapid and significant response time of the river water temperature. For example, in late June, an approximate 1,000 cfs flow release increase corresponded with a significant decrease in air temperature, resulting in a rapid 5º F drop in water temperature over the next several days (as recorded at the Ancil Hoffman gauge).

#### 3.2.14.1. FOLSOM RESERVOIR COLDWATER POOL MANAGEMENT

The critical period for water temperature control to benefit steelhead is July through September, when juvenile steelhead are rearing in the river. The critical period for fall-run chinook salmon is October and November when peak spawning occurs. Fall-run chinook salmon juveniles emigrate from the river by the end of June and, therefore, are not present during the July through September period.

**Figure 3-2. Mean daily flow, mean daily water temperature and maximum daily air temperatures in 1992 for the lower American River.**

**Figure 3-3. Mean daily flow, mean daily water temperature, and maximum daily air temperatures in 1993 in the lower American River.**

Managing Folsom Reservoir release temperatures for the sole benefit of steelhead in the summer could adversely affect fall-run chinook salmon spawning in the fall. Conversely, conserving cold water throughout the summer and releasing it in the fall would benefit fall-run chinook salmon, but could result in worse summer temperatures for steelhead. Hence, from a biological and logistical basis, a balanced management of Folsom Reservoir's coldwater pool is necessary annually in order to maximize temperature benefits to both steelhead and fall-run chinook salmon.

Within the constraints of annual water availability (i.e., hydrology conditions of the year), lower American River flows are dictated by releases from Folsom Reservoir that balance in-river, local water supply, and Delta needs as a part of integrated CVP/SWP operations. As such, instream flows receive substantial attention by numerous parties (e.g., American River Operations Group) on a monthly basis, which results in effective flow management. River water temperatures are affected by river flow rates, meteorology, and the temperature of water released from Folsom Reservoir. The latter factor, the temperature of water released from Folsom Reservoir, has a significant effect on lower American River temperatures, yet relatively little attention has been given in the past to managing the temperature of water released from Folsom Reservoir throughout each year. Consequently, lower American River temperatures could be improved annually to benefit steelhead and fall-run chinook salmon by improving the management of Folsom Reservoir release temperatures.

### 3.2.14.2. COLDWATER POOL MANAGEMENT MODEL (CPMM)

The Coldwater Pool Management Model (CPMM) is an operational management tool to analyze the effects of alternative "actions" that affect the hydrology of Folsom Reservoir and the lower American River, including river water temperatures. "Actions" may be described as any combination of altered inflows, diversions, releases, instream temperature requirements, shutter operations, or powerplant operations. Use of the CPMM allows the operators of Folsom Dam to develop alternative water and facility management strategies, to minimize or avoid water temperature effects to the lower American River fishery resources associated with a given action.

The CPMM is used to select: (1) the most beneficial seasonal target water temperature objectives for the lower American River during a given year; and (2) the operational plan to obtain the selected temperature objectives. Selection of seasonal temperature objectives is: (1) characterized by the rate and duration with which cold water must be released from Folsom Reservoir to control lower American River temperatures; (2) based on the biological benefit expected from controlling lower American River temperatures; and (3) limited by the amount of coldwater available in Folsom Reservoir.

The analysis process used to select temperature objectives for the lower American River and the desired operational plan involves two steps. The model user: (1) determines the most beneficial, reasonably achievable lower American River temperatures at Watt Avenue, assuming releases are not constrained by either Folsom shutter operational constraints or hydropower operational constraints; and (2) starting with the temperature objectives selected in Step 1, applies shutter and hydropower operations constraints in an iterative process to select an operational plan that accomplishes the water temperature objectives. The result is a coldwater pool management strategy that is implementable and which optimizes lower American River temperatures for fisheries benefits, within hydrologic and operational constraints.

### Model Components

The CPMM includes three components: (1) Folsom Reservoir Temperature Model; (2) Lower American River Temperature Model; and (3) Input/Output User Interface. The reservoir temperature model is a modified version of the Army Corps of Engineers Waterways Experiment Station's (CEWES) CE-THERM-R1 model. Modifications include the addition of a customized outlet/shutter selection routine, water supply intake operations routine, and additional inputs/outputs. The model calibration was developed by J. Humphrey and W. Blood on behalf of SAFCA in support of SAFCA's Interim Folsom Dam and Reservoir Re-Operation Project. The riverine temperature model is an equilibrium temperature model similar to USBR's model developed by J. Rowell. The input/output user interface is a Lotus 123 spreadsheet, CPMM.123.

### Data Requirements

A variety of data are used by the CPMM to model temperatures for the lower American River. The CPMM is designed to forecast the response of the system to various alternative operations. Data should be developed/selected recognizing that the model results will be used in a comparative fashion. There are numerous potential sources of error that could occur in the application of the models contained in the CPMM.

### 3.2.14.3. MORTALITY MODELS

USBR operates two early lifestage mortality models for chinook salmon in the Sacramento and American rivers. The mortality estimates generated in these models are based on output from USBR's water temperature models. Temperature units (TUs), defined as the difference between river temperatures and 32°F, are accounted for on a daily basis by the model, and are used to track life-stage development. Eggs are assumed to hatch upon exposure to 750 TUs following fertilization. Incubating eggs, for example, exposed to 52°F water for one day would experience 20 TUs. Similarly, the model assumes that fry emerge from the gravel after exposure to 750 TUs.

USBR's chinook salmon mortality models produced a single estimate of early lifestage chinook salmon mortality for each year of the simulation. This estimate consolidates calculations of salmon mortality for three separate early-lifestages: (1) pre-spawned eggs; (2) fertilized eggs; and (3) pre-emergent fry. For the Sacramento River, the model computes mortality for each of the four chinook salmon runs; fall, late-fall, winter, and spring. For the American River, the model generates estimates of fall-run chinook salmon mortality only.

Currently, no mortality model exists for steelhead in the lower American River. The potential effects of water temperature on steelhead, particularly for juvenile steelhead rearing, in the summer are qualitatively assessed using the monthly average Watt Avenue temperatures generated by USBR's American River water temperature model.

## 3.2.15. AMERICAN RIVER – TEMPERATURE MANAGEMENT

The Central Valley Evolutionary Significant Unit (ESU) for steelhead, which includes the lower American River, has been listed as "threatened" under the federal Endangered Species Act. NMFS has provided USBR with "recommendations" regarding the manner with which CVP operations should accommodate steelhead in the lower American River, and is currently consulting with USBR in the development of a biological opinion regarding steelhead.

Early in 2000, USBR, USFWS, and NMFS recognized the need to utilize an efficient, consistent characterization of the management of the coldwater pool in Folsom Reservoir. This characterization was considered important for various environmental documentation applications (e.g., NEPA and ESA) and provided a means of prioritizing focus on endangered and threatened species. The Automated Temperature Selection Procedure (ATSP) was developed to accomplish this characterization for use with USBR's existing water temperature model.

#### 3.2.15.1. ATSP Schedules

The ATSP utilizes a schedule of target temperatures for the American River at Watt Avenue to set target release temperatures at Folsom Dam for each year of a temperature model simulation. The ATSP utilizes an iterative process to achieve the "best possible" management of Folsom Reservoir's coldwater pool.

The model initially attempts to achieve the first set, or "schedule," of target temperatures specified for each month. If those temperatures cannot be met, then the next schedule is examined. This iterative process continues through the list of schedules for each individual year included in the simulation until one of the schedules can be met, as determined by the hydrologic characteristics (reservoir storage volume, inflow, release flow, etc.) associated with that particular year.

The ATSP schedules reflect the management objective to balance the beneficial effects of coldwater pool management for both steelhead and fall-run chinook salmon.

A numeric, incremental approach was developed to arrive at a lower American River target temperature "schedule." The year was broken into 15 different time periods. Twenty-five (25) different schedules were developed each utilizing a varying amount of cold water release from Folsom Reservoir. The 25 target temperature schedules describe temperature conditions that, if achieved, balanced fisheries needs throughout the year. These schedules and selection logic are incorporated into the CPMM. Schedule #1 is the most beneficial application of cold water, and can be chosen if sufficient cold-water releases can be made from Folsom Reservoir. Schedule #25 is the least desirable for fisheries benefits, but requires much less cold water to be released from Folsom Reservoir, relative to other schedules. Each schedule represents an incremental change in temperature objectives from the previous that reduces the amount of cold water release required from Folsom Reservoir.

The CPMM selection logic allows the user to specify differing target temperature schedules throughout the year thereby shifting priorities away from that prescribed by the predefined schedules. The CPMM allows the user to select a priority for each of 4 periods: (1) January - April, (2) May - June, (3) July - September and (4) October - December.

In developing the schedules, an assumption was made to always have all Folsom Dam shutters in place during April. The following is a text description of the incremental changes in target temperatures:

1. Attempt to achieve maximally beneficial year-round temperature conditions.
2. Allow June temperatures to increase to 59°F, followed by an increase to 57°F in May. Then allow July & August temperatures to increase up to 66°F. Then allow first week of October temperature to increase to 59°F, with temperatures in subsequent weeks decreasing.

3. Allow September temperatures to increase to 66°F. Then allow temperature in the third and fourth weeks of October to increase to 57°F. Then allow an increase to 60°F in June then 58°F in May.
4. Allow June temperatures to increase to 61°F, followed by an increase to 59°F in May.
5. Allow June temperatures to increase to 62°F.
6. Allow temperatures to increase to 59°F in the second week of October. Then allow June temperatures to increase to 63°F.
7. Allow June temperatures to increase to 64°F.
8. Allow July and August temperatures to increase up to 67°F, with September being maintained 1°F colder while not exceeding 60°F in May, 65°F in June and 60°F in the first week of October. Then allow temperature in the first and second weeks of November to increase to 56°F.
9. Allow temperatures to increase to 61°F in the first week of October and 60°F in the second week of October. Then allow June temperature to increase to 66°F, followed by an increase to 61°F in May.
10. Allow temperatures to increase to 58°F in the third and fourth weeks of October, followed by an increase to 57°F in the first week of November. Then allow June temperature to increase to 67°F, followed by an increase in May temperatures to 62°F.
11. Allow temperatures to increase to 59°F in the third week of October. Allow May temperature to increase to 63°F in May.
12. Allow water temperature to increase to 60°F in the third week of October, 59°F in the fourth week of October, 56°F in the third week of November then 64°F in May.
13. Allow temperatures to increase to 68°F in July and August, then 67°F in September, then 68°F in June, then 65°F in May.
14. Allow temperatures to increase to 60°F in the fourth week of October.
15. Allow temperatures to increase to 58°F in the first week of November, 57°F in the second week of November, and 56°F in the fourth week of November.
16. Allow temperatures to increase to 62°F in the first week of October, then 61°F in the second week of October.
17. Allow temperatures to increase to 68°F in September, 69°F in July and August, 69°F in June, then 66°F in May.
18. Allow temperatures to increase to 67°F in May.
19. Allow temperatures to increase to 68°F in May, then 63°F in the first week of October, 62°F in the second week of October, and 61°F in the third week of October.
20. Allow temperatures to increase to 69°F in May.
21. Allow temperatures to increase to 59°F in the first week of November.
22. Allow temperatures to increase to 60°F in the first week of November.

23. Allow temperatures to increase to 64°F in the first week of October, then 63°F in the second week of October, then 62°F in the third week of October, then 61°F in the fourth week of October.
24. Allow temperatures to increase to 70°F in July and August, then 70°F in June.
25. Allow temperatures to increase to 69°F in September, then to 70°F May.

# 4.0 WATER QUALITY

## 4.1. HISTORIC OVERVIEW

Historically, water quality conditions in the lower American River were typically well within acceptable limits to achieve water quality objectives and beneficial uses identified for this water body (SWRCB 1992), despite the contribution to the river of pollutants and other contaminants from urban runoff and stormwater discharges. However, the lower American River's water quality has reflected the influence of the same historical activities that have affected the river's fluvial geomorphology, channel morphology, and sediment supply and transport—mining activities, dam and levee construction, and agricultural development and urbanization. Each of these is discussed more fully below.

### 4.1.1. HYDRAULIC GOLD MINING IN THE SIERRAS

Until construction of Folsom Dam, mining debris from the upstream portions of the American River Basin represented a significant portion of the lower American River's suspended sediment and bedload. These materials were principally made up of very fine gravel, sand, and sediment. Consequently, gold mining, particularly hydraulic mining, resulted in high turbidities in the lower American River.

Gold mining also introduced mercury to the basin. During the 19$^{th}$ century, mercury was transported from the Coast Range to the Sierra Nevadas for use in the gold amalgamation process. Widespread mercury contamination of bottom sediments has occurred, and continues to occur in many northern California rivers, including the American River. The American River drains many of the gold fields where mercury was once used.

### 4.1.2. FOLSOM DAM/NIMBUS DAM CONSTRUCTION

Folsom Dam and Nimbus dams, completed in 1955, block sediment supplies originating in the upper watershed from reaching the lower American River. Most of the river's sediment supply is now derived from bank erosion upstream of Goethe Park.

Concentrations of mercury, which are at levels of concern in the lower American River (and even more so downstream in the lower Sacramento River), are affected by the dams on the river. Elements that adsorb to sediments, such as mercury, may be trapped in reservoirs. In particular, foothill reservoirs have been found to operate as sinks for both bioavailable and sediment-associated inorganic mercury (Slotten et al. 1997; Larry Walker and Associates 1997). Significantly lower levels of mercury were found in aquatic organisms below reservoirs as compared to concentrations both in and above them. Similarly, these studies showed that bulk loads of mercury entering foothill reservoirs were greater than the amounts exported. This suggests that the reservoirs in gold mining districts may act as interceptors of mercury, trapping and preventing downstream transport. This may explain the smaller than expected loads measured in both the American and Feather rivers by two recent studies (RWQCB 1998; Larry Walker and Associates 1997). The mercury loads now present after storms in the Sierra Nevada rivers may primarily result from resuspension of bedload material located below dams.

### 4.1.3. URBANIZATION AND WATER QUALITY MONITORING

Urbanization throughout the greater Sacramento area has led to a replacement of agricultural land uses within the American River floodplain with urban land uses, and a corresponding increase in urban runoff. Water quality monitoring conducted in other rivers in urbanized areas in the 1980s (e.g., Fresno Nationwide Urban Runoff Study) identified toxic substances associated with urban runoff in concentrations that could potentially impair beneficial uses of the American River. This concern resulted in the City and County of Sacramento undertaking urban runoff and receiving water quality studies to determine the extent of contamination, and the parameters of concern. Wet and dry weather stormwater monitoring has been conducted by these agencies in most years beginning in 1990. An Ambient Monitoring Program which seeks to characterize baseline water quality conditions in the lower American River (and Sacramento River) was initiated by these agencies in 1992. Before 1990, water quality monitoring was not conducted in the lower American River in a consistent or comprehensive manner.

## 4.2. CURRENT CONDITIONS

This section describes lower American River water quality as assessed by the primary water quality monitoring programs ongoing in the region. Monitoring results for approximately the last decade are summarized and compared to regulatory water quality criteria. In addition, this section provides an overview of the federal and state laws, regulations and regional plans that have established water quality standards applicable to the lower American River.

### 4.2.1. REGULATORY SETTING

#### 4.2.1.1. FEDERAL LAWS

**Clean Water Act**

The Clean Water Act (CWA, 33 U.S.C. Section 1251 et seq.) was last reauthorized in 1987. No substantive amendments have been made to the CWA since 1987. Under Section 303(d) of the CWA, states are required to identify waters within their boundaries for which technology-based effluent limitations[2] on point sources are not stringent enough to meet the applicable water quality standard for the receiving water. Once these waters are identified, states must then rank these waters, taking into account the severity of the pollution and the uses to be made of the identified waters.

California's regional 303(d) lists were prepared for each region of the state by the Regional Water Quality Control Boards (RWQCBs) in 1997. These lists were submitted for public review in early 1998 and, once finalized by the State Water Resources Control Board (SWRCB), the final California 303(d) list was submitted to the U.S. Environmental Protection Agency (EPA) on June 25, 1998. On November 3, 1998, EPA Region IX partially approved and partially disapproved of California's 303(d) list. The American River was not listed.

[2] The technology standards identified under this section are the Best Practicable Technology (BPT) control standards for industrial discharges (§301(b)(1)(A)) and secondary treatment requirements for municipal discharges (§301(b)(1)(B)).

For all waters identified by states (and in this case, EPA) pursuant to the 303(d) listing process, Total Maximum Daily Loads (TMDLs) must be established. TMDLs set the total amount of each pollutant, which can be discharged into a particular water body by all sources. The level set must protect the applicable water quality standards, taking into account seasonal variations and a margin of safety (CWA 303(d)(1)(C)).[3]

### Endangered Species Act

The Endangered Species Act (ESA, 16 U.S. Section 1531 et seq.) protects species of fish, wildlife, and plants that are in danger of, or threatened with, extinction. Section 7 of the Act requires that before taking any action that may adversely affect designated critical habitat, the USFWS or NMFS must be consulted. In order to promote recovery and protection of listed species, National Pollutant Discharge Elimination System (NPDES) permitting requirements may be adjusted.

On January 15, 1999, EPA published a Federal Register notice (64 *Federal Register* 2742-2757) that contained a Draft Memorandum of Agreement (MOA) between EPA, USFWS and NMFS regarding enhanced coordination under the CWA and the ESA. The proposed MOA would greatly expand the role that USFWS and NMFS play in the adoption of national water quality criteria and in the NPDES permitting processes. This expanded role might extend as far as giving the agencies essentially veto power over state water quality standards and NPDES permits that might be construed as adversely affecting (i.e., jeopardizing) threatened or endangered species. It is unclear what actions will be taken by EPA, USFWS and NMFS to amend the MOA prior to finalization of this document.

### The Magnuson-Stevens Fishery Conservation and Management Act

Among other things, the Magnuson-Stevens Fishery Conservation and Management Act of 1976 (Magnuson Act, 16 U.S.C.A. Section 180l et seq.) sets forth a national program for the conservation and management of the fishery resources of the United States to prevent overfishing, to rebuild overfished stocks, to ensure conservation, to facilitate long-term protection of essential fish habitats, and to realize the full potential of the Nation's fishery resources. NMFS has primary responsibility for implementing this Act. The emphasis of the Magnuson-Stevens Act is on coastal fisheries and anadromous fish populations. However, the Magnuson-Stevens Act has application to the inland stretches of the Sacramento River due to anadromous fish migration and spawning.

In 1996, the Sustainable Fisheries Act amended the Magnuson Fishery Conservation and Management Act (renamed the Magnuson-Stevens Fishery Conservation and Management Act). Sustainable Fisheries Act amendments and changes to the Magnuson Act include numerous provisions requiring science, management and conservation action by NMFS. NMFS was mandated to implement these changes and amendments by December 1998. This Act may bring NMFS into the NPDES permit review process where discharges are deemed to have the potential to affect an "essential fish habitat." As with the ESA, this Act may also result in a tightening of

[3] The "margin of safety" buffer takes into account any lack of scientific knowledge concerning the relationship between effluent limitations and water quality.

wastewater discharge restrictions or additional monitoring requirements in order to protect anadromous fish.

### 4.2.1.2. FEDERAL REGULATIONS

#### California Toxics Rule (CTR)

On August 5, 1997, EPA Region IX published the proposed CTR in the *Federal Register*. The CTR was intended to establish water quality standards for toxic pollutants (trace metals, pesticides, PCBs, other trace organics) for California that were not already addressed under the National Toxics Rule (NTR, 40 CFR §13l.36(d)(10)). The CTR was intended to put numeric toxic pollutant standards in place until the SWRCB reissues the statewide water quality control plans that were judicially overturned in 1994.

Some of the key elements of EPA's proposed CTR included:

- Amended numeric criteria for 30 toxic pollutants and new criteria for 8 toxic pollutants to protect aquatic life and human health uses;
- Criteria expressed as "dissolved" for most trace metals;
- Endorsement for the use of translator mechanisms;
- Compliance schedules of 3-10 years, providing time for permittees to meet new standards;
- Provision for establishment of mixing zones; and
- Allowing use of interim limits in NPDES permits.

Although neither the NTR nor the CTR directly affect NPDES permit requirements, both have the potential to contribute to significant regulatory requirements. EPA regulations require that the water quality criteria contained in the CTR and NTR be used to set new effluent limits. These regulatory requirements are dependent on the implementation of the NTR/CTR criteria by California's regulatory agencies. Use of these criteria in California's State Implementation Policy and RWQCB permitting processes are described in the State Law subsection set forth later in this section.

#### Draft Biological Opinion

On April 10, 1998, NMFS and USFWS issued a Draft Biological/Conference Opinion on the EPA's "Proposed Rule for the Promulgation of Water Quality Standards: Establishment of Numeric Criteria for Priority Toxic Pollutants for the State of California." This draft opinion declared that the proposed criteria for mercury, pentachlorophenol, selenium, and 8 metals (arsenic, nickel, cadmium, copper, lead, chromium III, chromium VI, and zinc) would jeopardize the continued existence of numerous endangered and threatened species. The draft opinion also proposed reasonable and prudent alternatives to avoid jeopardy, including alternative criteria. Because of this disagreement over the proposed criteria, EPA is currently in a formal consultation process with USFWS and NMFS. The issues in contention have been elevated to the headquarters level of all involved agencies for resolution. The final CTR is being held up pending the final determination on the criteria challenged in the draft Biological Opinion.

#### 4.2.1.3. EPA'S WATER QUALITY POLICIES

**Antidegradation Policy**

Differing from the two-pronged statutory definition of water quality standards (i.e., uses and criteria to protect uses), EPA defines state water quality standards as being three-pronged, comprised of water quality criteria, designated uses, and an antidegradation policy. 40 CFR §131.6. Federal water quality regulations require each state to adopt an "antidegradation" policy and to specify the minimum requirements for the policy (40 CFR Section 131.12). The SWRCB has interpreted State Water Board Resolution 68-16 to incorporate the federal antidegradation policy.

The SWRCB adopted State Water Board Resolution No. 68-16 on October 28, 1968. The goal of this policy is to maintain high quality waters where they exist in the State. Resolution No. 68-16 does not prohibit any reduction to existing water quality. Rather, the RWQCB applies Resolution No. 68-16 when considering whether to allow a certain degree of degradation to occur or remain. As stated in Resolution No. 68-16, whenever the existing quality of water is better than that defined by State water quality objectives and policies, such existing high water quality will be maintained until it has been demonstrated to the State that any change will: 1) be consistent with the maximum benefit to the people of the State; 2) not unreasonably affect present and anticipated beneficial use of such water; and 3) not result in water quality less than that prescribed in water quality control plans or policies (RWQCB, 1994). In addition, the discharger must apply best practicable treatment or control measures to assure that: 1) a pollution or nuisance will not occur; and 2) the highest water quality, consistent with the maximum benefit to the people of the State, will be maintained (RWQCB, 1994). Hence, for actions that produce significant changes in water quality, the State policy states that a showing must be made that such changes result in the maximum benefit to the people of the State and are necessary to the social and economic welfare of the community in order to be consistent with the antidegradation policies.

The Porter-Cologne Water Quality Control Act states that water quality objectives are to be established that " . . . will ensure the reasonable protection of beneficial uses of water or the prevention of nuisance within a specific area." The State Water Code further states that " . . . it may be possible for the quality of water to be changed to some degree without unreasonably affecting beneficial uses." This policy statement supports the position that some level of water quality change is allowable under the antidegradation policies. Additional guidance is expected via the TMDL regulations and guidance currently being prepared by EPA.

**EPA's Concept of Independent Applicability**

Of importance to any discussion of water quality or environmental criteria is EPA's independent applicability policy. This policy states that the failure to comply with any single criterion is cause to identify a water quality impairment, despite other evidence demonstrating compliance with the criteria. The policy presumes that all criteria are independently valid for the water body in question. For example, if toxicity tests or biological studies in a water body do not indicate a water quality problem, but a single chemical criterion is exceeded in the water column, the independent applicability policy says that the water body must be judged to be impaired. Thus, this policy places significant importance on each criterion proposed for a water body or ecosystem and places increased importance on the availability of accurate data. The future of this policy is uncertain, but it seems to remain intact as EPA recently requested comments on the future applicability of this policy as part of its Advanced Notice of Proposed Rule Making for Water Quality Standards. Additional guidance is expected via the TMDL regulations and guidance currently being prepared by EPA.

#### CALFED Bay-Delta Program

The mission of the CALFED Bay-Delta Program is to develop a long-term comprehensive plan that will restore ecological health and improve water management for beneficial uses of the Bay-Delta System. The California Environmental Quality Act (CEQA) Bay-Delta Program is managed by an interdisciplinary, interagency staff team and is assisted by technical experts from state and federal agencies as well as consultants. The CALFED Bay-Delta Program is carrying out a three-phase process to achieve broad agreement on long-term solutions. First, a clear definition of the problems to be addressed and a range of solution alternatives was developed. Second, to comply with CEQA and the National Environmental Policy Act (NEPA), a first-tier Environmental Impact Report (EIR) and Environmental Impact Statement (EIS) was prepared to identify impacts associated with the various alternatives selected. Finally, a project-level or second-tier EIR/EIS will be prepared for each element of the selected alternative. The first phase of work for the CALFED Bay-Delta Program developed three alternatives, which are the focus and content of the EIR/EIS issued in March of 1998. The alternatives selected give different options for achieving long-term solutions to the problems of the Bay-Delta Estuary; each contains a water quality element that is common to all three proposed alternatives. The implementation of this element may have an effect on the monitoring being performed in the Sacramento River watershed, particularly with respect to drinking water constituents of concern.

### 4.2.1.4. STATE LAWS

#### Porter-Cologne Water Quality Control Act

The California Legislature enacted the Porter-Cologne Water Quality Control Act (Cal. Water Code §13000 et seq.) in 1969. The Porter-Cologne Act provided a comprehensive management system that relied primarily on the permitting of point sources as its control mechanism.

The Porter-Cologne Act applies to point and non-point discharge sources to surface and ground waters, and to waste discharges to land. The Porter-Cologne Act creates a water quality control program administered regionally yet overseen through statewide coordination and policy. The SWRCB provides program guidance and oversight to the Regional Boards through adoption of statewide regulations, plans, policies, and administrative procedures. The SWRCB and Regional Boards carry out their water protection authority through specific Water Quality Control Plans or "Basin Plans" which: (1) designate beneficial uses; (2) set water quality objectives to protect beneficial uses; and (3) establish programs to achieve these objectives. Such plans may include prohibitions against the discharge of certain types of waste in specific areas under specified conditions. Discharge prohibitions may be adopted for non-point sources, such as surface runoff or waste discharge to land, or for direct discharges to surface or groundwater. The Porter-Cologne Act also requires the SWRCB to adopt a "State Policy for Water Quality Control," including water quality objectives directly affecting water projects.

The SWRCB and Regional Boards regulate activities affecting water quality and implement water quality control plans through the issuance of Waste Discharge Requirements (WDRs).

Any person discharging waste or proposing to discharge waste that could affect the quality of waters of the State, other than discharge into a community sewer system, must submit a Report of Waste Discharge to the Regional Board unless the Regional Board waives the filing of a report. WDRs serve as NPDES permits required under the federal CWA (discussed above).

The Porter-Cologne Act provides Regional Boards with additional enforcement powers to address unauthorized discharges, discharges violating WDRs or prohibitions of discharge, violations of reporting or monitoring requirements, or other activities that threaten water quality. The SWRCB may use its water rights authority to enforce requirements for the protection of water quality.

In addressing non-point source problems, the SWRCB and Regional Boards generally use three management approaches: (1) voluntary implementation of Best Management Practices (BMPs); (2) regulatory-based encouragement for BMP implementation; and (3) effluent requirements. The Regional Boards decide which option(s) to use to address particular problems. The Regional Boards generally refrain from imposing effluent requirements on dischargers that implement BMPs in accordance with an SWRCB or Regional Board order.

### SWRCB Statewide Plans

In 1991, the SWRCB adopted statewide water quality control plans (the Inland Surface Waters Plan [ISWP] and the Enclosed Bays and Estuaries Plan [EBEP]) for the control of toxic pollutants. These plans established numeric objectives for toxic pollutant and toxicity in California waters. In 1994, a Superior Court in Sacramento ruled that the plans had not been adopted in conformance with three state laws (the Porter Cologne Act, CEQA, and the Administrative Procedures Act) and required that the SWRCB rescind the statewide plans. In September 1994, the SWRCB withdrew the statewide plans and initiated actions to reformulate the plans.

The reformulated statewide plans are currently under development using a phased approach. As part of the reformulation process, the SWRCB coordinated eight public task forces to receive input from stakeholder groups to use in the development of the draft plans. The stakeholder groups represented on the task forces included publicly-owned treatment works, industry, agriculture, water supply, storm water, environmental groups, EPA, SWRCB, RWQCBs, public health agencies, fish and wildlife agencies, and the California Departments of Pesticide Regulation and of Food and Agriculture. Each of the task forces published final reports containing recommendations for action in the statewide plan readoption process.

### Draft State Implementation Policy (ISWP/EBEP) – Phase 1

On September 11, 1997, the SWRCB issued the "Draft Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays and Estuaries of California and the Functional Equivalent Document" (State Implementation Policy) for public review and comment. The Draft State Implementation Policy contained provisions for implementing the pollutant criteria promulgated by EPA in the CTR, the NTR, and the water quality objectives adopted by the RWQCBs in their respective Basin Plans. The State Implementation Policy also provides monitoring and source identification requirements for dioxin (2,3,7,8-TCDD equivalents), and chronic toxicity control provisions. The comment period for this draft policy closed on December 12, 1997.

Although issued as a "policy," the provisions of this document, once adopted, will have full regulatory effect. This document sets rules for establishing water quality-based effluent limitations for priority pollutant criteria/objectives. The following issues related to effluent limitations are addressed: selecting pollutants for regulation in NPDES permits; calculating water quality-based effluent limitations; translators for metals and selenium; mixing zones and dilution credits; chronic toxicity objectives; ambient background concentrations; and intake water credits.

The Draft State Implementation Policy requires that all effluent limitations protect beneficial uses, comply with antidegradation and antibacksliding requirements, and other applicable provisions of law. The SWRCB is making revisions to the Draft SIP and plans to reissue the policy within several months of the adoption of the CTR.

Once approved, the implementation procedures outlined in the State Implementation Policy could require water quality-based effluent limitations to be established for any constituent for which the ambient or effluent concentration exceeds the lowest applicable criteria in the CTR or NTR. Effluent limitations could also be required for any constituent whose effluent concentration exceeds the ambient background concentration. Therefore, accurate assessments of the ambient background concentrations of the constituents of concern are imperative to this process.

#### State Implementation Policy – Phase 2

In Phase 2 of the ISWP/EBEP re-adoption process, the SWRCB plans to develop and formally adopt the state's ISWP and EBEP. These final statewide plans will:

- Incorporate by reference existing basin plan beneficial uses;
- Establish state-adopted water quality objectives (the CTR criteria will be included among the alternatives considered in establishing these objectives); and
- Incorporate the Phase 1 implementation policy, with appropriate modifications.

### 4.2.1.5. Regional Activities

#### Water Quality Control Plan for the Sacramento-San Joaquin River Basins (Basin Plan)

Designated beneficial uses of water bodies, together with their corresponding water quality objectives, can be defined per federal regulations as water quality standards. Water quality objectives are established by the State in various plans to protect designated beneficial uses of a water body consistent with applicable provisions of Section 303 of the federal CWA and the State's Porter-Cologne Water Quality Control Act.

The Water Quality Control Plan for the Sacramento-San Joaquin River Basins (Basin Plan), adopted by the RWQCB on December 9, 1994, and approved by the SWRCB on February 16, 1995, provides water quality objectives and standards for waters of the Sacramento River and San Joaquin River Basins. The Basin Plan contains specific numeric water quality objectives for bacteria, dissolved oxygen (DO), pH, pesticides, electrical conductivity (EC), total dissolved solids (TDS), temperature, turbidity, and trace elements, as well as numerous narrative water quality objectives that are applicable to certain water bodies or portions of water bodies.

The lower American River has numerous beneficial uses. State law defines beneficial uses of California's waters as uses that may be protected against quality degradation (Water Code Section 13050(f)). The following existing and potential beneficial uses have been defined by the Central Valley Regional Water Quality Control Board (CVRWQCB) for the lower American River (RWQCB, 1994):

- Municipal, domestic, and industrial water supply;
- Irrigation;
- Power;
- Water contact and non-contact recreation;
- Warm and cold freshwater habitat, warm freshwater spawning habitat;
- Wildlife habitat;
- Recreational canoeing and rafting;
- Warm and cold fish migration habitat; and
- Cold spawning habitat.

#### Fish Consumption Advisories

The San Francisco RWQCB, along with the SWRCB and the CDFG, performed a pilot study to measure contaminants in edible fish tissue from species caught by anglers in the San Francisco Bay. A total of 16 geographic areas and 66 composites of fish tissue were sampled. The results showed the following 6 chemicals of concern relating to fish consumption: PCBs (total aroclors), mercury, dieldrin, total chlordanes, total DDTs, and total dioxin/furans. The Office of Environmental Health Hazard Assessment used the results of this study to adopt fish consumption advisories for the San Francisco Bay. It should be noted that these fish advisories were the basis for listing many waterbodies as impaired under Section 303(d) of the CWA. Because of this listing, TMDLs will be required for each of the constituents of concern.

### 4.2.2. COMPREHENSIVE MONITORING PROGRAMS

The monitoring programs described in this section include one or more of the following components:

- Measurement of levels of contaminant of concern (COC);
- Toxicity testing; and
- Assessments of aspects of the overall ecosystem.

How these three components relate to the health of aquatic life is described briefly below.

*Mercury and organics*. Mercury and certain organic contaminants (including DDT and PCBs) readily accumulate in the food web, resulting in concentrations in fish tissue that may be of concern to humans and wildlife. Monitoring levels of these pollutants in fish provides an effective way to assess the degree of contamination of a river system. Because fish accumulate contaminants throughout their life span and their habitat, measurements of contaminant concentrations in fish tissue provide an indication of average conditions over space and time. Fish tissue data can be useful in the determination of long-term levels and trends of bioaccumulative contaminants (such as mercury, DDT and PCBs) in the watershed. This long-term data can be used to measure the effectiveness of activities to control these pollutants. As described later in this section, concentrations of mercury and a few organics are at levels of concern in the lower American River.

*Trace metals*. Low levels of trace metals in water can affect the growth, reproduction and/or survival of sensitive aquatic species. Trace metals of potential concern to aquatic life in the Sacramento River system include copper, cadmium, zinc, lead, chromium (VI), selenium, silver, nickel, and arsenic (LWA, 2000).

*Toxicity in water and sediment*. Ambient samples of water and sediment can be tested in the laboratory for toxicity to provide an indication of the conditions that exist in the natural environment. Standard test species and test procedures are used to provide reliable and comparable results. Toxicity is deemed to occur when test species are significantly affected by exposure to ambient water or sediment as compared to laboratory controls. Toxic effects may include reduced growth or reproduction, increased abnormalities, or increased mortality of test species. Effects may occur rapidly over a period of hours (acute toxicity) or may occur over a longer period of days or weeks (chronic toxicity). As described later in the section lower American River samples have exhibited toxicity to indicator species.

*General constituents* (*suspended and dissolved solids, hardness, turbidity, minerals, and nutrients*). These conventional water quality characteristics are important to the evaluation of the attainment of a variety of uses, including drinking water supply, recreation, aesthetics, aquatic habitat, and agricultural supply. Concentrations of general constituents are not at levels of concern to aquatic life in the lower American River.

*Benthic invertebrates*. Benthic invertebrates are the aquatic insects and other organisms that live along the bottom of water bodies. Procedures have been developed and recently refined to standardize the assessment of biological habitat and benthic communities for use as a monitoring tool (Plafkin et al. 1989; CDFG 1996; DWR 1997). Information on invertebrate diversity, abundance, species richness, and other community metrics collected at specific sites is compared against expected conditions (or reference stream conditions) to evaluate the relative health of the biological community at that location. This information is used in combination with chemical concentration and toxicity data to assess ecosystem conditions at various locations. Different procedures are used depending on the characteristics of the stream (i.e., wadable versus non-wadable).

*Algae*. Levels of algae in surface waters may be used to assist in evaluating the health of an ecosystem. Community analysis of algal species is used in a fashion similar to benthic invertebrate data. Species diversity, number of species, presence of sensitive species and other measures are used in the evaluation. Elevated algal levels indicate a biologically productive, organically enriched aquatic environment. Detrimental effects of elevated algal levels may include poor water clarity, aesthetic impairment, reduced dissolved oxygen levels and degraded drinking water quality. Data on community parameters and algal biomass can be used to assess beneficial use issues and to establish a baseline for future trend monitoring.

#### 4.2.2.1. SACRAMENTO COORDINATED WATER QUALITY MONITORING PROGRAM (CMP)

The Sacramento Coordinated Monitoring Program (CMP) was initiated and implemented by the Sacramento Regional County Sanitation District, the City of Sacramento, and the County of Sacramento Water Resources Division (County) in 1991. These three public agencies are responsible for the management of all municipal wastewater and most stormwater in the Sacramento urban area within Sacramento County. The Ambient Monitoring Program (AMP) was established under the CMP to characterize ambient water quality conditions in the Sacramento and American rivers. Water quality samples for the AMP have been obtained from sampling sites within the greater Sacramento County area since December 1992.

Five river sites are now monitored under the AMP, three on the Sacramento River at Veteran's Bridge (near Alamar Marina), at Freeport Bridge, and at River Mile 44 downstream of the Sacramento metropolitan area) and two on the American River (at Nimbus Dam and at Discovery Park near the confluence with the Sacramento River). The monitoring sites have been selected to provide water quality data upstream and downstream of the influence of urban inputs from the Sacramento community. Locations of these sites are shown on **Figure 4-1**.

Before October 1995, the American River was also monitored near Folsom Dam, but this site was discontinued in 1996 because there were insignificant differences between the Folsom Dam and Nimbus results. From December 1992 to September 1995, the sampling frequency was twice per month at each station because there were insignificant differences between the Folsom Dam and Nimbus results. Beginning in October 1995, the sampling frequency was changed to once per month. The historic emphasis of the AMP has been on trace metals monitoring (total recoverable and dissolved metals) using clean techniques and low detection limits. Other parameters monitored under the AMP include organophosphate pesticides (diazinon, chlorpyrifos), total and fecal coliform bacteria, fecal streptococci, total organic carbon, dissolved organic carbon, pH, temperature, DO, hardness, total suspended solids (TSS), and EC. Monitoring of trace organics began during 1998/1999. Monitoring of four trace elements (antimony, selenium, silver, and thallium) was discontinued in October 1995, reducing the number of trace elements monitored to eight.

**Results**

The CMP 1998 annual report (SRCSD, 1999) presents an evaluation of results from AMP sampling efforts for the period December 1992 through December 1998 (108 sampling events). The evaluation of the ambient data characterizes water quality conditions, identifies important spatial and temporal patterns, and determines compliance with projected water quality objectives. Evaluation methodology and time series plots for the lower American River sites are presented in Appendix A of the CMP 1998 annual report.

**Figure 4-1. Lower American River monitoring sites of water quality and fish tissue monitoring programs.**

The AMP results for the lower American River for the period December 1992 to December 1998 are presented in **Table 4-1** and **Table 4-2**, with comparisons to regulatory criteria presented in **Table 4-3** and **Table 4-4**. The data were compared to the lowest objective or criterion for the protection of human health or aquatic life from the (then) proposed CTR, the Basin Plan, or other regulatory water quality limits. The ambient water quality characteristics of the American River are summarized as follows:

**Table 4-1. Summary statistics for CMP water quality data (1992-1998): American River at Nimbus.**

| Analyte | Fraction (a) | Units | n (b) | Number detected (c)[c] | Percent detected (d) | max (e) | min (f) | Geometric or arithmetic mean[g] | 95% UL[h] | 95% LL[i] |
|---|---|---|---|---|---|---|---|---|---|---|
| antimony | dissolved | µg/L | 28 | 0 | 0 | <3 | <3 | id | id | id |
| antimony | total recoverable | µg/L | 28 | 0 | 0 | <3 | <3 | id | id | id |
| arsenic | dissolved | µg/L | 54 | 1 | 2 | <1 | <1 | id | id | id |
| arsenic | total | µg/L | 96 | 42 | 44 | 2.9 | 0.08 | 0.31 | 0.36 | 0.27 |
| cadmium | dissolved | µg/L | 103 | 13 | 13 | 0.07 | 0.01 | id | id | id |
| cadmium | total recoverable | µg/L | 103 | 26 | 25 | 5.1 | 0.01 | id | id | id |
| chromium | dissolved | µg/L | 0 | 0 | 0 | 0 | 0 | id | id | id |
| chromium | total recoverable | µg/L | 105 | 47 | 45 | 41 | 0.09 | 0.34 | 0.41 | 0.29 |
| copper | dissolved | µg/L | 104 | 77 | 74 | 1.9 | 0.21 | 0.54 | 0.59 | 0.50 |
| copper | total recoverable | µg/L | 105 | 95 | 90 | 4.3 | 0.27 | 0.74 | 0.82 | 0.67 |
| cyanide | total | µg/L | 38 | 0 | 0 | <2 | <2 | id | id | id |
| lead | dissolved | µg/l | 105 | 15 | 14 | 0.2 | 0.1 | id | id | id |
| lead | total recoverable | µg/L | 105 | 53 | 50 | 1.4 | 0.1 | 0.094 | 0.115 | 0.078 |
| mercury | dissolved | ng/L | 79 | 70 | 89 | 4.43 | 0.29 | 0.97 | 1.12 | 0.84 |
| mercury | total | ng/L | 79 | 79 | 100 | 15.4 | 0.74 | 2.24 | 2.59 | 1.94 |
| nickel | dissolved | µg/L | 46 | 8 | 17 | 1.9 | 0.34 | id | id | id |
| nickel | total recoverable | µg/L | 85 | 55 | 65 | 30 | 0.21 | 0.79 | 0.97 | 0.64 |
| selenium | dissolved | µg/l | 28 | 0 | 0 | <1 | <1 | id | id | id |
| selenium | total recoverable | µg/L | 29 | 0 | 0 | <1 | <1 | id | id | id |
| silver | dissolved | µg/L | 47 | 9 | 19 | 0.06 | 0.02 | id | id | id |
| silver | total recoverable | µg/L | 48 | 15 | 31 | 0.07 | 0.02 | id | id | id |
| thallium | dissolved | µg/L | 28 | 0 | 0 | <2.5 | <1 | id | id | id |
| thallium | total recoverable | µg/L | 28 | 0 | 0 | <2.5 | <1 | id | id | id |
| zinc | dissolved | µg/L | 105 | 30 | 29 | 68 | 0.11 | id | id | id |
| zinc | total recoverable | µg/L | 105 | 56 | 53 | 60 | 0.1 | 0.89 | 1.26 | 0.63 |
| hardness | total, as $CaCO_2$ | mg/L | 83 | 83 | 100 | 64 | 4 | 26.0A | 28.1 | 23.9 |
| TSS | n/a | mg/L | 104 | 53 | 51 | 68 | 1 | 1.20 | 1.62 | 0.89 |
| DOC | n/a | mg/L | 47 | 1 | 2 | 2 | 2 | id | id | id |
| TOC | n/a | mg/L | 47 | 2 | 4 | 3.5 | 2 | id | id | id |
| chlorpyrifos | n/a | µg/L | 19 | 0 | 0 | <.05 | <.004 | id | id | id |
| diazinon | n/a | µg/L | 24 | 0 | 0 | <.01 | <.002 | id | id | id |
| fecal coliform | n/a | MPN/100 mL | 25 | 25 | 100 | 170 | 4 | 35 | 48 | 25 |
| total coliform | n/a | MPN/100 mL | 25 | 25 | 100 | 500 | 13 | 79 | 118 | 53 |
| fecal strep | n/a | MPN/100 mL | 4 | 4 | 100 | 170 | 8 | id | id | id |
| temperature | n/a | ÞC | 99 | 99 | 100 | 21.8 | 7.04 | 13.1A | 13.8 | 12.4 |
| DO | n/a | mg/L | 94 | 94 | 100 | 13.63 | 6.1 | 10.3A | 10.7 | 9.9 |
| pH | n/a | std. units | 104 | 104 | 100 | 8.46 | 5.82 | 7.09A | 7.19 | 6.99 |
| EC | n/a | µmhos/cm | 101 | 101 | 100 | 123 | 18.5 | 52.2A | 55.2 | 49.2 |

(a) Indicates whether value apply to total, total recoverable, or dissolved fraction
(b) Number of samples analyzed
(c) Number of samples in which analyte was detected.
(d) Percent of samples in which analyte was detected.
(e) Maximum detected value reported, or maximum detection limit.
(f) Minimum detected value reported, or minimum detection limit.
(g) Geometric or arithmetic mean, "A" indicates arithmetic mean is reported; Statistic reported only for analytes detected in ≥35% of samples and n≥10;"id" indicates insufficient data to accurately calculate statistic.
(h) 95% upper confidence limit for mean statistic
(i) 95% lower confidence limit for mean statistic.

Source: LWA, 1999

**Table 4-2. Summary statistics for CMP water quality data (1992-1998): American River at Discovery Park.**

| analyte | fraction (a) | Units | n (b) | Number detected (c)[c] | Percent detected (d) | max (e) | min (f) | Geometric or arithmetic mean[g] | 95% UL[h] | 95% LL[i] |
|---|---|---|---|---|---|---|---|---|---|---|
| antimony | dissolved | μg/L | 28 | 0 | 0 | <3 | <3 | id | id | id |
| antimony | total recoverable | μg/L | 28 | 0 | 0 | <3 | <3 | id | id | id |
| arsenic | dissolved | μg/L | 56 | 1 | 2 | 1.1 | 1.1 | id | id | id |
| arsenic | total | μg/L | 98 | 41 | 42 | 1.23 | 0.07 | id | id | id |
| cadmium | dissolved | μg/L | 103 | 16 | 16 | 0.05 | 0.01 | id | id | id |
| cadmium | total recoverable | μg/L | 104 | 33 | 32 | 3.3 | 0.01 | 0.004 | 0.007 | 0.003 |
| chromium | dissolved | μg/L | 59 | 0 | 0 | <1 | <1 | id | id | id |
| chromium | total recoverable | μg/L | 106 | 47 | 44 | 2.2 | 0.13 | 0.39 | 0.45 | 0.34 |
| copper | dissolved | μg/L | 104 | 84 | 81 | 1.9 | 0.29 | 0.59 | 0.64 | 0.55 |
| copper | total recoverable | μg/L | 106 | 102 | 96 | 3.6 | 0.4 | 0.88 | 0.97 | 0.81 |
| cyanide | total | μg/L | 39 | 0 | 0 | <2 | <2 | id | id | id |
| lead | dissolved | μg/l | 105 | 20 | 19 | 0.5 | 0.1 | id | id | id |
| lead | total recoverable | μg/L | 106 | 89 | 84 | 1.3 | 0.1 | 0.18 | 0.21 | 0.15 |
| mercury | dissolved | ng/L | 75 | 69 | 92 | 3.89 | 0.07 | 1.26 | 1.47 | 1.08 |
| mercury | total | ng/L | 79 | 79 | 100 | 13.3 | 1.1 | 3.17 | 3.62 | 2.78 |
| nickel | dissolved | μg/L | 48 | 4 | 8 | 1.1 | 0.43 | id | id | id |
| nickel | total recoverable | μg/L | 87 | 58 | 67 | 8 | 0.18 | 0.81 | 0.94 | 0.69 |
| selenium | dissolved | μg/l | 29 | 0 | 0 | <1 | <1 | id | id | id |
| selenium | total recoverable | μg/L | 30 | 2 | 7 | 1.2 | 1 | id | id | id |
| silver | dissolved | μg/L | 49 | 8 | 16 | 0.2 | 0.02 | id | id | id |
| silver | total recoverable | μg/L | 50 | 18 | 36 | 0.1 | 0.02 | 0.012 | 0.009 | 0.016 |
| thallium | dissolved | μg/L | 29 | 0 | 0 | <2.5 | <1 | id | id | id |
| thallium | total recoverable | μg/L | 29 | 0 | 0 | <2.5 | <1 | id | id | id |
| zinc | dissolved | μg/L | 105 | 35 | 33 | 11 | 0.11 | id | id | id |
| zinc | total recoverable | μg/L | 106 | 61 | 58 | 230 | 0.18 | 1.43 | 1.91 | 1.07 |
| hardness | total as $CaCO_2$ | mg/L | 86 | 86 | 100 | 52 | 14 | 24.9A | 26.5 | 23.3 |
| TSS | n/a | mg/L | 105 | 73 | 70 | 41 | 1 | 2.45 | 3.13 | 1.92 |
| DOC | n/a | mg/L | 50 | 4 | 8 | 3 | 2 | id | id | id |
| TOC | n/a | mg/L | 49 | 2 | 4 | 2.9 | 2 | id | id | id |
| chlorpyrifos | n/a | μg/L | 18 | 0 | 0 | <.05 | <.025 | id | id | id |
| diazinon | n/a | μg/L | 21 | 5 | 24 | 0.03 | 0.01 | id | id | id |
| fecal coliform | n/a | MPN/100 mL | 25 | 25 | 100 | 3000 | 12 | 62 | 97 | 40 |
| total coliform | n/a | MPN/100 mL | 25 | 25 | 100 | 16000 | 50 | 332 | 565 | 195 |
| fecal strep | n/a | MPN/100 mL | 4 | 4 | 100 | 500 | 16 | id | id | id |
| temperature | n/a | ρC | 101 | 101 | 100 | 24.4 | 7.6 | 13.9A | 14.7 | 13.1 |
| DO | n/a | mg/L | 99 | 99 | 100 | 15.21 | 6.18 | 10.1A | 10.4 | 9.8 |
| pH | n/a | std. units | 100 | 100 | 100 | 8.62 | 6.37 | 7.27A | 7.36 | 7.18 |
| EC | n/a | μmhos/cm | 101 | 100 | 100 | 100 | 17 | 52.0A | 55.0 | 49.0 |

(a) Indicates whether value apply to total, total recoverable, or dissolved fraction
(b) Number of samples analyzed
(c) Number of samples in which analyte was detected.
(d) Percent of samples in which analyte was detected.
(e) Maximum detected value reported, or maximum detection limit.
(f) Minimum detected value reported, or minimum detection limit.
(g) Geometric or arithmetic mean, “A” indicates arithmetic mean is reported; Statistic reported only for analytes detected in ≥35% of samples; “id” indicates insufficient data to accurately calculate statistic.
(h) 95% upper confidence limit for mean statistic
(i) 95% lower confidence limit for mean statistic.

Source: SRCSD, 1999.

**Table 4-3. CMP water quality data (1992-1998) - comparisons with projected water quality limits: American River at Nimbus Dam.**

| Parameter | Fraction (a) | Units | Water Quality Limits (b) | | | Minimum limit (c) | Probability of meeting limit (d) |
|---|---|---|---|---|---|---|---|
| | | | CTR | BP | Other | | |
| arsenic | dissolved | μg/L | - | 10 | - | 10 | OK |
| arsenic | total | μg/l | 150 | - | 50(EPA) | 50 | 100.00% |
| cadmium | dissolved | μg/l | 0.83 | - | - | 0.83 | 100.00% |
| cadmium | total recoverable | μg/l | - | - | 5 (EPA) | 5.0 | 99.84% |
| chromium (iii) | dissolved | μg/l | 59 | - | - | 59 | OK |
| chromium (iii) | total recoverable | μg/l | - | - | 50 (DHS) | 50 | 100.00% |
| copper | dissolved | μg/l | 2.8 | 10 | - | 2.8 | 100.00% |
| copper | total recoverable | μg/l | - | - | 1000(LCR) | 1000 | 100.00% |
| lead | dissolved | μg/l | 0.57 | - | - | 0.57 | 99.99% |
| lead | total recoverable | μg/l | - | - | 15(LCR) | 15 | 100.00% |
| mercury | total | ng/l | 50 | - | 2000(EPA) | 50 | 100.00% |
| nickel | dissolved | μg/l | 17 | - | - | 17 | OK |
| nickel | total recoverable | μg/l | - | - | 100(EPA) | 100 | 100.00% |
| zinc | dissolved | μg/l | 38 | 100 | - | 38 | 99.97% |
| zinc | total recoverable | μg/l | - | - | 5000(DHS) | 5000 | 100.00% |
| TOC | - | mg/l | - | - | 2(DBP) | 2 | >WQC |
| chlorpyrifos | - | μg/l | - | - | 0.02(DFG) | 0.02 | OK |
| diazinon | - | μg/l | - | - | 0.04(DFG) | 0.04 | OK |
| fecal coliform | | MPN/100mL | - | 200 | 200(DHS) | 200 | 98.72% |
| total coliform | - | MPN/100mL | - | - | 1000(DHS) | 1000 | 99.53% |
| DO | - | mg/L | - | 7 | - | 7 | 96.18% |
| pH | - | std. Units | - | 6.5-8.5 | | 6.5-8.5 | 86.43% |
| EC | - | μmhos/cm | - | 240 | - | 240 | 100.00% |

(a) Indicates whether criterion and statistics are based on total, total recoverable, or dissolved fraction.
(b) The lowest objective or criterion for the protection of human health or aquatic life from the proposed California Toxics Rule (CTR) and the Central Valley Region Basin Plan (BP). Other water quality limits provided for comparison include: Safe Drinking Water Act MCLs (EPA), California Department of Health Services Guidance Levels(DHS); Lead and Copper Rule Action levels (LCR), Department of Fish and Game Guidance Levels (DFG); and Disinfection/Disinfection By-Product Rule (DBP) treatment threshold for TOC - indicates there is no applicable limit.
(c) Lowest applicable water quality limit.
(d) Estimated probability of meeting minimum applicable water quality limit; One exceedance in three years is equivalent to 99.91% compliance; Estimates are based on lognormal distribution; Results with parameters with less than 10 percent detected data are reported as follows:
1) "OK" when max <0.2 x water quality limit.
2) ">WQC" when max > water quality limit.
3) "id" (insufficient detected data ) when 0.2 x limit < maximum detected value < water quality limit.

Source: SRCSD, 1999.

**Table 4-4. CMP water quality data (1992-1998) - comparisons with projected water quality limits: American River at Discovery Park.**

| Parameter | Fraction (a) | units | Water Quality Limits (b) | | | Minimum limit (c) | Probability of meeting limit (d) |
|---|---|---|---|---|---|---|---|
| | | | CTR | BP | Other | | |
| arsenic | dissolved | μg/L | - | 10 | - | 10 | OK |
| arsenic | total | μg/l | 150 | - | 50(EPA) | 50 | 100.00% |
| cadmium | dissolved | μg/l | 0.8 | - | - | 0.80 | 100.00% |
| cadmium | total recoverable | μg/l | - | - | 5 (EPA) | 5.0 | 99.91% |
| chromium (iii) | dissolved | μg/l | 57 | - | - | 57 | OK |
| chromium (iii) | total recoverable | μg/l | - | - | 50 (DHS) | 50 | 100.00% |
| copper | dissolved | μg/l | 2.7 | 10 | - | 2.7 | 99.99% |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| copper | total recoverable | μg/l | - | - | 1000(LCR) | 1000 | 100.00% |
| lead | dissolved | μg/l | 0.5 | - | - | 0.54 | 99.75% |
| lead | total recoverable | μg/l | - | - | 15(LCR) | 15 | 100.00% |
| mercury | total | ng/l | 50 | - | 2000(EPA) | 50 | 100.00% |
| nickel | dissolved | μg/l | 16 | - | - | 16 | OK |
| nickel | total recoverable | μg/l | - | - | 100(EPA) | 100 | 100.00% |
| zinc | dissolved | μg/l | 36 | 100 | - | 36 | 99.99% |
| zinc | total recoverable | μg/l | - | - | 5000(DHS) | 5000 | 100.00% |
| TOC | - | mg/l | - | - | 2(DBP) | 2 | >WQC |
| chlorpyrifos | - | μg/l | - | - | 0.02(DFG) | 0.02 | OK |
| diazinon | - | μg/l | - | - | 0.04(DFG) | 0.04 | id |
| fecal coliform | | MPN/100mL | - | 200 | 200(DHS) | 200 | 86.28% |
| total coliform | - | MPN/100mL | - | - | 1000(DHS) | 1000 | 80.36% |
| DO | - | mg/L | - | 7.0 | - | 7 | 98.38% |
| pH | - | std. Units | - | 6.5-8.5 | | 6.5-8.5 | 95.59% |
| EC | - | μmhos/cm | - | - | - | 240 | 100.00% |

(a) Indicates whether criterion and statistics are based on total, total recoverable, or dissolved fraction.
(b) The lowest objective or criterion for the protection of human health or aquatic life from the proposed California Toxics Rule (CTR) and the Central Valley Region Basin Plan (BP). Other water quality limits provided for comparison include: Safe Drinking Water Act MCLs (EPA), California Department of Health Services Guidance Levels(DHS), Lead and Copper Rule Action levels (LCR), Department of Fish and Game Guidance Levels (DFG), and Disinfection/Disinfection By-Product Rule (DBP) treatment threshold for TOC.
- indicates there is no applicable limit.
(c) Lowest applicable water quality limit
(d) Estimated probability of meeting minimum applicable water quality limit.
One exceedance in three years is equivalent to 99.91% compliance
Estimates are based on lognormal distribution.
Results for parameters with less than 10 percent detected data are reported as follows:
1) "OK" when: max <0.2 x water quality limit;
2) ">WQC" when: max > water quality limit;
3) "id" (insufficient detected data ) when: 0.2 x limit < maximum detected value < water quality limit.

Source: SRCSD, 1999.

- With few exceptions, ambient water quality characteristics monitored by the AMP meet applicable regulatory standards. Although observed mercury concentrations meet regulatory criteria proposed in the August 1997 CTR (50 ng/l total mercury), detected levels would frequently exceed the existing EPA water quality criterion for human health (equal to or less than 12 ng/l). The CTR criterion finally adopted is likely to be equal to or lower than the EPA criterion. (The criterion for mercury is still pending in the Final Rule adopted May 18, 2000.)
- Unlike the Sacramento River, water quality of the lower American River is not greatly influenced by changes in flow.
- Concentrations of chromium, copper, lead, mercury, zinc, diazinon, total coliform bacteria, temperature, pH, EC, and TSS increased between Nimbus and Discovery Park. In all cases, these changes were small as a percentage of observed concentrations. With the possible exceptions of mercury, diazinon, and coliform bacteria, the observed changes in water quality do not appear to be of regulatory or environmental significance.
- Rainfall events—and by extension, urban stormwater runoff—appeared to have some impact on changes in downstream ambient water quality characteristics for a few parameters. At Discovery Park, dissolved zinc concentrations and diazinon were observed to increase significantly only during rain events, and temperature was observed to increase only during non-rain events. The wet weather increases in American River diazinon concentrations and total coliform numbers may be of some regulatory significance.

Statistically significant differences were observed for fifteen water quality parameters in the American River between Nimbus and Discovery Park (**Table 4-5**). Dissolved and/or total concentrations of chromium, copper, lead, mercury, and zinc, total coliform bacteria, temperature, pH, EC, and TSS were all consistently higher at Discovery Park, and in general, average values for these parameters were also greater at Discovery Park. DO was the only parameter for which statistically significant decreases were observed at Discovery Park. Changes in concentrations of dissolved zinc, diazinon, and numbers of total coliform bacteria were significantly affected by the occurrence of rainfall, with significantly greater increases in the concentrations of these parameters on sample event days with rainfall. Increases in temperature were significantly greater on days without rainfall.

In general, the observed increases in pollutant concentrations in the American River are consistent with the existence of sources of these pollutants in the Sacramento metropolitan area. Based on the analyses summarized herein, there is also evidence that wet weather runoff is a significantly greater source of zinc, diazinon, and total coliform bacteria than dry weather runoff. Changes observed for most parameters were small relative to water quality criteria and appeared to have little practical or regulatory significance. However, for mercury, diazinon, and total coliform bacteria, the observed changes in downstream water quality may be of some regulatory significance. The regulatory significance of the observed increase in mercury concentrations depends largely on the CTR criterion that is finally adopted. Compliance with the currently proposed CTR criterion (50 ng/L) and the existing EPA human health criterion (12 ng/L) for mercury is high in the American River in the CMP study area (see Table 4-3 and Table 4-4). However, the CTR criterion finally adopted may be significantly more stringent, and it is possible that the increase in total mercury concentrations may be considered to be contributing to excursions above the water quality criterion. The increases in diazinon concentration may have some regulatory significance because diazinon is a constituent of concern for the Sacramento Comprehensive Stormwater Management Program. Diazinon is also cited as the cause for listing Delta waterways and several urban runoff-affected water bodies in the Sacramento area on the RWQCB's 1998 303(d) list of impaired California water bodies.

The increases in coliform bacteria (especially during wet weather) may also be of regulatory significance because conformance with the Department of Health Services guidance level for total coliform bacteria (1000 most probable number (MPN)/100 ml) was reduced from greater than 99% at Nimbus Dam to approximately 80% at Discovery Park.

**Table 4-5. Statistically significant changes in downstream water quality in the CMP study area, 1992-1998 monitoring data.**

| | | Estimated Mean Differences (a) | | |
|---|---|---|---|---|
| | | American River | Sacramento River | |
| Parameter | Units | Discovery Park | Freeport | River Mile 44 |
| arsenic, dissolved | μg/L | - | -0.21 | - |
| arsenic, total | μg/L | - | -0.24 | -0.24(d); -0.12 (e) |
| cadmium dissolved | μg/L | - | - | 0.004 |
| cadmium total recoverable | μg/L | - | - | - |
| chromium, dissolved | μg/L | - | - | - |
| chromium, total recoverable | μg/L | 0.025 (b) | -0.169 | - |
| copper, dissolved | μg/L | 0.04 | - | - |
| copper, total recoverable | μg/L | 0.14 | -0.243 | - |
| lead, dissolved | μg/L | - | - | - |
| lead, total recoverable | μg/L | 0.10 | -0.042 | - |
| mercury, dissolved | ng/L | 0.40 | - | - |

| | | | | |
|---|---|---|---|---|
| mercury, total | ng/L | 0.95 | - | - |
| nickel, dissolved | μg/L | - | - | - |
| nickel, total recoverable | μg/L | - | -0.84 | - |
| zinc, dissolved | μg/L | 1.5 (d); -0.08 (e) | - | - |
| zinc, total recoverable | μg/L | 4.5 | - | - |
| organic carbon, dissolved | mg/L | - | - | - |
| organic carbon total | mg/L | - | - | - |
| chlorypyrifos | μg/L | - | - | - |
| diazinon | μg/L | 0.015 (d); 0.003 (e) | - | - |
| fecal coliform | MPN/100mL | - | - | - |
| total coliform | MPN/100mL | 756(d); 106(e) | - | - |
| fecal streptococci | mg/l | - | - | - |
| temperature | °C | .003(d); 1.3(e). | - | - |
| dissolved oxygen | mg/l | -0.32 | -0.12 | -0.2 |
| pH | std. units | 0.22 | - | -0.19 |
| conductivity (c) | μmho/cm | 1.3 | -9.9 | -9.0 |
| hardness as $caco_3$ | mg/L as $CACO_3$ | - | -3.2 | - |
| total suspended solids | mg/l | 1.6 | -6.6 | 0.08 |

(a) Estimated Mean Difference is the arithmetic mean of differences calculated: Downstream concentration minus Upstream concentration; Upstream sites are Nimbus Dam for the American River and Veterans Bridge for the Sacramento River. "-" indicates difference is not significant at the 95% confidence level. Mean Differences are presented only for parameters with significant differences in water quality ($p \leq 0.05$).
(b) Calculated as 10% trimmed mean to exclude possible outlier data.
(c) Excludes data prior to June 1994
(d) Estimated mean difference for rain events.
(e) Estimated mean difference for non-rain events.

Source: SRCSD, 1999

Based on the frequency distributions of the accumulated river data and comparisons to relevant regulatory criteria, the percent of time that ambient water quality characteristics are expected to exceed the regulatory limits are as follows:

- On the American River at Discovery Park: 5% for mercury concentrations and 20% for fecal coliform bacteria concentrations; and
- On the American River at Nimbus: no exceedance issues are apparent.

(All mercury exceedances were based on the EPA ambient water quality criterion. The applicable regulatory limit for chlorpyrifos was lower than the detection limit, resulting in insufficient data for comparison.)

#### 4.2.2.2. COMPREHENSIVE STORMWATER MANAGEMENT PROGRAM (SMP)

As part of the ongoing stormwater NPDES permit requirements of the County of Sacramento and the cities of Sacramento, Folsom, Galt, and Citrus Heights, a wet weather monitoring program is conducted. The monitoring program is designed to characterize urban runoff quality, assist in the identification of constituents of concern, and provide information which can be used to assess the effectiveness of the stormwater management program. Both urban runoff sites and receiving waters are sampled for up to five separate storm and dry weather events. Samples are analyzed for total (or total recoverable) and dissolved metals, conventional parameters, total and fecal coliform, fecal streptococci, diazinon, and chlorpyrifos.

For the urban runoff discharge monitoring element of the program, three urban runoff sites are sampled, including Sump 111 and Strong Ranch Slough on the American River (see Figure 2.5). For two of the storm events monitored each season (the "first flush" event and one subsequent storm), the sampling events are coordinated with AMP sampling. Coordinated events include additional sampling for several parameters. In addition to the urban runoff sampling portion of the study, the Sacramento and American rivers are sampled by the AMP during the first flush storm and one of the four subsequent events sampled for urban runoff. On the American River, samples are collected from below Nimbus Dam and at Discovery Park (see Figure 2.5).

The SMP was developed to determine the impacts of stormwater discharges on the Sacramento and American rivers, using both water chemistry and aquatic toxicity studies. Recently, the focus has shifted to identifying and controlling specific constituents of concern (COCs), a transition still in progress that represents a significant change in SMP activities. Urban creek monitoring and control measure effectiveness studies also have been added to the SMP since its inception in 1990.

For the 1998-99 program year, monitoring was also conducted at four discharge sites and at five Arcade Creek sites for two creek monitoring events through the Organophosphate Pesticide Toxicity Control Program. Quantification of metals removed from sediment in sumps in the City of Sacramento storm drainage system and detention basins in the County of Sacramento was conducted, along with water quality monitoring of the Laguna West Lake System.

### Discharge Characterization Monitoring

Discharge monitoring data have been collected from Sacramento urban area monitoring stations since 1990, including monitoring events during both dry and wet weather conditions. The data have been used to develop the prioritized COC List and urban runoff discharge characterization loading estimates, and to support source identification work. Dry weather data have been collected to characterize non-storm urban runoff quality. All of these data may also be used in assessing the long-term effectiveness of urban runoff controls and developing water quality models. Discharges from the urban runoff sites are considered to be generally representative of runoff quality throughout the Sacramento urban area.

The RWQCB staff approved a one-year hiatus from discharge characterization monitoring in 1998-99. In previous years, monitoring had been conducted every year. In the future, a new monitoring frequency is anticipated involving monitoring for two years, then not monitoring for one year.

### Results

This section presents an analysis of the SMP's 10-year stormwater quality database (LWA 1999). Urban runoff data collected from 1990 to 1999 were compiled and compared to relevant water quality criteria to identify constituents that exceed criteria in urban runoff (SRCSD 1999). River data collected by the Sacramento CMP and the United States Geological Survey (USGS) National Water Quality Assessment (NAWQA) Program were reviewed to determine potential problems in rivers. Available creek data collected by the SMP, NAWQA, and RWQCB were also reviewed for exceedances of relevant water quality criteria. River and creek constituents that exceeded criteria were compared to those exceeding criteria in urban runoff to determine potential impacts from urban runoff to receiving waters. Additionally, results of toxicity and other studies conducted in the Sacramento River basin were compared to urban runoff constituents that exceeded criteria.

## Urban Runoff

Urban runoff data for all COCs were compiled separately for each of the Stormwater Monitoring Program long-term discharge monitoring sites. Compiled data sets for each site were used to calculate the percent probability of measured constituents meeting the lowest relevant water quality criteria. If available, water quality criteria from the proposed CTR (*Federal Register*, August 5, 1997) or the Basin Plan objective (Regional Board, 1994) were used for comparisons. If these criteria were not available, other applicable criteria were used, including Safe Drinking Water Act maximum contaminant levels (MCLs), California Department of Health Services guidance levels, EPA criteria for the protection of aquatic life, and California Department of Fish and Game guidance levels. It is important to note that all of these criteria apply to receiving waters. As such, they do not apply directly to urban runoff discharges, which are not a drinking water source.

Rainfall events—and by extension, urban stormwater runoff—appear to have some impact on changes in downstream ambient water quality characteristics for a few parameters. At Discovery Park, dissolved zinc concentrations and diazinon were observed to increase significantly only during rain events, and temperature was observed to increase only during non-rain events. From the results of routing water quality testing conducted at E.A. Fairbairn WTP, it appears that concentration of total coliform increases significantly during first flush events. The wet weather increases in American River diazinon concentrations and total coliform numbers may be of some regulatory significance (LWA 1999).

Urban runoff occurs on a year-round basis. It has been estimated that over the course of a year, about an equal load of many contaminants is discharge in dry weather runoff as in wet weather runoff (LWA 1992). Wet weather runoff results from seasonal winter storms. Dry weather runoff results from activities such as over-irrigation and car washing. Wet weather runoff is of relatively short duration, exceeding the length of the storm by several hours to several days (AWC and MW 1998). The highest concentrations of most contaminants occur in wet weather runoff following extended dry periods and during the first few hours of runoff from individual storms due to the accumulation of contaminants during periods of dry weather. Wet weather runoff also can have highly variable contaminant concentrations. Dry weather runoff is generally characterized by a narrower range of contaminant concentrations than wet weather runoff.

There are over 40 urban runoff discharges along the lower American River. It is not fully understood whether some portions of the urban area may have better or worse water quality than other areas. Generally, urban runoff water quality is so variable that real distinctions between one discharge and another are not possible without a very large amount of data (AWC and MW 1998).

## Sump 111 Results

At Sump 111, a primarily industrial watershed, low percent probabilities of meeting water quality criteria were estimated for diazinon (5.6%) and fecal coliform (1.4%). Copper (16%), lead (28%), mercury (86%), zinc (13.6%), bis(2-ethylhexyl)phthalate (44.5%) and chlorpyrifos (42%) had relatively low probabilities of meeting water quality criteria. Several constituents, including malathion, carbaryl, several PAHs, pentachlorophenol, and cyanide, were detected less than 5 times, but had maximum detected concentrations that exceeded the lowest relevant water quality criterion. Despite some exceedances, cadmium, chromium, nickel, and diuron had high probabilities (>95%) of meeting the lowest criteria.

### Chicken/Strong Ranch Slough Results

At Chicken/Strong Ranch Slough, a mixed-use urban watershed, low percent probabilities of meeting water quality criteria were estimated for copper (8.8%), lead (4.2%), and fecal coliform (5.3%). Zinc (71%) and cadmium (96.7%) were also estimated to exceed criteria more than once in three years. Several of the constituents of concern were only detected once at this site; therefore, percent probabilities could not be calculated. However, the detected value observed for each of these constituents (diazinon, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, indeno(1,2,3-cd)pyrene, bis(2-ethyhexyl) phthalate, and cyanide) exceeded the lowest relevant water quality criterion.

Samples were collected at the combined Chicken/Strong Ranch Slough site from the 1989/90 wet season through the 1993/94 wet season. Beginning in 1994/95, samples were collected from a site on Strong Ranch Slough (upstream of its confluence with Chicken Ranch Slough). It was determined that more representative samples could be collected from the current Strong Ranch Slough location.

### Strong Ranch Slough Results

At Strong Ranch Slough, a mixed-use urban watershed, low percent probabilities of meeting water quality criteria were estimated for fecal coliform (0%), diazinon (0.03%), carbaryl (3.6%), and chlorpyrifos (7%). Chromium, copper, lead, mercury, zinc, and bis(2-ethylhexyl)phthalate, and diuron also demonstrated a probability of exceeding the lowest water quality criteria at least once in three years. Several polyaromatic hydrocarbon (PAH) compounds and pentachlorophenol were detected less than five times, but maximum detected concentrations exceeded the lowest water quality criteria.

### Toxicity

Under the SMP, several toxicity and Toxicity Identification Evaluation (TIE) studies on urban runoff and receiving waters were conducted. During 1993/94 and 1994/95, toxicity of Sacramento urban runoff was tested using three-species bioassay and TIEs in a collaborative study with the Regional Board. Results of this study indicated that urban runoff and urban runoff-dominated creeks were toxic to all three species (*Ceriodaphnia*, fathead minnow and algae). Toxicity to *Ceriodaphnia* was attributed primarily to diazinon and chlorpyrifos; however, copper, nickel, and zinc were found to contribute to *Ceriodaphnia* toxicity at Sump 111. Urban runoff samples were occasionally toxic to fathead minnows, but the toxicant could not be identified. Toxicity to algae was seen occasionally and was primarily due to diuron. Copper and zinc in the Sump 111 sample also contributed to toxicity to algae.

Additional TIEs were conducted on these samples to determine the joint toxicity of diazinon and chlorpyrifos to *Ceriodaphnia*. Results of these TIEs showed that diazinon and chlorpyrifos, when present together, exhibit additive toxicity (i.e., toxicity in proportion to their combined concentrations and relative toxicities).

Additional TIEs were conducted on urban runoff and urban creek samples collected in two late-season storms in 1994/95 and in the fall first flush event of 1995/96. Toxicity to *Ceriodaphnia* was attributed to diazinon and chlorpyrifos. Although metals were detected at levels high enough to contribute to toxicity, TIEs did not implicate metals as possible toxicants. TIEs identified a non-polar organic as the possible toxicant to fathead minnows. Additional TIE phases were not completed to identify the specific non-polar organic compound.

**Receiving Waters**

The SMP uses American River receiving water quality data from the CMP and NAWQA monitoring programs to assess the ambient water quality of the river. For the evaluation of the monitoring data, refer to the respective CMP and NAWQA sections within this report.

#### 4.2.2.3. SACRAMENTO RIVER WATERSHED PROGRAM (SRWP)

The SRWP was initiated by the Sacramento Regional County Sanitation District (SRCSD) in 1996 to reduce and control priority pollutant loadings to the Sacramento River and Delta from key point and non-point sources on a watershed-wide basis. Formation of the SRWP was facilitated by the Sacramento River Toxic Pollutant Control Program, a locally initiated effort led by Sacramento County and the SRCSD. The SRWP is led by an association of stakeholders in the Sacramento River watershed that includes representatives of local municipalities and districts, state and federal agencies, agriculture, industry, landowners, environmental organizations, universities, technical consultants, and watershed conservancies.

The Sacramento River Toxic Pollutant Control Program and the SRWP designed a long-term water quality monitoring program for the watershed to identify the causes, effects and extent of constituents of concern that affect the beneficial uses of water and to measure progress as control strategies are implemented. The majority of the monitoring program for the watershed was implemented in June 1998 at 24 sites. Sites were chosen to expand upon ongoing monitoring (e.g., Regional Board monitoring that began in 1996), to provide information at the mouths of major tributaries, and to coincide with flow monitoring stations.

The data generated by the SRWP and other collaborating water quality monitoring programs (USGS NAWQA, CMP, City of Redding NPDES Monitoring, and the Department of Water Resources (DWR) intensive tributary monitoring program) are used to assess spatial and temporal distributions of a variety of important water quality characteristics, to evaluate the attainment of beneficial uses and potential impairment in the Sacramento River watershed, and to compare the relative contributions of different inputs to the Sacramento-San Joaquin Delta. **Table 4-6** shows the source monitoring programs for the three American River sites, and the parameters tested.

The 1998-99 (Year 1) SRWP monitoring program included sample collection at 63 locations in the Sacramento River watershed, including two on the American River (J Street and Discovery Park). The following environmental monitoring elements are included in the SRWP monitoring program:

- Mercury, PCBs, and chlorinated pesticides in fish tissue;
- Trace metals in water;
- Toxicity in water and sediment;

- Pathogens in water;
- Organic carbon in water;
- General constituents (minerals, nutrients, solids, turbidity, hardness) in water;
- Benthic invertebrates and habitat characterization; and
- Benthic algae (periphyton).

Toxicity monitoring was undertaken to characterize toxicity in the watershed, and to identify sources and causes of toxicity. Laboratory toxicity tests to assess water quality and toxicity were performed with EPA standard freshwater test organisms: the *Pimephales promelas* (fathead minnow) 7-day growth and survival test, and the *Ceriodaphnia* (water flea) 7-day reproduction and survival test. (*Selenastrum* (algae) 4-day cell growth tests were not performed on the American River in the 1998-99 monitoring year.) TIEs were performed on selected samples to attempt to identify the toxicants responsible for repeated adverse effects in toxicity tests.

Sediment toxicity monitoring was conducted by the SRWP as a pilot project to evaluate the value of sediment toxicity testing in identifying potential sources of toxic pollutants. Toxicity testing was performed in elutriates of sediment samples with *Ceriodaphnia* and in bulk sediment samples with *Hyalella* (an amphipod) at the American River at J Street.

Fish tissue monitoring was initiated in 1997, and continues at several locations in the watershed. As a component of the SRWP, fish tissue samples were collected at 18 locations in the Sacramento River watershed by the California Department of Fish and Game in September and October, 1998. Specifically, largemouth bass, carp, Sacramento squawfish, rainbow trout, and white catfish were collected. The objectives of the study were to:

- Determine whether mercury, organochlorine pesticides and PCBs occur in fish that are being used as human food in the Sacramento main stem and major tributaries at concentrations of potential human health concern;
- Measure contaminant levels in fish to begin to track long-term trends and evaluate the effectiveness of management efforts;
- Determine spatial patterns in contamination in the watershed; and
- Provide useful data for assessing the ecological hazards of mercury and organochlorines in organisms at high trophic levels.

**Table 4-6. Summary of American River sampling sites, sampling frequency, and parameters for SRWP Source Monitoring Programs.**

| Parameters | American River at Fairbairn WTP[a] | American River at J Street | American River at Discovery Park |
|---|---|---|---|
| Mercury, total | | | AMP |
| Copper, total and dissolved | | NAWQA | AMP |
| Cadmium, total and dissolved | | NAWQA | AMP |
| Zinc, total and dissolved | | NAWQA | AMP |
| Arsenic, total and dissolved | SAC (total) | NAWQA | AMP (total) |
| Lead, total and dissolved | | NAWQA | AMP |
| Chromium, Selenium, Silver, Nickel, total | | NAWQA | AMP (chromium and nickel only) |
| Total Suspended Solids | | NAWQA | AMP |
| Hardness | SAC | NAWQA | AMP |
| Turbidity | SAC | | |
| Total Organic Carbon | SAC | NAWQA | |
| Dissolved Organic Carbon | DWR | NAWQA | |
| Total Dissolved Solids | SAC | | |
| Dissolved Oxygen, Temperature, pH, EC | | NAWQA | AMP |
| Nutrients | | NAWQA | |
| General Minerals | DWR | NAWQA | |
| Organophosphate Pesticides, Carbamates | | NAWQA | |
| Pathogens | | | |
| Giardia/Cryptosporidium | SAC (6) | | |
| Total and Fecal Coliforms | SAC | | AMP |
| Aquatic Toxicity | | | 12 |
| Water Column—*Ceriodaphnia* | | | 12 |
| Water Column—Fathead Minnow | | | |
| Sediment Toxicity | | 2 | |
| Fish Tissues | | | |
| Mercury | | | 1 |
| PCBs, chlorinated pesticides | | | 1 |
| **Bioassessment**[e] | | | |
| Benthic invertebrates | | 1 | |
| Algae | | 1 | |

SAC = City of Sacramento Department of Utilities
DWR = Department of Water Resources
AMP = Ambient Monitoring Program
NAWQA = National Water Quality Assessment Program

[a] This site is not monitored independently by the SRWP.
[b] Nutrients include nitrogen compounds (nitrite, nitrate, ammonia, organic) and phosphorus compounds (orthophosphate, total).
[c] General minerals include alkalinity, chloride, iron, manganese, calcium, magnesium, silica, sodium, sulfate and potassium
[d] Assumes same fish used for mercury and organic analyses.
[e] Bioassessment monitoring includes both physical habitat and biological assessments.
Source: LWA, 2000

### Results

The data generated by the SRWP and other collaborating water quality monitoring programs for the American River (USGS NAWQA, CMP, City of Sacramento, and DWR) are compiled and assessed *as a whole* for the SRWP (**Table 4-7** and **Table 4-8**). Therefore, the SRWP evaluation includes some water quality monitoring data that have been reported in other programs in this report.

The American River consistently meets drinking water quality goals and standards, suggesting achievement of the designated beneficial uses as a source of municipal supply water. The exceedances of goals and standards on the American River are noted below:

- The Basin Plan limit for median fecal coliform numbers (200 MPN/100 mL) was not exceeded, but the maximum limit (400 MPN/100 mL) was exceeded in 1 of 25 samples on the American River at Discovery Park (Table 4-6).
- Summary statistics for mercury are presented in Table 4-6. These data are compared with EPA water quality criteria in **Table 4-9.**
- Total trace metals concentrations in the American River generally exhibit a strong seasonal pattern. Concentrations typically peak after the early precipitation events and increased river flows of the early wet season, and then decrease steadily through the next wet season. In general, this pattern is consistent with the adsorption of metals to fine-grained particles and the seasonal resuspension and transport of these particulates deposited during the dry season. This pattern is less distinct for dissolved metals concentrations.
- In **Table 4-10** total and dissolved metals concentrations were compared to proposed CTR water quality criteria and Basin Plan objectives, and the percent compliance calculated. Trace metals concentrations in the American River were rarely observed to exceed proposed CTR criteria or other water quality objectives. Maximum dissolved concentrations of copper for the American River at J Street were observed to exceed the median hardness-adjusted chronic criterion once. Concentrations of other trace metals were not observed to exceed proposed CTR criteria or other applicable regulatory limits.
- None of the 1998-99 American River samples caused significant toxicity or significant mortality to *Ceriodaphnia*; however, one sample exhibited a significant decrease in reproduction (**Table 4-11** and **Table 4-12**).
- In the 1998-99 monitoring, significant toxicity to *Pimephales* was observed in 25 percent of the samples collected (Table 4-11). Decreased growth (two samples) and mortality (one sample) were also observed for *Pimephales* (**Table 4-13**).
- The causes for observed toxicity on the American River have not yet been determined; however, *Ceriodaphnia dubia* toxicity attributable to organophosphate pesticides in agricultural runoff and urban runoff has been strongly suggested by SRWP monitoring and other studies.
- Although concentrations of monitored organochlorines did not exceed FDA Action Levels in any samples, aroclors exceeded screening values in fish collected from the American River at Discovery Park (**Table 4-14**). Exceedance of these screening values indicates that more data are needed to fully interpret potential risks to human health.

**Table 4-7. SRWP summary statistics: American River at J Street.**

| | Monitoring Period | | | | | | | Percentile Statistics Median | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Start | End | n | n det | % det | Min det | Max det | 10th | 25th | (50th) | 75th | 90th | Min RL |
| Trace Metals | | | | | | | | | | | | | |
| Arsenic, Dissolved | 3/18/96 | 4/16/98 | 26 | 0 | 0% | – | – | <RL | <RL | <RL | <RL | <RL | 1 |
| Cadmium, dissolved | 3/18/96 | 4/16/98 | 26 | 0 | 0% | – | – | <RL | <RL | <RL | <RL | <RL | 1 |
| Chromium, dissolved | 3/18/96 | 4/16/98 | 26 | 1 | 4% | 1.4 | 1.4 | <RL | <RL | <RL | <RL | <RL | – |
| Copper, dissolved | 3/18/96 | 4/16/98 | 26 | 6 | 23% | 1 | 2.8 | <RL | <RL | <RL | <RL | 1.7 | – |
| Lead, dissolved | 3/18/96 | 4/16/98 | 26 | 0 | 0% | – | – | <RL | <RL | <RL | <RL | <RL | 1 |
| Nickel, dissolved | 3/18/96 | 4/16/98 | 26 | 4 | 15% | 1 | 1.3 | <RL | <RL | <RL | <RL | 1.0 | – |
| Selenium, dissolved | 3/18/96 | 4/16/98 | 26 | 0 | 0% | – | – | <RL | <RL | <RL | <RL | <RL | 1 |
| Silver, dissolved | 3/18/96 | 4/16/98 | 26 | 0 | 0% | – | – | <RL | <RL | <RL | <RL | <RL | 1 |
| Zinc, dissolved | 3/18/96 | 4/16/98 | 26 | 13 | 50% | 1 | 11 | <RL | <RL | 1.00 | 1.65 | 2.70 | – |
| Drinking Water Parameters | | | | | | | | | | | | | |
| Organic Carbon, dissolved | 2/21/96 | 4/16/98 | 27 | 27 | 100% | 1.1 | 6.4 | 1.2 | 1.3 | 1.5 | 1.6 | 1.9 | – |
| Organic Carbon, total | 2/21/96 | 4/16/98 | 26 | 26 | 100% | 1.2 | 8.1 | 1.35 | 1.525 | 1.75 | 2.075 | 2.5 | – |
| Total Dissolved Solids | 2/21/96 | 4/16/98 | 27 | 27 | 100% | 24 | 52 | 33 | 35 | 40 | 45 | 48 | – |
| Nutrients | | | | | | | | | | | | | |
| Nitrate as NO3 | 2/21/96 | 4/16/98 | 27 | 14 | 52% | 0.05 | 0.18 | <RL | <RL | 0.05 | 0.1085 | 0.126 | – |
| Nitrate as NO2 | 2/21/96 | 4/16/98 | 27 | 8 | 30% | 0.01 | 0.02 | <RL | <RL | <RL | 0.01 | 0.01 | – |
| Ammonia as N | 2/21/96 | 4/16/98 | 27 | 8 | 30% | 0.017 | 0.07 | <RL | <RL | <RL | 0.02 | 0.029 | – |
| Orthophosphate as P, dissolved | 2/21/96 | 4/16/98 | 27 | 6 | 22% | 0.01 | 0.02 | <RL | <RL | <RL | <RL | 0.015 | – |
| Phosphorus, total | 2/21/96 | 4/16/98 | 27 | 14 | 52% | 0.01 | 0.09 | <RL | <RL | 0.01 | 0.02 | 0.044 | – |
| Minerals | | | | | | | | | | | | | |
| Calcium, dissolved | 2/21/96 | 4/16/98 | 27 | 27 | 100% | 7.0 | 7.8 | 7.2 | 7.4 | 7.5 | 7.7 | 7.7 | – |
| Chloride | 2/21/96 | 4/16/98 | 27 | 27 | 100% | 0.5 | 1.0 | 0.6 | 0.6 | 0.7 | 0.7 | 0.8 | – |
| Iron, dissolved | 2/21/96 | 4/16/98 | 27 | 27 | 100% | 3.0 | 48.0 | 4.5 | 6.5 | 8.0 | 13.0 | 25.0 | – |
| Magnesium, dissolved | 2/21/96 | 4/16/98 | 27 | 27 | 100% | 4.0 | 6.4 | 4.5 | 4.9 | 5.1 | 5.5 | 6.0 | – |
| Manganese, dissolved | 3/18/96 | 4/16/98 | 26 | 26 | 100% | 1.5 | 11.0 | 1.9 | 2.0 | 3.0 | 3.9 | 6.3 | – |
| Potassium, dissolved | 2/21/96 | 4/16/98 | 27 | 27 | 100% | 1.4 | 2.6 | 1.8 | 1.9 | 2.0 | 2.2 | 2.3 | – |
| Silica as SIO2, dissolved | 2/21/96 | 4/16/98 | 27 | 0 | 0% | 0.0 | 0.0 | <RL | <RL | <RL | <RL | <RL | 0.1 |
| Sodium, dissolved | 2/21/96 | 4/16/98 | 27 | 27 | 100% | 1.3 | 3.0 | 1.4 | 1.4 | 1.6 | 2.05 | 2.34 | – |
| Sulfate | 2/21/96 | 4/16/98 | 27 | 27 | 100% | 0.9 | 2.3 | 1.3 | 1.3 | 1.4 | 1.7 | 1.9 | |
| Other Conventional Water Chemistry Parameters | | | | | | | | | | | | | |
| Alkalinity, total | 2/21/96 | 4/16/98 | 27 | 27 | 100% | 16 | 27 | 17 | 18 | 20 | 22 | 22 | – |
| Total Suspended Solids | 2/21/96 | 4/16/98 | 26 | 26 | 100% | 2 | 116 | 3 | 3 | 5 | 11 | 33 | – |
| Hardness | 2/21/96 | 4/16/98 | 27 | 27 | 100% | 16 | 28 | 17 | 18 | 20 | 22 | 23.8 | – |
| Field Data | | | | | | | | | | | | | |
| Dissolved Oxygen | 2/21/96 | 4/16/98 | 26 | 26 | 100% | 8.2 | 12.8 | 8.8 | 9.2 | 10.6 | 11.2 | 12.1 | – |
| Temperature | 2/21/96 | 4/16/98 | 27 | 27 | 100% | 8.4 | 19.7 | 9.2 | 10.3 | 14.4 | 17.0 | 18.9 | – |
| pH | 2/21/96 | 4/16/98 | 27 | 27 | 100% | 7.0 | 7.7 | 7.3 | 7.4 | 7.5 | 7.5 | 7.6 | – |
| Specific Conductance | 2/21/96 | 4/16/98 | 27 | 27 | 100% | 40 | 68 | 45 | 47 | 50 | 57 | 58 | – |

Source: LWA, 2000

Summary Statistics Table Notes: monitoring period start and end — Dates of first and last reported data; n—Total number of data reported; n det—total number of data above reporting limits; % det—Percent of data above reporting limits; min det—Minimum value for data detected above reporting limits; max det—Maximum value of data detected above reporting limits; percentiles—Percentile data are provided for data above reporting limits. "<RL" indicates insufficient data to calculate statistic; min RL—Lowest reporting limit for data below detection. Min RL only reported where percent detection (% det)=0

**Table 4-8. SRWP summary statistics: American River at Discovery Park.**

| | Monitoring Period | | | | | | | Percentile Statistics Median | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Start | End | n | n det | % det | Min det | Max det | 10th | 25th | (50th) | 75th | 90th | Min RL |
| Mercury, total | 1/18/94 | 12/16/98 | 79 | 79 | 100% | 1.10 | 13.3 | 1.53 | 1.97 | 3.3 | 4.56 | 6.89 | – |
| Trace Minerals | | | | | | | | | | | | | |
| Arsenic, total | 1/4/94 | 12/16/98 | 73 | 38 | 52% | 0.07 | 1.23 | <RL | <RL | 0.62 | 1 | 1 | – |
| Cadmium, dissolved | 1/4/94 | 12/16/98 | 78 | 11 | 14% | 0.01 | 0.04 | <RL | <RL | <RL | <RL | 0.015 | – |
| Cadmium, total | 1/4/94 | 12/16/98 | 79 | 21 | 27% | 0.01 | 0.2 | <RL | <RL | <RL | 0.01 | 0.018 | – |
| Chromium, total | 1/4/94 | 12/16/98 | 81 | 43 | 53% | 0.13 | 2.2 | <RL | <RL | 1.00 | 1.00 | 1.10 | – |
| Copper, dissolved | 1/4/94 | 12/16/98 | 79 | 66 | 84% | 0.29 | 1.3 | <RL | 0.44 | 0.57 | 0.8 | 0.91 | – |
| Copper, total | 1/4/94 | 12/16/98 | 81 | 78 | 96% | 0.4 | 3.6 | 0.52 | 0.63 | 0.82 | 1.1 | 1.70 | – |
| Lead, dissolved | 1/4/94 | 12/16/98 | 80 | 16 | 20% | 0.1 | 0.5 | <RL | <RL | <RL | <RL | 0.101 | – |
| Lead, total | 1/4/94 | 12/16/98 | 81 | 71 | 88% | 0.1 | 1.28 | <RL | 0.119 | 0.200 | 0.300 | 0.500 | – |
| Nickel, total | 1/4/94 | 12/16/98 | 62 | 49 | 79% | 0.18 | 8 | <RL | 0.58 | 0.61 | 1.26 | 1.98 | – |
| Zinc, dissolved | 1/4/94 | 12/16/98 | 80 | 31 | 39% | 0.11 | 7.4 | 0.11 | 0.20 | 0.39 | 0.75 | 1.37 | – |
| Zinc, total | 1/4/94 | 12/16/98 | 81 | 48 | 59% | 0.18 | 230 | <RL | <RL | 1.24 | 3.45 | 6.60 | – |
| Pathogens | | | | | | | | | | | | | |
| Coliform, total | 10/29/96 | 12/16/98 | 25 | 25 | 100% | 50 | 16000 | 80 | 220 | 240 | 800 | 1600 | – |
| Coliform, fecal | 10/29/96 | 12/16/98 | 25 | 25 | 100% | 12 | 3000 | 23 | 30 | 50 | 110 | 196 | – |
| Other Conventional Water Chemistry Parameters | | | | | | | | | | | | | |
| Alkalinity, total | 6/23/98 | 5/18/99 | 12 | 12 | 100% | 18 | 74 | 20 | 23 | 24 | 30 | 30 | – |
| Total Suspended Solids | 1/4/94 | 12/16/98 | 80 | 53 | 66% | 1 | 41 | <RL | <RL | 3 | 6 | 14 | – |
| Hardness | 1/18/94 | 5/18/99 | 74 | 74 | 100% | 14 | 56 | 16 | 20 | 24 | 30 | 34.7 | – |
| Field Data | | | | | | | | | | | | | |
| Temperature | 1/4/94 | 12/16/98 | 80 | 80 | 100% | 7.6 | 24.4 | 9.1 | 10.1 | 13.9 | 17.3 | 20.3 | – |
| pH | 1/4/94 | 12/16/98 | 77 | 77 | 100% | 6.4 | 8.6 | 6.8 | 7.0 | 7.1 | 7.4 | 7.7 | – |
| Specific Conductance | 1/4/94 | 12/16/98 | 77 | 77 | 100% | 28 | 80 | 39 | 44 | 52 | 61 | 67 | – |

Source: LWA, 2000
Summary Statistics Table Notes:
monitoring period start and end — Dates of first and last reported data.
n—Total number of data reported.
n det—total number of data above reporting limits.
% det—Percent of data above reporting limits
min det—Minimum value for data detected above reporting limits.
max det—Maximum value of data detected above reporting limits.
percentiles—Percentile data are provided for data above reporting limits. "<RL" indicates insufficient data to calculate statistic.
min RL—Lowest reporting limit for data below detection. Min RL only reported where percent detection (% det)=0

**Table 4-9. Compliance with EPA total mercury water quality criteria for human health.**

| Location | % probability of meeting USEPA criteria for protection of human health | | |
|---|---|---|---|
| | 1997 USEPA 3.1 ng/L Great Lakes standard | 1985 USEPA 12 ng/L criterion | 1999 USEPA 50 ng/L criterion |
| American River at J Street | 75.0 | 99.5 | >99.9 |
| American River at Discovery Park | 47.4 | 98.8 | >99.9 |
| Source: LWA, 2000 | | | |

**Table 4-10. Proposed toxics rule water quality criteria and Central Valley Region Basin Plan objectives for trace metals and percent compliance.**

| | Arsenic, total | | Cadmium, dissolved | | Chromium, dissolved | Copper, dissolved | | Lead, dissolved | Nickel, dissolved | Selenium, total | Silver, dissolved | | Zinc, dissolved | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Objectives*** | CTR | BP | CTR | BP | CTR | CTR | BP | CTR | CTR | CTR | CTR | BP | CTR | BP |
| American River at J Street | 150 | 10 | 0.68 | NA | 48 | 2.3 | 10 | 0.42 | 13 | 5 | 0.22 | 10 | 30 | 100 |
| American River at Discovery Park | 150 | 10 | 0.78 | NA | 55 | 2.6 | 10 | 0.52 | 16 | 5 | 0.30 | 10 | 35 | 100 |
| ***Percent Compliance*** | | | | | | | | | | | | | | |
| American River at J Street | — | — | 100 | NA | 100 | 96.2 | 100 | 100 | 100 | — | 100 | 100 | 100 | 100 |
| American River at Discovery Park | 100 | 100 | 100 | NA | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

Notes (Objectives): CTR criteria are proposed California Toxic Rule (USEPA 1997) chronic criteria for protection of aquatic life.
BP values are Central Valley Region Basin Plan water quality objectives for the protection of aquatic life.
NA indicates that there is no applicable criterion.

Notes (Percent Compliance): Values indicate percent of samples that meet applicable water quality criteria or objective.
"NA" indicates that there is no applicable criterion.
"—" indicates that parameter was not monitored at this location.
Shaded values indicate observed exceedances of objective.
Source: LWA, 2000.

**Table 4-11. Summary of 1998-99 toxicity monitoring survey results for the American River.** [a]

| | *Pimephales* | *Ceriodaphnia* | *Selenastrum* |
|---|---|---|---|
| Percent of samples exhibiting significant toxicity[b] | 25 | 0 | n/t |

Notes: n/t = Not Tested;
[a] Toxicity samples taken at Discovery Park site only.
[b] Significant toxicity is defined as increased mortality and/or decreased growth (*Pimephales*) or increased mortality and/or decreased reproduction (*Ceriodaphnia*) that is significantly different from controls at a 95% statistical confidence level.
Source: LWA, 2000

**Table 4-12. Summary of SRWP 1998-1999 *Ceriodaphnia* test results for the American River.**

| | Sample Dates | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jun 23-24 | Jul 21-22 | Aug 18-19 | Sep 15-16 | Oct 20-21 | Nov 16-17 | Dec 14-15 | Jan 19-20 | Feb 16-17 | Mar 16-17 | Apr 20-21 | May 18-19 |
| **Lab Control** | | | | | | | | | | | | |
| *Ceriodaphnia* reproduction, neonates/adult | 18.2 | 24.8 | 22.6a; 18.4b | 22.8 | 25.3 | 24.8 | 24.8 | 22.3 | 17.9 | 20.7 | 21.2 | 22.7 |
| Percent mortality | | | | | | 0 | 0 | 0 | 0 | 0 | 10 | 0 |
| American River at Discovery Park | | | | | | | | | | | | |
| *Ceriodaphnia* reproduction, neonates/adult | 28.3 | 12.1 | 19.2a | 24.9 | 22.8; 25.8d | 26 | 29.3 | 26 | 20.3 | 23.5 | 22.4 | 26.2 |
| Percent mortality | 0 | 30 | 0 | 0 | 0;0 | 0 | 0 | 0 | 10 | 0 | 10 | 0 |

Notes: "d" indicates field duplicate results
*Ceriodaphnia* tests were set up on separate days with separate controls. Endpoints labeled "a" or "b" were compared to the first and second endpoint listed, respectively

Although concentrations of organochlorines did not exceed FDA Action Levels in any samples, aroclors exceeded screening values in fish collected from the American River. Significant decrease in reproduction or increase in mortality in shaded cells.

Percent mortality = days to 100 percent mortality
Source: LWA, 2000.

**Table 4-13. Summary of SRWP 1998-1999 Fathead toxicity test results for the American River.**

| | Sample Dates | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jun 23-24 | Jul 21-22 | Aug 18-19 | Sep15-16 | Oct 20-21 | Nov 16-17 | Dec 14-15 | Jan 19-20 | Feb 16-17 | Mar 16-17 | Apr 20-21 | May 18-19 |
| Lab Control | | | | | | | | | | | | |
| Fathead growth, mg/surviving fathead | 0.49 | 0.311 | 0.447 | 0.586 | 0.467 | 0.348 | 0.418 | 0.383 | 0.336 | 0.458 | 0.437 | 0.375 |
| Percent mortality | 0 | 2.5 | 0 | 2.5 | 2.5 | 0 | 0 | 2.5 | 2.5 | 5 | 0 | 2.5 |
| American River at Discovery Park | | | | | | | | | | | | |
| Fathead growth, mg/surviving fathead | 0.52 | 0.314 | 0.267 | 0.5 | 0.458; 0.376d | 0.315 | 0.401 | 0.403 | 0.220 | 0.426 | 0.430 | 0.421 |
| Percent mortality | 12.8 | 20 | 7.5 | 2.5 | 17.5; 7.5d | 5 | 5 | 17.5 | 12.5 | 0 | 2.5 | 30 |

Notes: "d" indicates field duplicate results
Significant decreases in growth or increases in mortality in shaded cells.
Percent mortality = days to 100 percent mortality
Source: LWA, 2000.

**Table 4-14. Organochlorines in fish tissue: SRWP 1997 fish tissue data for the American River and comparisons to relevant fish tissue limits.** [a]

| | PCBs (Sum of Aroclors) | Sum of Chlordanes | Sum of DDTs | Dieldrin |
|---|---|---|---|---|
| Species: White Catfish | 81 | 8.0 | 62 | 0.7 |
| Updated USEPA Screening Values[b] (SFRWQCB et al. 1995) | 23 | 18 | 69 | 1.5 |
| FDA Action Levels[c] | 2000 | 300 | 5000 | 300 |

Notes: units = ng/g, wet weight
[a] Samples taken at J Street only.
[b] Screening value is based on a consumption rate of 30 g/day
[c] FDA Action Level is based on a consumption rate of 6.5 g/day
Source: LWA, 2000

### UC Davis Toxicity Monitoring Study

The SRWP conducted three-species toxicity tests, TIEs and chemical analysis on samples collected monthly from August 1996 to July 1997 at three locations: the American River at Discovery Park, the Sacramento River at Freeport, and Arcade Creek. American River samples caused toxicity once to *Ceriodaphnia* (in February) and once to fathead minnows (in June); none of the samples were toxic to algae. Sacramento River water was toxic to *Ceriodaphnia* in January, but was not toxic to fathead minnows or algae. All Arcade Creek samples except one were toxic to *Ceriodaphnia.* TIEs conducted on Arcade Creek samples linked *Ceriodaphnia* toxicity to diazinon and chlorpyrifos. Arcade Creek samples collected in October, November, March, and June were toxic to algae. Part of the toxicity to algae was attributed to diuron. No toxicity to fathead minnows was observed. Additional pesticide analyses were performed for the Arcade Creek samples collected in October and November. Pesticides detected above relevant water quality criteria in these samples included aldrin, carbaryl, and diazinon.

Under the SRWP, UC Davis Aquatic Toxicology Laboratory staff (under contract to the Regional Board) conducted toxicity testing; samples were collected at several locations within the Sacramento River watershed during 1997 and 1998. Results of the study are presented in a final report prepared by UC Davis for the Regional Board entitled *Sacramento River Watershed Project Toxicity Monitoring Results: 1997-98, November 1998 Final Report.* The study was conducted to further characterize the distribution of toxicity to aquatic organisms in the Sacramento River watershed and begin determining the toxicants responsible for all major incidents of toxicity by employing Phase I toxicity identification evaluations (TIEs). The study results are used to help design the water quality pollutant source monitoring program being developed by the SRWP.

Two components were covered in the study between October 1997 and May 1998. First, a special study of fathead minnow mortality was conducted at four sites from October 1997 through December 1997. Second, routine toxicity monitoring of the SRWP was conducted on samples collected from 24 sites between January 1998 and May 1998. Four out of five samples collected from Arcade Creek were toxic to *Ceriodaphnia,* and diazinon was identified as the primary cause.

*Ceriodaphnia* also exhibited reproductive impairment in 48 percent (20 out of 42) of the samples collected throughout the watershed in the winter of 1998, and acute mortality was observed in the one sample collected during the dormant spray season. TIEs and chemical analyses were not conducted due to limited funding; therefore, the cause of this toxicity could not be determined. All three of the samples collected from the Sacramento River above Lake Shasta exhibited toxicity to *Ceriodaphnia*, and TIE analysis suggested that dissolved nickel was the cause.

Significant progress has been made in identifying the cause of fathead minnow mortality observed throughout the watershed. Results show that a chemical contaminant may not be the cause; mortality may be associated with the presence of bacterial and fungal pathogens. Follow-up work on fathead minnow toxicity is being funded through CALFED and focuses on the ecological significance of the mortality.

#### 4.2.2.4. SACRAMENTO RIVER NATIONAL WATER QUALITY ASSESSMENT (NAWQA) PROGRAM

In 1991, the USGS began conducting a significant monitoring effort in the Sacramento River watershed. This work is being performed as an element of the NAWQA program for the Sacramento River. Based on a combination of physiography, land use, hydrology, and contaminant issues for a particular basin, the nationwide NAWQA program has the following objectives:

- To describe current water quality conditions for a large part of the freshwater streams, rivers, and aquifers in the United States;
- To describe how water quality is changing over time; and
- To improve understanding of the primary natural and human factors that affect water quality conditions.

The Sacramento NAWQA includes a set of 11 monitoring sites that provides information on metals, pesticides, and urban runoff inputs to the Sacramento Basin. The surface water activities from the Sacramento River Basin NAWQA will include assessments of the Sacramento River and its major tributaries, as well as an assessment of the major agricultural impacts to the river, and runoff from an urban source. One of the key sources of contaminants being studied is mine pollution, which is a major contributor of acid-mine drainage and trace metals (especially copper, lead and zinc) to the upper reach of the system. Agricultural drainage is also being studied to determine pesticide and other contaminant inputs.

Basic fixed sites are selected on major rivers to assess water quality conditions at locations affected by a multitude of land uses. Those on smaller tributaries are used to assess the potential impacts or loadings of contaminants from drainage basins of relatively homogeneous land uses and physiography. The eleven sites were selected for this study based on hydrology, the ability to obtain a mass balance of various constituent loadings on the Sacramento River, and possible inputs of contaminants to the Sacramento River. The American River (at J Street) was chosen as one of the eleven sites because it is a major tributary to the Sacramento River and because it might be impacted by urban runoff.

The American River site is sampled monthly for the following parameters:

- Field measurements, total hardness, and suspended sediment;

- Major inorganic constituents in filtered water;
- Nutrient and gross organic carbon;
- Trace elements in filtered water;
- Mercury in unfiltered water;
- Pesticides in filtered water analyzed by gas chromatography/ion trap mass spectrometry (Sacramento laboratory);
- Stream flow (measured at the nearby American River at Fair Oaks site); and
- Hydrograph of daily mean discharge (measured at the nearby American River at Fair Oaks site) and date of sampling event.

**Results**

NAWQA data was described under the SRWP data evaluation.

#### 4.2.2.5. COORDINATION AMONG THE SRWP, AMP, AND SMP

The CMP and the SRWP are being coordinated at several levels. The SRWP monitoring program has been developed in coordination with a number of ongoing monitoring efforts, including the AMP. The AMP sampling team takes samples for analysis by the SRWP at four of the five AMP sampling sites. The analytical results produced by the AMP are combined with other data collected under the SRWP.

The SMP also coordinates its sampling with both the CMP and the SRWP. Since the 1994/95 wet season, the AMP has coordinated two of its river monitoring events each year with the SMP wet weather discharge monitoring, including the annual fall first-flush event. The Organophosphate Pesticide Toxicity Control Program sampling has been coordinated with the monthly AMP and SRWP sampling since May 1999.

The NAWQA study is addressing urban runoff effects by utilizing data from the Sacramento CMP and a sampling station in Arcade Creek, in addition to its own Sacramento River data.

### 4.2.3. ADDITIONAL MONITORING STUDIES

Related monitoring studies that include lower American River monitoring sites are described below.

#### 4.2.3.1. AMERICAN RIVER WATERSHED SANITARY SURVEY

The California Surface Water Treatment Rule (SWTR) requires public water supply systems using surface water sources to conduct a sanitary survey of the watershed every five years. A sanitary survey involves an evaluation of watershed contaminant sources, source water quality, treatment plant capabilities, and treated water quality to assess the ability of a water agency to provide safe drinking water that meets all drinking water standards. This report compiled and evaluated raw and treated water quality data from the 10 agencies currently diverting and treating American River water, as well as raw river data collected by EBMUD and other ambient monitoring programs (Archibald and Wallberg et al., 1998). The water quality findings are summarized below; the complete evaluation of this data is provided in Appendix C to this report. The watershed contaminant sources reported by the sanitary survey are also summarized below.

### Summary of Water Quality Findings

The sanitary survey included a compilation of raw and treated water data from 1993 through 1997 for the 10 American River water supply agencies. A more detailed evaluation was conducted for several parameters pertinent to the existing SWTR, the future Enhanced Surface Water Treatment Rule (ESWTR), the future Disinfectants/Disinfection By-Products (D/DBP) Rule, and the existing Trihalomethane (THM) Regulation. These parameters include several microbiological organisms (coliform bacteria, *Giardia, Cryptosporidium,* and viruses), turbidity, and several parameters related to disinfection by-products (DBPs). The latter include total organic carbon (TOC), specific UV absorbency (SUVA), and THMs. Methyl tert-butyl ether (MTBE) and perchlorate were also examined. MTBE is a gasoline additive being found throughout the state in groundwater contaminated by leaking underground storage tanks and in surface waters used heavily for recreation. Perchlorate is a rocket fuel component found in contaminated groundwater underlying the Aerojet facility, which is located just south of Lake Natoma.

- The source water quality along the entire American River is generally excellent. All regulated drinking water parameters in treated water fall below MCLs standards. Also, based on available data, concentrations of constituents that have trigger levels for additional treatment (i.e., *Giardia,* viruses, TOC) are below the trigger levels.

- The evaluation of the coliform data showed that high coliform levels are frequently associated with storms, although high levels are also observed during dry weather. There is a clear trend of increasing concentrations from upstream to downstream, with the largest increase along the lower American River. The most likely sources of the increased coliform levels along the lower American River are urban runoff discharges and recreational use along the river. As a result of numerous research projects, it is becoming increasingly clear in the water quality field that coliform bacteria are not good indicators of *Giardia,* viruses, or *Cryptosporidium.* Monitoring directly for the pathogenic organisms, with increasingly reliable methods, is important in evaluating their presence. Nevertheless, in the absence of more reliable pathogen data, the coliform bacteria data should continue to be seriously regarded and evaluated as one of several inexact tools used in our attempt to understand the overall quality of the source water.

- A substantial amount of *Giardia* and *Cryptosporidium* data and a limited amount of virus data have been collected over the last 5 years. Detections of these organisms have been uncommon; however, since the accuracy and reliability of the analytical methodology is limited, this may indicate only that these pathogens are present at low levels.

- As follow-up to the Information Collection Rule, the EPA will be conducting a voluntary sampling program for pathogens in surface water. The EPA will be collecting 12 monthly water samples from 47 utilities around the United States for analysis of *Cryptosporidium,* and potentially *Giardia,* by the new EPA Method 1622. This method is used to analyze for pathogens using a combination of filtration, immunomagnetic separation, and immunofluorescence assay, and is expected to provide higher recovery rates than the immunofluorescence assay method alone. The City of Sacramento volunteered to participate as part of the study.

- Increased turbidity in the river reaches of the American River system correlates positively with increased flow. In general, turbidity levels in the source water exceed 10 Nephelometric Turbidity Units (NTU) less than 10% of the time and exceed 100 NTU less than 1% of the time.

- TOC levels average 1.5 mg/L. A limited amount of SUVA data, collected along the lower American River, show an average of 3.3 ml/mg. This concentration indicates that the organic material present is humic in nature and will contribute to DBP formation. Each agency has observed varying levels of THMs in the treated water due to different physical removal and chemical treatment processes and distribution system configurations.

- MTBE has been monitored regularly in Folsom Lake and irregularly along the lower American River. It has been detected once, in Folsom Lake, by El Dorado Irrigation District at a concentration of 0.92 µg/L.

- Perchlorate has been monitored a few times on the lower American River (below Folsom Dam) by the California Department of Health Services. It was not found above the detection limit of 4 µg/L.

In addition to the information described above, a comprehensive compilation of data and other pertinent information was made in order to provide in one document information needed by the Department of Health Services to evaluate watershed-wide monitoring waivers. This included information on arsenic, asbestos, cyanide, and pesticides. The average arsenic concentration in the lower American River is about 0.35 µg/L.

The Sanitary Survey compiled pesticide monitoring data for several programs, including the AMP, and the SMP and USGS and RWQCB monitoring programs. There have been few detections, even at ultra-low detection limits (i.e., nanograms per liter), with three exceptions: diazinon, diuron, and simazine. The concentrations are well below drinking water levels of concern. There are no CTR aquatic life criteria for these chemicals; however, CDFG has recommended maximum values for aquatic life for diazinon, and toxic effects to aquatic organisms have been determined for diuron and simazine from laboratory toxicity tests (pers. comm. Stella Seipmann, 2000). Diazinon was detected in 7 of 76 samples, ranging from 0.13 to 0.74 µg/l, above CDFG's recommended maximum value for diazinon of 40 ppt (0.04 µg/l). Diuron was detected in 1 of 4 samples at 0.2 µg/l. The slightly toxic level of diuron to fish is 0.14 ppm (140 µg/l). Simazine was detected in 2 of 21 samples at 0.007 and 0.032 µg/l. Simazine is considered "practically nontoxic," with a slightly toxic level of greater than 10,000 ppm (10,000,000 µg/l). The concentrations of diuron and simazine are well below these toxicity values for fish.

### Summary of Watershed Contaminant Sources

The study included an evaluation of various contaminant sources in the watershed including: (1) storm-related turbidity and pathogen sources; (2) recreation; (3) wastewater; (4) industrial facilities; (5) urban runoff; and (6) transportation and pipeline corridors.

- Many drinking water contaminants, including pathogens, are transported into the river system during storm events. The upper watershed has a high erosion potential due to its topography and soil composition, while the lower watershed is highly urbanized with a high percentage of impervious area. Both of these conditions provide a mechanism for contaminant transport.

- Exposed soil can contribute to elevated turbidity levels in the river system and can be caused by timber harvesting, fires, landslides, and over-grazing. Forest health, including timber harvesting and fires, is beginning to be addressed in part of the upper watershed (Placer County) through the American River Coordinated Resources Management Plan.

- Fecal waste from wild animals, livestock, and pets, whether in undeveloped or urban areas, can be transported during storms. There is less concern with these sources during the dry season since there is virtually no runoff from undeveloped areas during this time period. In addition, heat and dry conditions (i.e., desiccation) play an important role as inactivation factors for protozoa. Pathogen occurrence in wild animal species, livestock, and companion animals is an active area of research.

- In urban areas, wild and domestic animal populations contribute fecal matter to the land surface. The impervious nature of an urban area results in more rapid and complete transport of contaminants than in undeveloped areas. Monitoring data show that urban runoff probably contains some level of fecal/pathogen contamination. In urban areas, although heat and dry conditions prevail during the dry season, a continual dry weather flow from outdoor water use may carry some animal fecal waste. Pathogens in Sacramento area urban runoff are being addressed through the Sacramento SMP in a process of problem identification and an exploration of potential source identification methods and control measures.

- Recreation is the other major potential source of pathogens in this watershed during dry weather. Recreational use of the American River system involves an estimated 8 million visitor-days per year. Improper sanitary practices during body contact recreation and handling of waste on boats may contribute pathogens directly to the river system. Water agencies that own or have a high degree of control of their reservoirs typically limit recreational use. The entire American River system is, however, a multi-use system with recreation being one of the key benefits to the surrounding population.

- Boating and urban runoff are both sources of MTBE. MTBE is being addressed at a policy level through state legislation, the adoption of an MTBE policy statement by the Association of California Water Agencies, and various other activities. If MTBE is banned or its use is severely curtailed as a result of these efforts, it will rapidly become a low-priority issue in surface waters. If not, it will remain a potential problem. More monitoring data are needed to evaluate the extent of the problem on the American River system.

- The potential for untreated human wastewater inputs in this watershed is very limited, but is more likely to occur during storms.[4] The Colfax and Placerville wastewater treatment plants both have capacity problems due to high flows during storms. Also, some of the small non-discharging community wastewater systems have had spills during major storms.

- Septic systems are of concern because: (1) there are a large number in the upper watershed – somewhere in the order of 27,000 to 35,000 (many of which are close to the South Fork) and (2) due to a lack of resources for monitoring, there is little assurance that they are properly maintained once installed.

- In general, industries pose little risk to the drinking water quality of the river system. This is in large part due to the relatively low level of industrialization in the watershed.

- The only industry currently of potential concern to source water quality is the Aerojet facility which is located just south of Lake Natoma and has discharges to the lower American River system. Although effluent discharge limits for Aerojet's discharges to the river system have been developed to protect all the beneficial uses of the river based on current knowledge and analytical capabilities, there is a history of finding previously unknown constituents of concern to drinking water (i.e., perchlorate and n-Nitrosodimethylamine [NDMA]) in Aerojet's treated groundwater once analytical method detection limits are lowered sufficiently. In addition, there is a concern with groundwater extraction and treatment systems disposal options for the potentially very large volume of water that may eventually be generated by groundwater extraction and treatment at the facility, i.e., the potential for additional discharges to the American River and/or the Folsom South Canal.

- Finally, there is the potential for spills of hazardous materials due to truck accidents, railroad, or pipeline spills. The agencies need timely notification in order to respond properly at the water treatment plant. There is currently no assurance that the agencies will be notified promptly, except for Placer County Water Agency (PCWA) and Sacramento, which have direct notification procedures in place, providing coverage for most of the area tributary to their water treatment plant intakes. Neither the City of Sacramento nor PCWA have notification procedures in place for El Dorado County.

#### 4.2.3.2. Regional Board Sacramento River and Cache Creek Mercury Study (RWQCB 1998)

The Regional Board conducted a study to measure mercury concentrations in Cache Creek and the Sacramento River and to estimate loads to the Sacramento-San Joaquin Delta Estuary. The original objectives of the study were threefold: (1) measure mercury concentrations in the Sacramento River during low and high flows to ascertain whether exceedance of EPA criteria occurred; (2) use these concentrations to estimate bulk mercury loads to the Estuary from the Sacramento watershed; and, (3) determine both the source(s) and fate of the bulk material. The highest concentrations of mercury were consistently observed in Cache Creek; therefore, a

[4] Since completion of the Sanitary Survey in 1998, there have been several wastewater spills into the lower American River. These spills involved the City of Sacramento and the City of Folsom.

follow-up study was initiated in that subwatershed, with the same goals as identified above for the Sacramento River.

During the last century, mercury was mined extensively in the Coast Range and transported across the Central Valley for use in gold mining in the Sierra Nevadas. Widespread sediment mercury contamination occurred in the Coast Range, Sierra Nevadas and downstream in Central Valley rivers and in the Sacramento-San Joaquin Delta Estuary. The Sacramento River drains many of the major mercury mining districts north of the Estuary and all the northern gold fields. Mercury is a potent human neurotoxin with developing fetuses and small children being most at risk. The principal route of human exposure is through consumption of mercury-contaminated fish.

Mercury biomagnifies in aquatic food chains with predacious fish, like striped bass and shark, having the highest concentrations (Regional Board, 1998). At present, there is uncertainty about what the appropriate mercury concentration should be in water to maintain fish at levels that do not pose a human health risk. Fish tissue level guidelines include the National Academy of Sciences guideline of 0.5 ppm and the U.S. Food and Drug Administration Action Level of 1.0 ppm to protect human health. The Regional Board's Basin Plan does not have a numerical water quality objective for mercury.

The EPA has proposed three water quality criteria for mercury. First, in 1984, the Agency recommended that excessive concentrations in fish could be avoided if the 4-day average water concentration did not exceed 12 ng/l of total mercury more than once every three years (USEPA 1984). If concentrations were above this, then the Agency recommended that edible fish tissue be analyzed to determine whether its consumption might pose a human health risk. Second, in 1995, the Agency promulgated the NTR recommending dissolved mercury concentrations of 1.8 ng/l to protect human health (USEPA 1995). The main difference in the derivation of the two standards was that the 1995 value incorporated both bioconcentration and bioaccumulation[5] in its development, while the 1985 value did not. The NTR does not apply in California because the state had instead adopted the ISWP, which also contained a mercury objective. As explained earlier, however, the ISWP was nullified by court action, thus the EPA, as required by the CWA, promulgated a draft Toxics Rule for California. The draft Ruling recommended a dissolved mercury criteria of 50 ng/l to protect human health (USEPA 1997). As with the 1985 criteria, the EPA did not consider bioaccumulation in deriving the draft Ruling.

A water quality objective for mercury will ultimately be adopted in California; however, neither the method nor the value is yet known. In the interim, this mercury study was conducted to acquire information on ambient concentrations of mercury in the Sacramento-San Joaquin Delta Estuary and its major tributaries to determine the values that have resulted in the present health advisories.

### Results

Water samples were taken in 1993-1994 at selected locations in the Sacramento-San Joaquin Delta Estuary (including all major freshwater inputs) to establish baseline mercury

[5] Bioconcentration is a measure of the direct uptake of mercury by biota from water (mostly across gill membranes), while bioaccumulation also considers transfer through the food chain.

concentrations. Intensive monitoring in the Sacramento River (and tributary rivers) was undertaken during the high runoff period of the wet winter of 1994-1995. The Feather and American rivers were found to have contributed mercury to the Sacramento River, although substantially less than the upper Sacramento River Basin. This conclusion was based on concentrations detected on these rivers, as well as measurements on the Sacramento River at Greene's Landing (located below the confluence with the American River). (During this high flow period, much of the upper Sacramento River flows were being diverted to the Yolo Bypass.) The American River Basin was calculated to have exported 0.3 kg of mercury on 11 March 1995 (see **Table 4-15**). These loads are consistent with the conclusions of Larry Walker and Associates (1997) who estimated the American River contributes only 9 percent of the mercury load to the Sacramento River, as compared to the Sacramento Basin above the confluence of the Feather River (which is estimated to contribute 58 percent) and the Feather River (which is estimated to contribute 31 percent).

**Table 4-15. Mercury and suspended sediment concentrations and loads in the American River in March 1995.** [a]

| Location | Mercury (ng/l) | TSS (mg/l) | Mercury/TSS (ppm) | Flow (cfs) | Sediment $10^3$ (t/d) | Mercury (kg/d) |
|---|---|---|---|---|---|---|
| American River | 3.9 | 9.83 | 0.40 | 34,500 | 0.8 | 0.3 |

[a] Sample was collected on March 11 during the largest storm of the year, from mid channel off bridge at California State University, Sacramento.
Source: RWQCB, 1998

Foothill reservoirs have been found to operate as sinks for both bioavailable and sediment associated inorganic mercury (Slotten et al., 1997; Larry Walker and Associates, 1997). Significantly lower levels of mercury were found in aquatic organisms below reservoirs as compared to concentrations both in and above them. Similarly, these studies showed that bulk loads of mercury entering foothill reservoirs were greater than the amounts exported. This suggests that the reservoirs in gold mining districts may act as interceptors of mercury, trapping and preventing downstream transport to the Estuary. This may explain the smaller-than-expected loads measured in both the American and Feather rivers by this study and by Larry Walker and Associates (1997). The mercury loads now present after storms in Sierra rivers may primarily result from resuspension of bedload material located below dams.

#### 4.2.3.3. SWRCB Toxic Substances Monitoring Program (TSMP)

The Toxic Substances Monitoring Program was initiated in 1976 by the California SWRCB to provide a uniform statewide approach to the detection and evaluation of the occurrence of toxic substances in fresh, estuarine, and marine waters of the state through the analysis of the tissues of fish and other aquatic life. The TSMP primarily targets water bodies with known or suspected water quality impairment and is not intended to give an overall assessment of the water quality of each of the state's waters.

In the past, samples were collected each year from over 100 locations throughout the state. Samples taken by the California Department of Fish and Game are analyzed for trace elements (metals), pesticides, and PCBs. Sampling results are compared to criteria such as Maximum Tissue Residue Levels, U.S. Food and Drug Administration action levels, Median International

Standards (MIS), and the National Academy of Sciences recommended guidelines for predator protection.

TSMP samples were most recently collected in the Sacramento region in 1993. During this year, mercury tissue concentrations in white catfish collected from the Sacramento River at Hood and in largemouth bass collected from the American River downstream of the Watt Avenue bridge did not exceed the MIS for mercury (0.5 mg/kg, wet weight, edible portion). Similar levels were found in white catfish collected from the Sacramento River in 1992. However, in 1991, some of the white catfish collected from the Sacramento River at Hood and some of the Sacramento suckers collected from the American River downstream of the Watt Avenue Bridge showed tissue concentrations in exceedance of the MIS for mercury. However, at both locations, the concentrations were below the Food and Drug Administration action level (1.0 mg/kg, wet weight, edible portion) (TSMP 1993; SRCSD 1999).

#### 4.2.3.4. Regional Board 104(b) Grant Toxicity and Toxicity Identification Evaluation Study

The Regional Board conducted a Toxicity and Toxicity Identification Evaluation Study on Sacramento and Stockton urban runoff and urban runoff-dominated creeks and sloughs (Regional Board and UC Davis, 1999). Samples were collected from urban streams, sumps and sloughs in the City of Sacramento and City of Stockton during the 1994-1995 precipitation season. The samples were analyzed for diazinon and chlorpyrifos, organophorphorous pesticides widely used in urban areas. The report provided a summary of results, but did not provide separate results for Sacramento versus Stockton.

The study showed that these samples frequently contained concentrations of diazinon and chlorpyrifos exceeding water quality criteria for the protection of aquatic life. Most of the samples were found to be acutely toxic to *Ceriodaphnia dubia*, and TIEs performed on selected samples confirmed that the observed toxicity could be attributed to these pesticides. The TIE results also suggested the presence of unknown toxicants in some samples, but it was not possible to determine the exact contribution of these toxicants to the observed toxicity. It was found that diazinon concentrations in the primarily residential catchment were on average at least twice as high as concentrations in the commercial and industrial catchment.

#### 4.2.3.5. Other Toxicity Studies

Additional toxicity investigations have been conducted in the Sacramento River basin. The RWQCB and Department of Pesticide Regulation evaluated toxicity during the orchard dormant spray period in 1996/97. The RWQCB study found diazinon to be the cause of toxicity in all *Ceriodaphnia* TIEs conducted. Although diazinon was detected, Department of Pesticide Reduction did not observe any toxicity to *Ceriodaphnia.* The RWQCB also performed TIEs as part of the Metal Concentrations, Loads and Toxicity Assessment conducted between 1993 and 1995. Metals were not implicated in any of the TIEs performed.

#### 4.2.3.6. Aerojet Groundwater and American River Monitoring Studies

The Aerojet Sacramento facility is located south of U.S. Highway 50 in Rancho Cordova, approximately 15 miles east of downtown Sacramento. Since the early 1950s, this facility has manufactured and tested solid rocket motors and liquid rocket engines. Chemicals used at the facility included chlorinated solvents, propellants, metals and oxidizers used in the manufacturing and production areas, as well as a variety of chemicals produced in the chemical manufacturing areas.

Historical operations at the Aerojet facility have resulted in the release of constituents of potential concern to soil and groundwater(Aerojet, 2000). Volatile organic carbons (VOCs), primarily trichloroethylene (TCE) and perchlorate, have been detected in soil and groundwater beneath a number of these source areas. NDMA, which was known to exist on the east side of Aerojet, was detected in groundwater on the west side of the Aerojet site. Sources of VOCs, perchlorate and NDMA may exist off-site due to activities not associated with the Aerojet facility. Chlorinated solvents, including TCE, were commonly used by different industries. Perchlorate has been, and nitrate is, a common constituent of fertilizers. NDMA is associated with various industrial and food processing industries and has been a contaminant in foods.

Numerous monitoring wells were installed both north and south of the American River to determine the extent of the migration of chemicals in the groundwater. Originally, the American River was thought to serve as a hydraulic barrier to the migration of the groundwater plume to the north side of the river (pers. comm. Alex McDonald, 2000). However, the presence of chemicals on the north side of the river indicates that the river is not a significant barrier to groundwater flow or chemical migration. Aerojet's Effectiveness Evaluation (GenCorp Aerojet 2000) acknowledges that the upper aquifer is at least partly unconfined and that some hydraulic connection exists between the upper aquifer and the American River (GenCorp Aerojet, 2000). Aerojet's geologic cross sections indicate that most of the upper aquifer is in hydraulic communication with the American River (GenCorp Aerojet 2000).

During the 1980's, TCE was found at detectable concentrations in the American River. The City of Sacramento monitored the river for TCE at the Sunrise Bridge crossing and at the E.A. Fairbairn WTP intake from 1983 to 1987. The source of the TCE was considered to be groundwater contamination from seeps into the American River across from Sailor Bar Park. A sample collected at the seep in 1986, showed a TCE concentration of 3,300 ug/L. TCE has not been detected in the American River since the mid1980s. It appears that the contamination in the groundwater that was communicated to the American River through the seeps has been depleted (AWC and MW, 1998).

The majority of contaminants in the upper aquifer do not cross the American River (Appendix B; GenCorp Aerojet, 2000), suggesting the river may form at least a partial barrier to contaminant migration. The TCE plume in the upper aquifer appears to be diluted as it crosses beneath the river and appears to be deflected northward away from the river, which is consistent with recharge from the river in the western part of the site. The highest concentration found in the upper aquifer is 1400 µg/l; a monitoring well which borders the lower American River measured 350 µg/l. However, the TCE detections north of the river are primarily in wells screened in the lower portion of the upper aquifer. Results for wells screened in the upper part of the upper aquifer are either non-detect or very low (GenCorp Aerojet 2000), suggesting possible dilution from the river (Montgomery Watson 2000b).

Contamination of the American River from groundwater sources is not likely under current hydrologic conditions. Groundwater contours in the vicinity of the TARGET facility are convex downstream (GenCorp Aerojet 1996; 2000), indicating that the American River was apparently losing water to the aquifer. Previous regional modeling results have indicated that this section of the American River is a losing stream (Montgomery Watson 2000b). Regional water level maps also indicate that the top of the regional aquifer is below the bottom of the American River (California Department of Water Resources 1974).

Aerojet has conducted water quality monitoring of the American River for over 10 years to investigate the migration of chemicals from groundwater into the American River; however, no contamination of the American River by the chemicals found in the groundwater has been identified (pers. comm. Alex McDonald, 2000). The monitoring has been conducted during low flows (to avoid the beneficial effects of dilution) at several sites (including just downstream of the fish hatcheries, upstream and downstream of the Buffalo Creek flow into the American River, and at the intake to the Fairbairn Water Treatment Plant).

Since the mid- to late-1980s, constituents of potential concern in groundwater flowing west from the source areas on the Aerojet Site have been intercepted by two interim perimeter groundwater extraction and treatment (GET) facilities, "GETs E and F" (Aerojet 2000). GETs E and F captured and treated groundwater for VOCs at northeastern and southwestern locations along the perimeter of the Aerojet Site, respectively. A series of recharge wells installed in the center of the western perimeter of the Aerojet Site provided a hydraulic barrier to direct the contaminated groundwater towards the extraction wells. The recharge water contained perchlorate, and, in early 1998, using an improved analytical method, NDMA was detected in the water extracted and recharged at GET E. Treated groundwater from two of the GET F extraction wells was initially discharged after VOCs were removed via a sprayfield located on the northwestern corner of the test site for a period of approximately 6 years. The treated groundwater discharged to the former sprayfield has percolated into hydrostratigraphic Layers B and C beneath the northwestern corner of the test site and formed a plume of perchlorate-impacted groundwater flowing to the west-southwest.

A biological reduction treatment system was added to GET F to remove perchlorate from the groundwater in December 1998. In September 1999, the NDMA concentration in the combined GET E/F effluent was below the NDMA method detection limit of 0.0075 ug/L. At full-scale operation in late 1999, each of the fluidized bed reactors achieved non-detect perchlorate effluent concentrations (Harding Lawson Associates, 2000 pending).

In 1998, the groundwater extraction and treatment systems began discharging into Buffalo Creek, which flows into the lower American River under an NPDES permit. There have been no exceedances of regulatory limits. The limit for perchlorate is 18 ppb; perchlorate is detected in the effluent at 5 ppb (pers. comm., Alex McDonald 2000).

### 4.2.4. SUMMARY

The water quality of the lower American River is assessed in this section, based on the results of the SMP, AMP, SRWP, and lower American River watershed sanitary survey described above. These three water quality monitoring programs and the watershed sanitary survey constitute a comprehensive assessment of lower American River water chemistry and aquatic toxicity during wet and dry weather, and at upstream and downstream locations along the lower American River. The Lower American River Watershed Sanitary Survey describes the source water quality along the entire American River as generally excellent. With regard to the monitoring programs, each has assessed the water quality of the American River to be good overall, based on compliance with drinking water and aquatic life criteria for monitored parameters.

As reported by the AMP, based on data from 1992 through 1998, monitored ambient water quality constituents meet applicable regulatory standards for both aquatic life and human health, with few exceptions. Most notable to aquatic life, four metals exceeded the California Toxics Rule or EPA criteria. Based on the exceedance rate during the 1992-1998 study period, at Nimbus, lead and zinc would exceed applicable criteria less than once every three years, and cadmium, more than once every three years. At Discovery Park, cadmium would exceed applicable criteria once every three years, and copper, lead and zinc would exceed applicable criteria less than once every three years.

SRWP water chemistry monitoring concluded the lower American River consistently meets drinking water quality goals and standards. Toxicity testing, however, revealed varying degrees of mortality or decreases in reproduction or growth in test species, and concentrations of PCBs (sum of aroclors) exceeded screening values in tissue samples from fish collected on the American River at Discovery Park. AMP pesticide monitoring conducted on the lower American River has occasionally detected diazinon, diuron, and simazine. The concentrations of diuron and simazine are well below concentrations identified as slightly toxic to fish; diazinon, however, was detected seven times over four years at concentrations above CDFG's recommended maximum values for fish.

Aerojet groundwater contamination, at present, does not appear to pose a water quality threat to fish resources in the lower American River.

# 5.0 RIVER HYDRAULICS AND RELATED FLUVIAL GEOMORPHOLOGY

From the lower American River's early beginnings as a natural river and corridor providing a water supply, food source, mode of transportation, and focal point for native inhabitant settlement, the river has undergone many changes, largely as a result of man's varied activities over time.

Despite these frequent changes, the river and its corridor have exhibited a dynamic form of stability. In constantly changing ecosystems, stability is the ability of a system to persist within a diverse range of conditions. This ability is known as "dynamic equilibrium." The maintenance of dynamic equilibrium requires that a series of self-correcting mechanisms be active in the river corridor ecosystem in response to external stressors.

In response to these external stresses, the river has adjusted, time and time again. The expression of today's river and its associated fluvial morphology is simply one static point within the river's constantly adjusting character. From a river hydraulics and related fluvial geomorphological perspective, the imposed stresses (e.g., changing river hydraulics due to some activity) have manifested themselves into expressed changes (i.e., self-correcting mechanisms) in river geomorphology (i.e., form features). While some induced hydraulic changes have long-term and significant influence on the morphological nature and features of the river, some are more short-term and localized in their expression.

Ayres Associates has recently prepared a detailed accounting of the American River Basin geomorphology, as well as some of the important physical processes that control the morphometry of the basin (Ayres 1997). Much of the text in this section is taken directly from that report.

## 5.1.1. HISTORIC OVERVIEW

Several key activities have occurred over the years that have affected the character of the lower American River, including its morphological nature. Historically, the lower American River has been influenced by hydraulic gold mining in the Sierra, mining and associated dredging of the lower American River, land use changes in and around the river (as a result of urbanization), and the hydrologic changes brought about with the construction of Folsom and Nimbus dams.

### 5.1.1.1. HYDRAULIC GOLD MINING IN SIERRAS

In January 1848, James Marshall discovered gold in the millrace of a water-powered lumber mill he was building for John Sutter on the South Fork of the American River. This discovery resulted in the famed Gold Rush into the Mother Lode of the Sierra Nevada. The influx of prospectors catapulted California to statehood in September 1850. Industrial scale mining was conducted at many river gravel bars along the American River during the late 1850s and replaced the individual miner as surface deposits became exhausted. The cumulative effects of the numerous mining companies that were formed helped divert the American River and other Sierra rivers into flumes and long sluices. Shoreline gravel substrates were excavated with the assistance of newly developed hydraulically powered pumps (Turner 1983).

Between 1849 and 1909, an estimated 257 million cubic yards of mining debris entered the various streams and channels of the American River basin (Hagwood 1981). Most of these tailings from the largest operations were permanently lodged in the upper watershed. The North Fork of the American River generated approximately 20 to 25 million cubic yards of mining debris. However, the majority of the South Fork's gold-bearing gravels was overlain by volcanic rocks, and hence did not experience hydraulic mining. Accordingly, the South Fork remains clear of mining debris.

#### 5.1.1.2. Dredging of Channels and Adjacent Areas

With the invention and rapid evolution of channel dredges beginning in the early 1900s, mining of channel deposits in the lower American River commenced in earnest. Some of the most productive dredge mining since the turn of the 20th century occurred on the American River near and below the City of Folsom (Hagwood 1981). Some of the relics of these operations can still be seen in the large stockpiles of dredge tailings in and around the lands presently occupied by the Aerojet Corporation (south of Highway 50, just west of the City of Folsom). Along this stretch of the lower American River, the river was constrained between high gravelly banks, ideally suited to gold mining. The banks were composed of cobble-stones, gravel, sand, and argillaceous material, packed together in various degrees of hardness, and overlaying a hard cement or bedrock hardpan. Gold was present in all of the material above the cement, and was extensively mined (Ayers 1997).

Dredge mining for gold occurred as far downstream on the lower American River as Goethe Park (RM 13.5). It caused reworking of the floodplain and bars, and significantly altered the out-of-bank topography. Past sand and gravel mining in both the river and its floodplain has resulted in the development of numerous split flow reaches within the river.

The tailings from most gold mining operations along the lower American River were dumped into the riverbed. The filling of the channel consequent to these operations cannot now be accurately ascertained; however, it has been variously reported at from 5 to 30 feet. The first noticeable effect of this filling was produced in 1862. The regimen of the river having been significantly changed, much destruction was wrought. Large tracts of land were swept away in some places, and immense deposits left in others. At one particular point, about 12 miles upstream from the City of Sacramento, 400 acres were eroded 5 feet and, on the opposite bank, approximately 200 acres were similarly swept away (Ayers 1997).

In numerous places along the lower American River, the extensive accumulation of mining debris during that period resulted in the formation of new channels (e.g., split channels). Additionally, near the mouth, the old channel was completely eliminated and approximately 15 square miles of land covered with debris. By the 1880s, the tides could not reach within 3 miles of the lower American River mouth, although this part of the river was previously subject to tidal actions of at least 2 feet (Ayers 1997).

#### 5.1.1.3. Agricultural Development/Land Clearing

Historically, agriculture played an important role in the development of the lower American River basin, particularly, the greater Sacramento area. Dryland farming allowed production of crops like wheat, hay, and some wine grapes. By the 1920's, gas engines and electric motors facilitated more extensive irrigation practices, thereby increasing the amount of irrigated cropland in the basin. Technological improvements after World War II resulted in the conversion of large previously undisturbed lands, into irrigated pastures and fields for corn, sorghum, strawberries, and grapes (Corps 1991a).

Over the years, urbanization within the greater Sacramento area, including upstream unincorporated areas and the City of Folsom, has led to a significant loss of cropland and farmland. Today, no appreciable agricultural lands exist within the American River Parkway or floodplain.

Unlike the Sacramento River, boat traffic up the lower American River was usually limited to periods of high water flows when steamers and other vessels could navigate the few miles upstream. During these early periods, lumbering, ranching, and limestone quarrying occurred within the floodplain. By the 1930s, with the onset of the Great Depression, resurgence in gold mining and associated river dredging occurred in the area with these miners often settling in the structures or campsites originally inhabited by the early gold rush miners (Corps 1991a).

#### 5.1.1.4. FOLSOM DAM/NIMBUS DAM CONSTRUCTION

The Corps completed construction of Folsom Dam in 1955. As a multipurpose water project operated by the USBR, it regulates runoff from about 1,875 square miles of drainage. Folsom Reservoir initially provided about 1,000,000 acre-feet of storage, but sedimentation over the years has resulted in a current storage capacity of about 974,000 acre-feet.

The original flood control diagram for Folsom Dam and Reservoir was developed and implemented in May 1956. That diagram required varying flood control space reservation for any given day based on the weighted accumulation of basin mean precipitation. The required flood control reservation could be anywhere from 200,000 to 400,000 acre-feet. That diagram was modified in July 1977, to base the flood control reservation space on the weighted accumulation of seasonal basin mean precipitation minus a recovery factor. The reservoir was required to be drawn down to elevation 426 ft mean sea level (msl) by November 10, and held no higher than that until December 31 of every year. Based on precipitation parameters, the reservoir could be refilled at varying rates until full between May 1 and June 9. Following the 1986 floods, the flood control diagram was again modified to emphasize the need to maintain the maximum flood control space later into the flood season. In 1994, through an interim agreement, that diagram was again changed. Today, under the continued interim condition, the flood control reservation is variable between 400,000 and 670,000 acre-feet.

Nimbus Dam, located about 7 miles downstream from Folsom Dam, is an afterbay structure constructed and operated by the USBR to re-regulate flows into the lower American River. Nimbus Dam impounds Lake Natoma. Lake Natoma stores 8,760 acre-feet of water when full, but fluctuates 4-7 vertical feet daily as a re-regulating afterbay.

The presence of Folsom and Nimbus dams, in addition to providing flood control, also provides operators with the ability to regulate flows into the lower American River. Flow regulation of the lower American River, as a multiple purpose waterway, provides benefits to instream aquatic resources, recreationists, and water supply for urban consumptive uses. However, flow regulation at Folsom and Nimbus dams have had an effect on the natural flow regime and its associated ability to affect the geomorphology of the riverine ecosystem.

#### 5.1.1.5. FLOOD CONTROL LEVEES

Bluffs naturally confine the upstream reach of the lower American River, but below Goethe Park the river flows through alluvial plains with little natural confinement. In this reach, from RM 13.7 to the confluence, the river is confined by levees. The levees join at the mouth of the lower American River with those of the Sacramento River levee system and flood bypass system. As part of the American River Flood Control Project constructed by the Corps in 1958, this levee system extends about 7 miles from high ground near Carmichael downstream along the north side of the river to a previously existing levee ending near the Interstate Business 80 river crossing. Two pumping plants discharge storm drainage, collected in low-lying areas landside of the levee, into the lower American River. Because of this levee system, Folsom Dam and Reservoir can be operated to its flood control design release capacity of up to 115,000 cfs.

Together with the lower levees that are part of the Sacramento River Flood Control Project, this system of levees protects the greater Sacramento metropolitan area from large-scale flooding. The construction of the levee system has, however, directed all river flows through a confined channel, effectively eliminating the natural frequency with which river flows would inundate the natural floodplain. While this was a primary designed purpose of the flood control levee system, it constituted a profound alteration of the natural function of the river.

#### 5.1.1.6. DOWN-CUTTING OF THE RIVER CHANNEL

River bed aggradation occurred in the lower American River as a result of the increased sediment loads generated by hydraulic mining. As mining decreased and eventually ceased, sediment loadings dissipated and degradation of the accumulated mining debris resulted. Today, the lower American River has degraded down to its Pleistocene-aged outcrop in several locations. The flow-related removal of all historic mining debris that once filled the river, downstream of present day Nimbus Dam, is now locally complete (Ayers 1997).

Together with sand and gravel mining, the construction of Folsom and Nimbus dams resulted in the degradation of the channel, and possibly exhumation of pre-existing bedrock topography at some locations along the lower American River. Such channel degradation has resulted in the need to reinforce numerous bridge piers along the river, especially in the lower reaches where the oldest bridges are situated. For example, the abandoned railway bridge at RM 2.2 has experienced channel bed degradation of at least 15 feet since 1906 (Ayers 1997).

#### 5.1.1.7. LATERAL EROSION OF BANKS

Prior to the construction of levees, lateral erosion was more pronounced along the lower American River, especially in the downstream reaches (i.e., downstream of Goethe Park) where the river floodplain is not constrained by bluffs or elevated terraces. Long-term documented estimates or comparisons of lateral erosion rates do not exist. Recent studies, however, have shown lateral migration rates in the lower American River between 1968 and 1986 to vary from 1.1 to 13.9 feet per year (Ayers 1997). This high variability in lateral erosion has been corroborated in other aerial photographic comparisons, which confirm the high variability in bank erosion between 0 to a maximum of 11.2 feet per year (depending on site and time of year). Bank erosion rates were generally highest during the 1981-1986 period, and lowest during the 1975-1981 period. Today, with the cessation of any appreciable upstream sediment supply, bank erosion is the primary source of sediment for the lower American River (Ayers 1997).

#### 5.1.1.8. CHANNEL MORPHOLOGY

The effects of historic hydraulic mining on the lower American River, construction of Folsom and Nimbus dams, and the establishment of the existing flood protection levee system have collectively acted to alter the channel morphology of the river.

Thalweg profiles reviewed for 1906, 1955, and 1987 reveal that channel bed elevation downstream of Goethe Park was about 15 to 18 feet higher in 1906 than in 1987. Upstream of Goethe Park, the profiles appear similar except that the 1906 profile is less irregular and variable than the 1987 profile. The aggradation apparent in the 1906 profiles can be largely attributed to the introduction of hydraulic mining debris into the Middle and North Forks of the American River during that time. The degradation apparent between 1955 and 1987 was probably accelerated by construction of Folsom and Nimbus dams, which effectively cut off the upstream sediment supply to the lower American River (Ayers 1997).

The upstream reaches of the lower American River have been the least susceptible to extensive flooding due to the relatively large channel capacity between the older-aged terraces, relative to the downstream reaches. With the construction of the levee system, however, the channelized nature of flood flows in the downstream areas has resulted in higher tractive capacities and erosional capabilities in these areas. Degradation in the lower reaches is more pronounced and the size range of depositional clasts have increased. Larger-sized cobbles and gravels are more frequently observed over a wider area, having being deposited during the high flows characteristic of the flood season.

#### 5.1.1.9. SEDIMENT SUPPLY

Mining debris reaching the Sacramento River from the upstream portions of the American River represented a significant portion of the river’s suspended sediment and bedload during recent times. These materials have been described as principally very fine gravel, sand, and sediment. With the construction of Folsom and Nimbus dams, this source of supply has ceased. Now, most of the river’s sediment supply is derived from bank erosion upstream of Goethe Park.

The sediments that comprise the active channel and floodplain deposits of the lower American River are divided into those of Recent and Pleistocene age. The Pleistocene-aged deposits form the bounding terraces and bluffs. The Recent-aged sediments form in several environments including floodbasin, floodplain, and channel deposits. Sedimentary deposits formed in these environments include floodbasin silt and clay, abandoned channel fill, and vertical and lateral accretion sediments.

Recent flow/sediment analyses show a general fining trend downstream from Nimbus Dam to RM 4. The median diameter ($D_{50)}$ diminishes from 90 mm at RM 22.3 to 30 mm at RM 4. Downstream of RM 4, the backwater effects caused by the tidally-influenced Sacramento River has resulted in the deposition of sand-sized sediment on the bed of the river ($D_{50}$=0.6 mm). Coarser sand-size sediments underlie the fines at the mouth of the river (Ayers 1997).

#### 5.1.1.10. SEDIMENT TRANSPORT

Historical sediment transport in the lower American River was facilitated by the natural flow regime of the river, dictated largely by river competence and tractive stress. Unconstrained by dams, the hydrograph of the river was purely a function of seasonal climatology, precipitation, antecedent moisture conditions, watershed drainage, and the existing morphology of the river at the time.

## 5.1.2. CURRENT CONDITIONS

### 5.1.2.1. FLOW VELOCITY AND DEPTHS

One hundred-year stage hydrographs for the mouth of the American River were developed for the flood control improvement design scenarios evaluated by Ayres (1997) (**Appendix E**). Ayres extended the recession limbs of the hydrographs by extrapolating the recession limbs using a gradually decreasing slope. A single rating curve was developed assuming concurrent flows on the Sacramento and American rivers with equal exceedance frequencies. This was accomplished using the flow duration and stage-discharge relationships for the I Street river gauge on the Sacramento River (downstream from the mouth of the American River) and the flow duration curve for the American River at the Fair Oaks river gauge. The I Street flow duration and stage-discharge curves provided by the Corps, and pre- and post-Folsom Dam flow duration curves for the Fair Oaks river gauge are provided in (Appendix E).

For a given exceedance frequency on the American River (post-Folsom Dam), the corresponding flow on the Sacramento River for the same frequency was then determined. The corresponding stage was then determined for the stage-discharge relationship, and a stage-discharge relationship for the lower American River mouth was developed using the I Street stages and the corresponding American River flows. The resulting stage-discharge curve for the mouth of the lower American River is provided in (Appendix E).

Ayres conducted a detailed hydraulic analysis to provide the necessary hydraulic information for use in their sediment transport and channel stability evaluations. Hydraulic conditions were modeled using the HEC-2 water surface profile program. Model output was used to evaluate channel capacity, bed shear stress, work done on the channel banks, and local scour at bridge crossings. Geometric and hydraulic roughness data for the HEC-2 model were also used to form the basic input for the hydraulic portion of the HEC-6 sediment transport model.

The HEC-2 model was run for discharges at the upstream end of the study reach (Nimbus Dam) ranging from 10,000 cfs to 180,000 cfs. Starting water surface elevations were set according to the stage-discharge relationships provided in Appendix E.

Bed and water surface elevation profiles for upstream discharges of 10,000, 20,000, 50,000, 100,000, and 180,000 cfs are presented in Appendix E. Included on the plot are top of bank elevations set at the minimum of the left and right bank elevations for each cross section.

Main channel velocity, topwidth, and hydraulic depth (area/topwidth) profiles for discharges of 10,000, 20,000, 50,000, 100,000 and 180,000 cfs are shown in Appendix E. The velocity and hydraulic depth profiles show a general trend of increasing velocities and decreasing hydraulic depths in the upstream direction, which can be related to an increase in channel slope. Sections of the river with large main channel topwidths occur at locations where the river crosses wide gravel bars, often at river bends. The variability in all the hydraulic parameters between cross sections reflects the highly variable nature of the flow in the lower American River.

From Nimbus Dam to Goethe Park, natural geomorphic processes control the distribution of flow depths (riffle, run, pool, glide sequences). Within this reach, deep water sections are located parallel to bluffs and terraces, which serve to capture the thalweg locations. Flow depths are controlled primarily by channel gradient, width, and substrate composition. Below Goethe Park, the floodplain becomes restricted by levees. These have resulted in long, deep, flatwater pool sections, which dominate the river channel down to its confluence with the Sacramento River.

From Nimbus Dam to Goethe Park, the surface width of the river is controlled primarily by resistant natural bluffs and terraces, which cause an increase in depth and a decrease in width for this section of the river. Below Goethe Park, the width of the floodplain becomes restricted by levees and the substrate composition changes to sand. This confinement by the levees has forced the river to scour its way through the alluvium substrate, creating predominantly a deep water channel of greater width than the upper reaches of the river. From RM 11.6 to 4.9, the floodplain narrows from a width of about 2,000 feet at the lower end to a width of about 1,000 feet over much of the remainder of the reach. In this reach, the stream channel is several hundred feet wide but narrows in places to 150 feet. The lowermost reach (RM 0-4.9) is unique in that it has a fairly wide floodplain (about 2,000-3,000 feet between levees), with the river confined to a relatively narrow channel 500 feet wide along the south levee at all times except during flood flows.

Different channel control attributes create local changes in flow and water depth distribution. Reach 1 has a gradient of 0.03%, and is characterized by deep flatwater pools of low velocity. Reach 2 has a slightly higher gradient at 0.05%, and has greater stream channel diversity (gravel-dredger pits and bar complex formations) with greater fluctuations of flow velocities. Reach 3 has a higher gradient (0.08%) than either of the lower reaches. This higher gradient combined with naturally resistant sandstone bluffs, has produced a diversity of bar complex formations with fluctuating flow velocities.

#### 5.1.2.2. MORPHOLOGICAL PROCESSES AND FORMS

Fluvial landforms in the lower American River are controlled by the nature of the river flow and the characteristics (e.g., geological, sedimentological, and associated vegetative) of the unconsolidated materials that make up the riverine corridor.

A solid understanding of how aquatic habitats develop, continually evolve, and are managed requires an appreciation for the forces (i.e., morphological processes) that control their development, and the resulting riverine landforms (i.e., habitats). Knowledge of this interrelationship is a prerequisite for all riverine restoration planning efforts.

From Folsom Dam to Fair Oaks, the American River floodplain is narrow. At Fair Oaks, the floodplain widens to about 1 to 5 miles, and the steep 125-foot high bluff of the Turlock Lake formation bounds the northern channel margin. Downstream, near Sacramento, the bluff height reduces to less than 10 feet and consists of the Riverbank Formation. The southern channel margin consists of a terrace of Recent-age alluvium that is lower than the northern bluff. The levees that have been constructed along both banks of the lower river are, therefore, critical to flood control operations.

The recent (1987) profile of the river is highly irregular. Upstream of RM 14, the channel bed elevation is controlled by irregularities in the Pleistocene-age materials that crop out intermittently all the way to Nimbus Dam. Downstream of RM 14, the bed irregularity can also be attributed to outcrops of erosion-resistant materials. Pleistocene-age materials crop out in the bed of the river at RM 13.5 and RM 9.9, and these appear to be providing local base-level control for the channel. Fine-grained abandoned channel fills are located at RM 6 and RM 4.5. At RM 4.5, the channel fill has been eroded and no longer provides a local base level control. It is likely that the channel fill at RM 6 will also erode eventually, and this will cause some local bed adjustment upstream. Currently, there is bed material storage immediately upstream of RM 6, and bed erosion will lead to downstream transport of these sediments. However, the bend downstream also exerts a major control on the hydraulic energy in this reach, and provided the existing planform is maintained, the rate of erosion of the channel fill may be slow.

The future status of the bed in the project reach is dependent on the inflow of sediment downstream of Nimbus Dam, the caliber of the bed materials in the reach, and the erosion-resistance of the Pleistocene-age outcrop in the bed of the channel. Since the Sacramento River bed elevation has remained relatively constant since 1930 (Meade 1982), it is unlikely that base level will change significantly in the future. Because of drought conditions, flows in the lower American River have been low since the 1986 flood. However, field evidence indicated that the 1993 flows transported and deposited bed material at different locations.

Based upon general geomorphic characteristics, the project reach was divided into five study subreaches.

- Subreach 1 extends from RM 0 at the Sacramento River to RM 4.8 near Cal State Expo. This subreach is characterized by little sediment storage in bars and intermittently eroding banks. It is strongly influenced by backwater conditions generated at the confluence with the Sacramento River.

- Subreach 2 extends from RM 4.8 to RM 8.0 and is characterized by sediment storage in large point bars and several mid-channel bars. A large percentage of the left bank is revetted within this subreach, which is adjacent to California State University at Sacramento.

- Subreach 3, extending from RM 8.0 to RM 11.5, is characterized by a large proportion of split flow and small sloughs, which result from sand and gravel mining. Modesto Formation outcrop is present in minor amounts within this subreach.

- Subreach 4 extends from RM 11.5 to RM 17.0, and encompasses sediment storage sites in point bars and mid-channel bars that are underlain by Pleistocene-age outcrops. The sediment commonly forms a relatively thin veneer over the strata surface.

- From RM 17.0 to the upstream study limit at RM 23, Subreach 5 of the lower American River is characterized by the high bluffs of the Turlock Lake Formation on the north bank and large, coarse-grained bars that commonly consist of dredge spoils.

### Sediment Composition

Sediment composition is an important component in the evolution of stream form and geomorphology. Although sediment and its transport occur naturally in streams, changes in sediment load and particle size can have negative ecological effects. Fine sediment can severely alter aquatic communities. Sediment may clog and abrade fish gills, suffocate eggs and aquatic insect larvae on the river bottom, and fill in the interstitial pore spaces between bottom substrates where fish lay eggs.

## Grain size

The bed of the American River is primarily composed of gravel to cobble-sized material. **Figure 5-1** shows average bed material surface gradations developed from the sediment samples collected for this and previous projects. The surface gradation for the approximate 2 miles of the downstream study reach is believed to represent a relatively thin layer of sand deposited over the coarser-grained channel bed during low flows. This material will be flushed during higher flows exposing the underlying coarser-grained bed.

Gravel size can change seasonally and from year-to-year. This temporal variability can affect the applicability of observed gravel sizes to actual conditions and have implications from an aquatic biota perspective. For example, the amount of interstitial fine sediment can increase during the incubation period by infiltration into the redd (Carling and McCahon 1987; Sear 1993) or by scour and fill (Lisle 1989). Thus, the timing of sediment transport in the channel in relation to incubation of salmonid embryos is very important in determining spawning success. Timing may be especially important with fine sediment inputs from human activities, because these may occur during low flows in the channel.

**Figure 5-1. Average surface bed material sediment size distributions.**

### Sediment Mobility and Transport

The mechanics of transportation of load include solution, flotation, suspension, saltation, and traction. With an increase in energy, parts of the bed load are thrown into suspension, and more of both suspended load and bed load is entrained. Deposition of material and reversion of some suspended sediment to bedload transport accompanies energy losses. Part of the gradation of bed load into suspended load is due to transport by saltation, a process of skipping or bouncing along the channel bed (Gilbert 1917).

Traction, the rolling and sliding of particles along the bed, constitutes true bed transport. However, in many situations in which traction is established, most of the material moves by saltation . The hydraulic shear stresses required to move particles on a stream-bed are complex and interactive. At some critical shear stress, particles on the bed begin to move. The transport rate increases with increasing shearing stress.

The relationship between the force of water pushing on the upstream side of a particle and the resistance of the particle to movement is described by the sixth power law: A particle on a stream bed is on the verge of motion when the force of the water against it equals the resistance of the particle to movement. A small increase in velocity (taken to the sixth power) will therefore produce a very large increase in the size of particle that can be moved. The power of streams to transport surprisingly large material during floods is thus more readily understood.

Because of the steep rate of change of velocity near the bed of a stream, grains on a streambed in the area of steepest velocity gradient experience a lowering of pressure on the top of each particle surface, known as hydraulic lift. This phenomenon, which is analogous to an airplane wing, is more effective on small particles than on larger ones. A particle on a sloping stream bed supports a column of water above it that exerts a critical tractive force proportional to the depth of water and the channel slope. The critical tractive force is significant for moving smaller particles, whereas the sixth power law is prominent in moving large particles (Rubey 1938).

Before grains can be set in motion on a streambed, both gravitational and cohesive forces must be overcome. Cohesion between sand-size or larger grains is low and less important than gravitational forces. However, for silt and clay, cohesion plays a prominent part in entrainment of grains. Clay particles that can be transported by a given velocity are more difficult to move from a streambed because of cohesion between grains that inhibits their motion.

A detailed sediment transport analysis of the study reach was performed to evaluate the vertical stability of the channel and to determine sediment yields to the Sacramento River under the various design scenarios. The sediment transport analysis involved the evaluation of watershed sediment yield, an incipient motion analysis of the channel bed material, detailed sediment routings, and sediment budget calculations. The results of the sediment transport analysis are presented in this subchapter.

#### Sediment Yield

Sediment delivered to the upstream end of the project reach from the American River watershed is significantly affected by Folsom and Nimbus Dams. Folsom Reservoir is a 975,000 acre-foot facility that traps all the bed material load and a significant portion of the wash load brought in from upstream. Nimbus Dam, a regulating afterbay located just downstream of Folsom Dam, has a reservoir capacity of approximately 9,000 acre-feet. Because of the presence of these two dams, no bed material-sized sediment is supplied to the lower American River from upstream. A trap efficiency calculation was performed for Folsom Reservoir to determine the percentage of upstream wash load delivered to the lower American River. Due to its small size and location just downstream from Folsom Dam, the trap efficiency of Nimbus Dam was not analyzed.

The trap efficiency for the wash load was evaluated using the procedures developed by Brune (1953) and Churchill (1948) in "Sedimentation Engineering" (ASCE 1975). Both procedures estimate the trap efficiency using average flow conditions and are thus applicable on an average annual basis. The results provided in **Table 5-1** indicate that from 90 to 100% of the wash load sediment yield will be trapped. Average annual wash load yield to the lower American River is approximately 0.005 acre-feet per square mile.

For purposes of evaluating the stability of the lower American River and sediment yield to the Sacramento River, these results are considered to be negligible. If the trap efficiency of Folsom Reservoir is assumed to reduce to approximately 80% during a 100-year storm event, the best estimate wash load sediment yield to the study reach would be about 0.22 acre-feet per square mile, which ranges from a lower bound of 0.04 acre-feet per square mile to an upper limit of 0.005 acre-feet per square mile.

**Table 5-1. Results of trap efficiency calculations for Folsom Reservoir.**

| Method | Sediment Trapped (%) |
|---|---|
| Brune (1953), Lower Envelope Curve | 90 |
| Brune (1953), Median Curve | 95 |
| Brune (1953), Upper Envelope Curve | 100 |
| Churchill (1948) | 99 |
| *Based on reservoir at flood control pool, 610,000 acre-feet of storage.<br>Source: Ayres 1997. | |

Potential sources of sediment supply to the mouth of the lower American include the Natomas East Main Drainage Canal (NEMDC) - the only significant tributary along the lower American River, runoff from local storm drainage facilities, and bank erosion. The NEMDC enters the lower American River floodplain at RM 1.9, parallels the main American River channel, and flows directly into the Sacramento River. For this reason, sediment delivery from the NEMDC was not considered in the analysis. Runoff from local storm drains may deliver a small amount of sediment to the reach; however, given the urbanized nature of most of the contributing area, the amount associated with this source is also considered to be small.

## Incipient Motion Analysis

Ayres conducted an incipient motion analysis to determine the hydraulic conditions required to mobilize the bed material sediments. The incipient motion analysis was performed using Shield's relationship and grain shear stresses computed by using hydraulic results from the HEC-2 model. Incipient motion is defined as the point where the computed grain shear is equal to the critical shear of the bed sediments. The grain shear is given by:

$$T_{gs} - \gamma R' S_f$$

Where $T_{gs}$ is the grain shear (lb/ft$^2$), $\gamma$ is the unit weight of water (lb/ft$^3$), R′ is the equivalent hydraulic radius associated with grain resistance, and $S_f$ is the energy slope (ft/ft). The equivalent hydraulic radius can be evaluated through boundary layer theory and a semi-logarithmic relation.

The critical shear stress required to initiate motion is given by the standard Shield's relation:

$$\tau_c = \tau_{*c} (\gamma_s - \gamma) D_c$$

where $\tau_c$ is the critical shear stress (lb/ft$^2$), $\gamma_s$ is the unit weight of the sediment (lb/ft$^3$), $D_c$ is the particle size (ft), and $\tau_{*c}$ is the dimensionless critical shear stress. Studies by Parker et al. (1982) and others have shown that the bed material in gravel and cobble bed streams will begin to mobilize at a dimensionless critical shear stress of 0.03 for the median ($D_{50}$) particle size.

**Table 5-2** summarizes $D_{50}$ values and computed critical shear stresses for the surface bed material graduations presented in **Appendix F**. To evaluate incipient motion conditions along the lower American River, dimensionless shear stresses were computed. Dimensionless shear stress is defined as the grain shear divided by the critical shear. When the dimensionless shear stress is less than 1.0, the bed is considered immobile. A dimensionless shear stress of 1.0 implies incipient motion conditions.

**Table 5-2. Critical shear stress for surface layer median sediment size($D_{50}$).**

| American River (River Mile) | $D_{50}$ (mm) | Critical Shear* (lb/ft$^2$) |
|---|---|---|
| 0.00 – 7.94 | 32.9 | 0.33 |
| 7.94 – 13.60 | 43.1 | 0.44 |
| 13.60 – 20.05 | 88.2 | 0.89 |
| 20.05 – 22.66 | 96.4 | 0.98 |
| *Based on a Shields parameter equal to 0.03<br>Source: Ayres 1997. | | |

Dimensionless shear stresses for discharges of 10,000, 20,000, 50,000, 100,000, and 180,000 cfs are plotted in Appendix F. The curves given in Appendix F were developed using downstream water surface elevations from the single valued rating curve given in Appendix F. The curves show that the bed of the channel is generally immobile at discharges less than or equal to approximately 50,000 cfs. At greater discharges, the bed becomes generally mobile, although isolated locations remain immobile even at 180,000 cfs.

The results given in Appendix F are based on average shear stresses computed at each cross section. The actual shear stress acting on the channel bed varies across the channel due to variations in depth, roughness, velocity, and channel irregularities. Computing the shear stress distribution across the channel based on conveyance weighting concepts allowed for an estimate of the magnitude of these effects. The computations for a range of discharges showed that maximum shear stresses average 15 to 20% greater than the shear stresses based on cross sectionally averaged hydraulics with a maximum increase of up to 60% in specific locations. Although these calculations are based solely on changes in conveyance and do not account for 2- and 3-dimensional effects caused by channel irregularities, the maximum shear stresses are generally not significantly higher than the average shear stresses. The dimensionless shear stresses based on cross sectionally averaged hydraulics given in Appendix F are thus a good representation of critical conditions required to mobilize the channel bed material.

## Sediment Routing

To evaluate the stability of the channel bed and quantify sediment delivery to the Sacramento River under the different design scenarios, Ayres performed detailed sediment routings. These sediment routings provide quantitative information on potential vertical changes along the lower American River in response to design storm events.

An experimental version of the Corps' HEC-6 computer program was used to perform the sediment routings. The model framework included a simplification of several local inflow/outflow points upstream of the levees.

Because Folsom and Nimbus dams are located just upstream of the project study area, and the fact that the NEMDC is physically separate from the main channel of the lower American River, bed material sediment inflow from upstream and tributary sediment inflows were assumed to be zero.

Measured sediment load data were not available for the project to calibrate computed sediment transport rates. The study assumed the Parker/Toffaletti relation to be the best available approach for computing bed material transport capacities for coarse bedded streams such as the American River. Since the Parker bed load equation is formulated as an excess shear stress relation based on the concept of approximately equal mobility, this approach was assumed to provide a reasonably accurate prediction of the transported gradation as well as the transport capacity. Since the technique used to obtain the surface bed material gradations were recognized as under-sampling the fine portion of the gradation, Ayres adjusted the tail of the distributions to reflect an appropriate amount of coarse sand and fine gravel.

The adjustments were made to produce reasonable agreements between the gradation of the transported material and the gradation of alluvial deposits along the reach (i.e., bars), which reflects the gradation of material transported at higher flows. The gradation of subsurface samples collected during the field reconnaissance was relatively consistent throughout the study reach. A single representative subsurface gradation developed from subsurface gradations was used for the entire study reach (Appendix F). The subsurface gradations were developed from bulk samples of sediment obtained from beneath the surface pavement. Because it is impractical to obtain large enough samples to contain the larger particles (i.e., cobbles) in representative quantities, the coarse end of the subsurface gradations do not reflect these sizes. The actual gradation of alluvial deposits will fall between the representative subsurface gradation and surface gradation.

The final adjusted surface layer gradations developed after several iterations, which reflect increased percentages of gravel and sand-sized material are shown in Appendix F. The amount of increase varied among the sample but was generally in the range of 10 to 20 percent. Transported gradations predicted by the HEC-6 model over a range of discharges at several key locations are presented in Appendix F, along with the adjusted surface bed material gradations and the representative subsurface gradation.

All of these figures show the same general trend of increasing size with increasing discharge. In general, the transported material is primarily sand and fine gravel at discharges (near and slightly higher than the critical discharge for mobilization of the bed material). As the discharge, and thus, bed shear, increase significantly above some critical point, the transported gradation approaches the subsurface gradation in the sand and fine gravel sizes and the surface gradation in the coarser sizes. The predicted gradations were, therefore, believed to be reasonable.

Cumulative bed-elevation changes along the study reach at the end of the 100-year simulation for each of the design scenarios, also are presented in Appendix F. The figure shows that the bed of the channel is relatively stable under each design scenario with local areas of aggradation and degradation. The model results indicate no general aggradation/degradation trends along the study reach. Local areas of aggradation tend to occur just downstream of local areas of degradation. The localized nature of the aggradation/degradation is consistent with field observations and is generally associated with scour in high energy areas. The scoured material is re-deposited at the next downstream location where the energy is reduced through either channel widening or flattening of the gradient.

Locations of aggradation and degradation are similar for each design scenario. **Table 5-3** summarizes the changes in bed elevation at key locations to facilitate a comparison among the different design scenarios at a given river location. The scenario creating the most change varies depending on the specific location being considered, although the maximum change occurs more frequently for Scenario 4. Thus, the conditions in this scenario suggests this case may have the greatest overall impact on the vertical stability of the channel bed. Given the relatively small amount of bed change predicted by the model (less than two feet in all locations and less than one foot for the majority) and the small difference among the scenarios, vertical instability within the study reach does not appear to be a significant problem.

**Table 5-3. End of simulation cumulative bed elevation changes at key locations, 100-year event (COE routed downstream stages).**

| River Mile | Ending Cumulative Bed Elevation Change (ft) | | | | |
|---|---|---|---|---|---|
| | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 | Scenario 5 |
| 4.230 | 0.21 | 0.38 | 0.30 | 0.28 | 0.61 |
| 4.459 | -0.28 | -0.52 | -0.40 | -0.38 | -0.83 |
| 5.770 | 0.53 | 0.72 | 0.41 | 0.81 | 0.45 |
| 6.618 | 0.66 | 0.65 | 0.78 | 0.49 | 0.95 |
| 7.061 | -1.57 | -1.79 | -1.13 | -1.91 | -1.26 |
| 9.479 | 0.60 | 0.60 | 0.50 | 0.61 | 0.34 |
| 9.904 | -0.72 | -0.78 | -0.56 | -0.84 | -0.39 |
| 14.418 | -0.45 | -0.52 | -0.45 | -0.36 | -0.50 |
| 15.200 | 0.68 | 0.55 | 0.25 | 0.76 | 0.10 |
| 15.902 | -1.04 | -1.15 | -0.87 | -1.28 | -0.34 |
| 17.290 | 0.69 | 0.67 | 0.50 | 0.88 | 0.52 |
| 17.498 | -1.16 | -1.06 | -0.67 | -1.33 | -0.63 |
| Source: Ayres 1997. | | | | | |

The bed elevation changes shown in Appendix F and tabulated in Table 5-3 are cumulative changes at the end of the simulation. Maximum simulated positive (aggradation) and negative (degradation) changes for each design scenario are plotted in Appendix F. The figure shows that maximum changes are similar to cumulative changes at the end of the simulation. This result is reasonable for the coarse bed conditions in the study reach since significant mobilization of the bed, which is required to cause changes in bed elevation, only occurs at very high flows. Since the bed material transport rates are relatively small, the potential for backfilling during the recessional limb in areas that scour during the high flows is small.

To determine the effects of downstream stage on the aggradation/degradation potential of the study reach, the 100-year simulation was repeated for each design scenario using downstream stages computed from the upper and lower bound rating curves. Cumulative bed elevation changes simulated for each design scenario are shown in Appendix F for the lower and upper bounds.

The figures show that aggradation/degradation trends for each case are similar to the original simulations, which were based on the routed downstream stage hydrograph. As would be expected, aggradation/degradation depths are generally larger in the downstream, approximate 8 miles of the reach using the lower bound rating curve (Appendix F) and smaller in that reach using the upper bound rating curve (Appendix F). The differences are relatively insignificant.

As sediment is mobilized during the passage of a flood hydrograph and areas of aggradation and degradation develop, the grain size distribution of the channel bed changes due to sediment sorting. To illustrate changes in the bed material sediment size distribution along the study reach, the $D_{16}$, $D_{50}$, and $D_{84}$ sediment sizes were plotted against time at selected cross sections where the model predicted bed elevation changes. Using the routed downstream stage hydrograph, plots were developed for the 100-year event Scenario 1 simulation. Cumulative bed elevation changes versus time are included on the plots for comparison. The changes at Cross Section 17.498 (midsection of Rossmar bar), a section with approximately 1.2 feet of total degradation, are shown in Appendix F. The plot shows that the bed of the channel becomes coarser during degradation with the median ($D_{50}$) size increasing from approximately 110 mm at the beginning of the simulation to approximately 140 mm at the end. The coarsening is the result of a winnowing of the finer particles during degradation.

The changes at Cross Section 17.290 (just upstream of Ancil Hoffman Park), an area of aggradation just downstream of Cross Section 17.498, are illustrated in Appendix F. The plot shows that the cross section aggrades throughout the simulation. In this case, the bed material fines during the early portion of the simulation, which is the typical response to aggradation, but it coarsens during the latter portion of the simulation. The coarsening is probably due to the deposition of coarser material eroded from Cross Section 17.498 during the peak flows. Changes at Cross Sections 7.061 (just downstream of Guy West Bridge) and 6.618 (northern end of Campus Commons Golf Course), are shown in Appendix F. Similar to the previously discussed cross sections, Cross Section 7.061 is degradational and Cross Section 6.618, located just downstream, is aggradational. In all the cross sections examined, changes in the surface bed gradation were minor. This reflects the relatively small aggradation/degradation trends along the project reach.

## Bed Material Sediment Budget

Ayres developed a bed material sediment budget for the study reach for the 100-year event under each design scenario by accumulating the total quantity of sediment transported past selected locations during the HEC-6 simulations. The locations were selected to define subreaches having similar geomorphic and sediment transport characteristics. **Table 5-4** identifies and defines the subreaches.

**Table 5-4. Subreach delineation used in sediment budget calculations.**

| Subreach Number | River Mile | Description |
|---|---|---|
| 1 | 22.657 | Fish weir downstream of Nimbus Dam |
| 2 | 18.127 | San Juan Rapids |
| 3 | 13.290 | Downstream end of expansion near Goethe Park |
| 4 | 8.282 | Upstream end of island between Howe and Watt Avenues |
| 5 | 4.230 | Upstream of Interstate 80 |
| 6 | 0.044 | Confluence with Sacramento River |
| Source: Ayres 1997. | | |

To facilitate evaluation of the results, the total bed material sediment load was divided into three segment-size groupings: (1) coarse sand through fine gravel (1-8 mm); (2) medium gravel through very coarse gravel (8-64 mm); and (3) fine cobbles through small boulders (64-512 mm). **Table 5-5** summarizes the results for each of the design scenarios. The results show that the overall study reach is degradational under all design scenarios with the quantity of material removed during the simulation varying from approximately 880 tn for Scenario 1 to 1,370 tn for Scenario 2. This result was expected since no bed material-sized sediment is brought into the reach from upstream due to the presence of Folsom and Nimbus Dams. Aggradation/degradation trends along the lower American River study reach vary with design condition. The following general observations can be made from Table 5-5.

1. Subreach 1 is degradational for all scenarios since the upstream supply is zero.
2. Subreach 3 is aggradational for all scenarios due to its relatively flatter gradient in comparison with the upstream reaches.
3. The aggradation/degradation tendency within Subreaches 2, 4, and 5 vary depending on the scenario; however, the volumes are small in comparison to the amount in Subreaches 1 and 3 (indicating that the bed is relatively stable in these reaches).
4. The majority (generally >80%) of the material transported and deposited and/or eroded within the study reach is coarse sand to fine gravel (1mm – 8mm).
5. In Subreaches 1 and 3, which show the greatest amount of aggradation/degradation, the volume of material is relatively insignificant, which corresponds to an average bed elevation change through the subreach for worst case conditions of less than 0.1 inch during the 100-year flood event.

**Table 5-6** and **Table 5-7** summarize the bed-material sediment budget results for the 100-year flood event under each of the design scenarios using the upper and lower bound rating curves. The results show that use of the lower bound rating curve (Table 5-6) increases overall degradation and use of the upper bound rate curve, Table 5-7 reduces overall degradation. The effects. The effects tend to be concentrated in the lower subreaches, which is consistent with the computed bed elevation changes.

**Table 5-5. Summary of bed material sediment budget, 100-year event (COE supplied downstream stage).**

| Subreach | Aggradation/Degradation Amount (tn) | | | |
|---|---|---|---|---|
| | Total | Size Group 1 (1mm - 8mm) | Size Group 2 (8mm - 64mm) | Size Group 3 (64mm–512mm) |
| **Scenario 1** | | | | |
| 1 | -3847 | -3486 | -254 | -108 |
| 2 | 384 | 251 | 29 | 104 |
| 3 | 2429 | 2268 | 160 | 1 |
| 4 | -187 | -146 | -40 | -1 |
| 5 | 340 | 330 | 10 | 0 |
| Study Reach Total | -881 | -783 | -95 | -3 |
| **Scenario 2** | | | | |
| 1 | -4147 | -3659 | -348 | -140 |
| 2 | 653 | 393 | 124 | 136 |
| 3 | 2381 | 2225 | 155 | 1 |
| 4 | -287 | -229 | -55 | -2 |
| 5 | 25 | 226 | -167 | -34 |
| Study Reach Total | -1374 | -1044 | -292 | -39 |
| **Scenario 3** | | | | |
| 1 | -4063 | -3672 | -302 | -90 |
| 2 | -747 | -892 | 60 | 86 |
| 3 | 3791 | 3611 | 178 | 2 |
| 4 | -323 | -275 | -47 | -1 |
| 5 | 293 | 312 | -16 | -4 |
| Study Reach Total | -1049 | -915 | -127 | -7 |
| **Scenario 4** | | | | |
| 1 | -4270 | -3771 | -326 | -174 |
| 2 | -1355 | -1487 | -39 | 170 |
| 3 | 4505 | 4212 | 291 | 1 |
| 4 | -165 | -116 | -46 | -3 |
| 5 | -58 | 154 | -177 | -35 |
| Study Reach Total | -1344 | -1008 | -296 | -40 |
| **Scenario 5** | | | | |
| 1 | -3802 | -3590 | -195 | -17 |
| 2 | 507 | 507 | -14 | 14 |
| 3 | 2143 | 1998 | 144 | 1 |
| 4 | -594 | -521 | -71 | -1 |
| 5 | 707 | 672 | 33 | 2 |
| Study Reach Total | -1039 | -934 | -103 | -2 |
| Source: Ayres 1997. | | | | |

**Table 5-6. Summary of bed material sediment budget, 100-year event (lower bound downstream stage).**

| Subreach | Aggradation/Degradation Amount(tn) | | | |
|---|---|---|---|---|
| | Total | Size Group 1 (1mm - 8mm) | Size Group 2 (8mm - 64mm) | Size Group 3 (64mm–512mm) |
| **Scenario 1** | | | | |
| 1 | -6745 | -6392 | -209 | -108 |
| 2 | 5679 | 5377 | 163 | 103 |
| 3 | 171 | 189 | -19 | 2 |
| 4 | -507 | -452 | -51 | -3 |
| 5 | -2804 | -1014 | -1428 | -293 |
| Study Reach Total | -4206 | -2292 | -1544 | -299 |
| **Scenario 2** | | | | |
| 1 | -4147 | -3660 | -348 | -140 |
| 2 | 708 | 431 | 141 | 137 |
| 3 | 2308 | 2170 | 137 | 1 |
| 4 | -460 | -376 | -79 | -6 |
| 5 | -1942 | -443 | -1242 | -257 |
| Study Reach Total | -3533 | -1877 | -1391 | -265 |
| **Scenario 3** | | | | |
| 1 | -4034 | -3659 | -292 | -83 |
| 2 | -401 | -559 | 120 | 79 |
| 3 | 3413 | 3302 | 109 | 2 |
| 4 | -422 | -364 | -57 | -1 |
| 5 | -347 | -38 | -261 | -48 |
| Study Reach Total | -1791 | -1358 | -381 | -51 |
| **Scenario 4** | | | | |
| 1 | -4269 | -3774 | -323 | -172 |
| 2 | -779 | -1025 | 77 | 169 |
| 3 | 3925 | 3751 | 173 | 1 |
| 4 | -286 | -215 | -65 | -6 |
| 5 | -1746 | -406 | -1117 | -223 |
| Study Reach Total | -3154 | -1668 | -1254 | -232 |
| **Scenario 5** | | | | |
| 1 | -3802 | -3590 | -195 | -17 |
| 2 | 580 | 555 | 11 | 14 |
| 3 | 2052 | 1933 | 118 | 1 |
| 4 | -731 | -650 | -79 | -2 |
| 5 | 30 | 36 | -5 | -1 |
| Study Reach Total | -1872 | -1717 | -149 | -5 |
| Source: Ayres 1997. | | | | |

Table 5-7. Summary of bed material sediment budget, 100-year event (upper bound downstream stage).

| Subreach | Aggradation/Degradation Amount(tn) | | | |
|---|---|---|---|---|
| | Total | Size Group 1 (1mm - 8mm) | Size Group 2 (8mm - 64mm) | Size Group 3 (64mm–512mm) |
| **Scenario 1** | | | | |
| 1 | -6748 | -6394 | -210 | -108 |
| 2 | 5705 | 5400 | 164 | 103 |
| 3 | 192 | 207 | -17 | 2 |
| 4 | -189 | -166 | -22 | 0 |
| 5 | 362 | 400 | -31 | -6 |
| Study Reach Total | -680 | -553 | -116 | -9 |
| **Scenario 2** | | | | |
| 1 | -4147 | -3659 | -348 | -140 |
| 2 | 747 | 480 | 130 | 137 |
| 3 | 2326 | 2175 | 151 | 1 |
| 4 | -37 | -5 | -33 | 0 |
| 5 | 395 | 390 | 9 | -3 |
| Study Reach Total | -716 | -619 | -91 | -6 |
| **Scenario 3** | | | | |
| 1 | -4038 | -3663 | -292 | -83 |
| 2 | -315 | -518 | 124 | 79 |
| 3 | 3395 | 3286 | 107 | 2 |
| 4 | -87 | -57 | -30 | 0 |
| 5 | 469 | 428 | 39 | 2 |
| Study Reach Total | -576 | -524 | -51 | -1 |
| **Scenario 4** | | | | |
| 1 | -4262 | -3770 | -321 | -172 |
| 2 | -609 | -860 | 83 | 169 |
| 3 | 3796 | 3627 | 168 | 1 |
| 4 | 92 | 108 | -16 | 0 |
| 5 | 334 | 325 | 11 | -2 |
| Study Reach Total | -649 | -570 | -74 | -4 |
| **Scenario 5** | | | | |
| 1 | -3801 | -3589 | -195 | -17 |
| 2 | 657 | 623 | 20 | 14 |
| 3 | 2054 | 1941 | 112 | 1 |
| 4 | -238 | -187 | -51 | -1 |
| 5 | 681 | 630 | 49 | 3 |
| Study Reach Total | -648 | -583 | -65 | 0 |
| Source: Ayres 1997. | | | | |

The above results indicate that the channel is vertically stable for the 100-year event under all of the design scenarios. These results, together with those of the incipient motion analysis, indicate that relatively high discharges are required to initiate bed material motion. It can be concluded, therefore, that the bed of the lower American River along this study reach will remain relatively stable regardless of the design scenario.

### Bed Material Sediment Yield to the Sacramento River

The average annual bed material sediment yield to the Sacramento River was developed by estimating the average annual bed material load generated within the study reach. This was accomplished by computing bed material sediment yields for individual storm events and integrating the results based on their relative probability of occurrence. This approach assumes that the bulk of the sediment is transported during individual storm events. Given the previous finding that the channel bed is generally immobile at discharges of less than 20,000 cfs, this is considered a realistic assumption.

**Table 5-8** presents the computed average annual sediment yields for each design scenario using developed sediment rating curves (i.e., lower bound, median, and upper bound sediment rating curves). The results for each sediment rating curve indicate that total yields are greatest for Scenario 4 and smallest for Scenario 2, although the differences are relatively small. The sediment distribution varies with the magnitude of the total load, with small total loads being composed mostly of sands and fine gravel (1mm – 8mm), and high total loads being composed of material in all of the size groups. This variation is a direct result of the fact that at higher discharges, the entire bed becomes mobile, with the distribution of transported material approaching that of the subsurface material (Appendix F). Even using the upper bound rating curve, the computed bed material sediment loads to the Sacramento River are small.

**Table 5-8. Average annual bed material sediment yields to the Sacramento River.**

| Design Scenario | Bed Material Sediment Yield (tn) | | | |
|---|---|---|---|---|
| | Total | Size Group 1 (1mm - 8mm) | Size Group 2 (8mm - 64mm) | Size Group 3 (64mm–512mm) |
| **Lower Bound Sediment Rating Curve** | | | | |
| Scenario 1 | 158 | 158 | 0 | 1 |
| Scenario 2 | 157 | 156 | 0 | 1 |
| Scenario 3 | 170 | 169 | 0 | 0 |
| Scenario 4 | 172 | 172 | 0 | 0 |
| Scenario 5 | 159 | 159 | 0 | 0 |
| **Median Sediment Rating Curve** | | | | |
| Scenario 1 | 1584 | 1186 | 164 | 234 |
| Scenario 2 | 1570 | 1171 | 164 | 235 |
| Scenario 3 | 1696 | 1316 | 156 | 223 |
| Scenario 4 | 1724 | 1343 | 157 | 224 |
| Scenario 5 | 1588 | 1188 | 165 | 235 |
| **Upper Bound Sediment Rating Curve** | | | | |
| Scenario 1 | 15838 | 5218 | 4373 | 6247 |
| Scenario 2 | 15695 | 5149 | 4342 | 6203 |
| Scenario 3 | 16956 | 6020 | 4503 | 6433 |
| Scenario 4 | 17235 | 6176 | 4554 | 6505 |
| Scenario 5 | 15880 | 5174 | 4409 | 6298 |
| Source: Ayres 1997. | | | | |

## Bank Erosion

The results of the sediment transport analysis indicate that vertical stability of the channel bed along the lower American River study reach is not a significant issue. However, because of the importance of the existing levees in maintaining the flood carrying capacity of the reach, lateral stability of the channel, is a significant issue.

In assessing, the potential for increased bank erosion or damage to existing bank protection associated with the different flow scenarios, duration of the flows must be considered, as well as their magnitude during a specific flow event. In addition, the relative effect of the range of possible flow events must also be considered because the infrequent, high discharges associated with the design event are not necessarily the most significant in causing bank erosion and lateral adjustment of the channel. This is in contrast to most design procedures for bank protection, which only consider conditions for a specific discharge.

To incorporate the both duration and magnitude into the evaluation of the effects of the various scenarios, lateral stability analyses for this project were performed. These were based on the concept of total work applied to the banks. Work was computed at specific locations for each design scenario using the results of the HEC-2 hydraulic modeling and measurements of bed geometry from available mapping. The resulting values were then used as an index of the erosive power of the flow. The work index values for the existing conditions flow scenario (Scenario 1) were related to the existing condition of the banks. These were based on field observations and other available information which define the variation along the study reach. The work index values for the alternative flow scenarios were then compared to the existing conditions result at specific locations to evaluate the potential change in erosive power associated with each scenario.

Work is defined as the product of the stream power expended on the banks and the incremental time over which it is applied. Bank stream power is the product of the average main channel velocity and the shear stress acting on the bank. For a given flood event, the total work at a given bank location can be determined by integrating the bank stream power over the entire hydrograph. **Figure 5-2** is a plot of the work index values derived from integration of the annual flow duration curve at each of the sites considered in the analysis. The two lines shown in the figure represent the results based on the upper and lower bounding rating curves at the mouth of the American River. Sites at which bank protection currently exist are also indicated in the figure. It is important to note that the computations were performed at available cross sections in the HEC-2 model. As previously described, these cross sections were selected to represent sites that were identified during the field reconnaissance and geomorphic analysis as having existing erosion problems or being near locations where erosion protection measures have been installed. The work index values at a particular site should be considered to represent typical conditions along the indicated bank in the vicinity of the cross section.

The difference in results between the upper and lower bounding rating curves appears to be relatively small for the range of flows in the annual flow duration curve, which diminishes to essentially zero approximately five miles upstream of the mouth. The results for the lower bounding curve tend to be higher than the upper bounding curve because of the lower water surface elevation at the mouth.

Comparison of the results along the reach indicates that the work applied to the channel banks along approximately 5 miles downstream of the study reach (downstream of the bend between Business 80 and H Street) is relatively low compared to upstream reaches. Work in the upstream bend between RM 5 and RM 6 is high, which results from a combination of the channel curvature and local steepening of the channel slope. Values in the straight reach between the bend and just downstream of Watt Avenue (RM 9.25) are generally less than those through the bend, but they are higher than in the downstream 5 miles.

**Figure 5-2. Work index values based on integration of the annual flow duration curve (lower bound rating curve).**

The site at approximately RM 10.5 has a relatively high work index value due to a local contraction of the flows by the erosion-resistant bank material along the left bank at that location. Sites upstream of the end of the left bank levee (RM 11) generally have higher values due primarily to the effects of the steeper gradient in this reach. The exception occurs at RM 16.35 where flows across the bar on the right side of the channel (inside of the bend) relieve the stress on the left bank.

Sites identified without existing bank protection in the approximate downstream 5 miles of the reach are characterized by either intermittent erosion or are the result of local conditions that cause a local increase in the stress on the banks. For example, sites at RM 3.74 and RM.76, which have relatively high work index values, are in the vicinity of the Southern Pacific Railroad (SPRR) Bridge; the site at RM 0.16 is at the relatively sharp bend in the right bank just upstream of the confluence with the Sacramento River. With the exception of these three sites, the work index values for this reach are less than 100 and average in the range of 50 to 60 for the upper and lower bounding rating curves. As discussed in the geomorphic analysis, this reach appears to be relatively stable laterally.

Locations between RM 5 and the upstream end of the left bank levee (RM 11) have significantly higher work index values. Most of these locations have existing bank protection, presumably because the higher stress on the banks has created bank erosion problems that required corrective action in the past. Locations in this reach that do not have existing bank protection (outside of the bend between RM 5 and RM 6, the right bank between RM 8.5 and RM 9.0, and just downstream of Watt Avenue RM 9.2) have intermittent bank protection in various states of repair. They are currently eroding and are probably in need of corrective action. Most of the locations between the upstream end of the left bank levee and Nimbus Dam with high work index values generally have erosion-resistant Pleistocene-age material in the bank.

### Bank Protection

Bank protection methods presently employed within the project reach of the lower American River include rock revetment, river cobble revetment, concrete walls, saccrete, gabions, stone dikes, and concrete rubble. **Table 5-9** lists existing bank protection emplacements (WET 1991). The extent of revetment is greatest within Subreach 2 (RM 4.8 to RM 8.0), where the levees are relatively close to the channel and California State University at Sacramento is located landward of the left bank levee. Some of the rock revetment adjacent to the university was constructed in 1986 under emergency status. The extent of bank protection presently in place along the lower American River is greatest in Subreaches 1 and 2, where Pleistocene outcrops are not present to provide lateral channel stability.

Bank protection performance on the lower American River has, in general, been satisfactory. **Table 5-10** lists locations of damaged bank protection along the river (WET 1991). The only damaged rock revetment mapped is located at RM 0.45R, where rocks have been dislodged due to extensive river access. The majority of damaged protection consists of toe failure of river cobble riprap, or toe failure of non-Corps concrete rubble or concrete walls. A total of 1,500 linear feet of bank protection was mapped as damaged.

**Table 5-9. Existing bank protection, lower American River (revetment dates retrieved from Corps records (WET 1991).**

| River Mile | Bank | Length (ft) | Type | Date |
|---|---|---|---|---|
| 0.65 | TLB | 3,120 | Local covered riprap | 1988 |
| 0.90 | TLB | 110 | Cobble at outlet | ? |
| 1.50 | TRB | 3,000 | Scattered concrete debris | ? |
| 1.95 | TLB | 868 | River cobble | 1952 |
| 1.95 | TRB | 800 | Concrete debris | ? |
| 2.45 | TLB | 8,850 | River cobble | 1951 |
| 2.55 | TLB | 1,375 | River cobble | 1948 |
| 4.20 | TLB | 1,537 | Emergency bank protection/rock | 1986 |
| 4.80 | TLB | 495 | River cobble | 1969 |
| 5.10 | TRB | 950 | River cobble | 1967 |
| 5.45 | TRB | 110 | Concrete | ? |
| 5.55 | TRB | 60 | Concrete | ? |
| 5.60 | TRB | 2,287 | River cobble | 1959 |
| 5.95 | TLB | 1,100 | River cobble | 1952 |
| 6.22 | TLB | 1,550 | River cobble | 1970 |
| 6.55 | TRB | 1,075 | River cobble | 1959 |
| 6.65 | TLB | 6,500 | River cobble | 1959 |
| 6.80 | TLB | 810 | Emergency bank protection/rock | 1986 |
| 7.25 | TLB | 7,400 | River cobble | 1959 |
| 7.30 | TRB | 960 | Rock | Date and origin unknown |
| 7.60 | TRB | 1,600 | Rock | ? |
| 7.75 | TRB | 240 | Bridge bank protection | ? |
| 8.80 | TRB | 400 | River cobble | Date and origin unknown |
| 9.05 | TRB | 2,302 | River cobble | 1951 |
| 9.20 | TRB | 280 | Rock | Date and origin unknown |
| 13.65 | TRB | 200 | Concrete and cobble debris | ? |
| 13.80 | TRB | 180 | Private rock | ? |
| 13.90 | TRB | 240 | Private concrete bank | ? |
| 14.20 | TRB | 910 | Concrete bank | ? |
| 14.40 | TRB | 1,160 | Concrete wall | ? |
| 15.0 | TLB | 1,320 | Rock/gabions | Date and origin unknown |
| 15.3 | TLB | 1,750 | Cobble/dikes | 1970 |
| Source: Ayres 1997. | | | | |

**Table 5-10. Locations of mapped damaged bank protection, lower American River.**

| River Mile | Bank | Length (ft) | Date | Comment |
|---|---|---|---|---|
| 0.45 | TLB | 200 | 1988 | Localized damage from river access. |
| 1.35 | TRB | 100 | | Int. failure of concrete rubble. |
| 4.80 | TLB | 100 | 1969 | Localized failure of river cobble and riprap. |
| 7.00 | TLB | 500 | | Int. toe failure of river cobble and riprap. |
| 8.70 | TRB | 400 | | Int. failure of non-Corps dumped rock. |
| 13.80 | TRB | 200 | | Private concrete bank; cracking at toe. |
| Source: Ayres 1997. | | | | |

Rock revetment has performed satisfactorily on the American River and should provide effective bank protection where further bank retreat is unacceptable. Less stringent methods can be applied where some additional retreat is acceptable. Through a large portion of the study reach, project levees are absent, so levee threat is absent. Where levees are present, they are generally set back from the channel. Consequently, long segments of bank line requiring highly dependable forms of bank revetment such as rock riprap have not been identified on the American River. The primary erosion control problem on the lower American River is not bank line erosion into the levee section, but potential levee failure related to seepage.

### Identification of Bank Erosion Sites Based on Lower American River Criteria

For the lower American River, a number of different criteria for identifying bank/levee protection requirements have been advanced in the past. These include the SACBANK criteria utilized by WET (1991), which incorporated a 50-foot wide buffer strip riverward of the toe of the levee, an average (1969 to 1986) lateral migration rate of 4.8 feet per year and a project construction timeframe 10 years. The buffer strip was incorporated into the criteria because of uncertainty associated with quantifying lateral migration rates (range of 1.4 to 13.9 feet per year). These rates are heavily dependent on the occurrence of significant morphogenetic flood events. Further, the composition of the channel bank materials is spatially varied and extremely complex and made more so by the effects of upstream hydraulic and dredge mining. Because of the age of the database (i.e., 1986 aerial photography) and the date of the analysis (i.e., circa 1993), the time base was increased by 7 years. This resulted in a conclusion that any site located within 82 feet of the 50-foot wide buffer would qualify as a high priority site.

Criteria for site selection and prioritization were also advanced by the Sacramento District in a memorandum entitled: "*Draft Bank Protection Criteria for Lower American River and Influencing Reaches of Sacramento River*" (dated February 23, 1994). Three criteria were identified as follows:

Criteria 1. Bank has already or is expected to erode into the levee section (IV:3H levee side slope projected to thalweg elevation) prior to construction of the American River Project.

Criteria 2. Bank is within 150 feet of the levee section (note that no time frame was identified).

Criteria 3. Protection provided to protect valuable environmental resources (note that no definition or quantification of resource values was made).

SAFCA has proposed three classes (i.e., criteria) of bank protection needs at the Lower American River Task Force Meeting (March 15, 1994, Agenda Item D), as follows:

Class 1. The threat to the levee or other infrastructure is imminent requiring immediate action.

Class 2. There is a threat to the levee or other infrastructure in the near term requiring immediate action unless there is clear evidence that the bank is stable (note that no time frame was specified).

Class 3. There is a low probability of immediate damage to the levee or other infrastructure but there may be an immediate risk to other environmental or recreational resources possibly requiring immediate action (note that there is no definition or quantification of resources or values).

When all of the proposed criteria are evaluated, it is clear that immediate risk to the project levees is the highest priority, but quantification is problematic. Longer-term threats to the levees or other significant infrastructure elements during the lifespan of the project are also of concern. Further, it is also evident that there is concern for protection/preservation of biological resources within the American River corridor, especially given the very constrained nature of the river. The river's somewhat static nature is a result of upstream dam construction and the very high incidence of Pleistocene-age or older outcrop along the course of the lower river. Both of these significantly limit the potential for supplying the sediment that is integral to the formation of hydro-geomorphic features, which form the substrate for the riparian communities.

Existing levee and infrastructure protection measures along the lower American River have experienced damage from a variety of sources, including anthropogenic activity. Many of the river cobble revetments were installed in the late 1950's and have generally performed very well. However, damage to these revetments, especially in the toe region (no toe trenches were utilized during construction), requires that they be repaired. Some of the bridge abutments along the lower American River have been protected in the past and the revetments have also experienced damage; as such, they should be repaired. Under existing conditions, a number of bridge abutments have been identified that require protection. This results from the uncertainty introduced by extremely complex hydraulic conditions generated by the bridge piers and abutments that are very difficult to model or predict (refer to Federal Highway Administration Hydraulic Engineering circular, HEC No. 18, 1991).

## Criteria for Lower American River

The following criteria (Types 1, 2, 3) for channel bank protection have been developed to encompass the above stated concerns. An attempt has been made to provide quantitative and repeatable criteria that are based on the existing knowledge of the dynamics of the lower American River. The following assumptions have been used in development of these criteria:

1. The average bank height along the lower American River project reach is about 15 feet. Therefore, projection of the levee side slope (IV:3H) results in a levee section that projects 50 feet riverward of the toe of the levee. Invasion of the levee section by the river is an unacceptable condition.
2. The average rate of lateral migration of the river is 5 ft/yr.
3. Immediate threat sites will be constructed within 2 years. (Refer to letter from The Reclamation Board to District Engineer, Sacramento District COE, dated 8 July, 1994.)
4. The Lower American River Project will be constructed within 12 years.
5. The project life for installed revetment on the lower American River is 50 years.
6. Damaged existing revetments and other infrastructure protection measures require immediate repair.
7. The width of the environmental resources to be protected will be sufficient that protection of the resource will not result in degradation of the resource value.

### Type 1. Require Protection Within 2 to 12 Years

1. There is an immediate need for construction of new protection because the river has already, or will within a 2-year period, erode into the levee section. All sites within 60 feet of the levee toe are included in this category.
2. New protection will be required prior to construction of the Lower American River Project (12 years) because the river will have invaded the levee section within that time period. All sites between 60 and 110 feet of the toe of the levee are included in this category.
3. There is an immediate repair of existing revetments that have been damaged since original emplacement.
4. There is an immediate repair of existing bridge abutment protection that has been damaged since original emplacement.
5. There is an immediate protection of currently unprotected bridge abutments.

### Type 2. Require Protection Within 50 Years

New protection will be required within the life of the Lower American River Project because the river will have invaded the levee section. Sites between 110 and 300 feet of the levee toe are included in this category.

### Type 3. Protection of Environmental Resources

New protection is required primarily for stands of riparian vegetation that have sufficient width. This width is necessary such that loss of vegetation consequent on construction of the protection will not degrade the resource value significantly. A key element of this category should be the inability of the resource to be regenerated by lateral migration of the channel because of floodplain width constraints imposed by the distance between the levees. No assignment of a timeframe has been made for this category. It could be assumed that further loss of the resource is unacceptable, in which case, Type 3 sites would fall into an immediate action category. Average lateral migration rates can be used to assess the future rate of resource loss.

## Channel Migration

Subreaches 1 and 5 contain the largest percentages of eroding bankline, which reaches 13% on the right bank in Subreach 1 and 12% on the left bank in Subreach 5. Whereas bank erosion within Subreach 1 involves eroding Recent-age American River alluvium, erosion within Subreach 5 generally involves slowly eroding inundated Pleistocene-age alluvia deposits.

The extent of outcrop decreases downstream from more than 30% on the right bank in Subreach 5 to 0% in Subreaches 1 and 2. This downstream reduction in Pleistocene outcrop corresponds to the gradual emergence of the American River from confining Pleistocene-age alluvia terraces onto a broad floodplain of Recent-age sediments. Furthermore, the general lack of project flood control levees within Subreaches 4 and 5 is related to the presence of high terraces within those subreaches. These upstream subreaches are least susceptible to extensive flooding due to the relatively large channel capacity between the older terraces.

In order to determine historical channel migration through time, aerial photographs containing bank lines of the lower American River from 1968 and 1986 were compared by WET (1991). Migration rates varied from 1.1 to 13.9 feet/year within the study reach.

Erosion rates at 30 sites between RM 0 and RM 9.25 (Watt Avenue) were determined from aerial photographs for 4 time periods between 1963 and 1986 by Mitchell Swanson and Associates (MSA 1993). Photography was available for 1963, 1971, 1981, and 1986. At each of the sites, the rate of erosion was quite variable within the different periods. Bank erosion rates varied from 0 to a maximum of 11.2 feet/year (depending on the site and the time period). Rates were generally highest in the 1981-1986 period and lowest in the 1975 - 1981 period.

### 5.1.3. SUMMARY

The existing channel and floodplain conditions have resulted from the combined effects of a number of man-induced perturbations. These include hydraulic mining, dredge mining, sand and gravel mining, levee construction, bank protection, and flow regulation. The highly irregular longitudinal thalweg profile is controlled by outcrops of erosion-resistant Pleistocene-age bedrock units upstream of Goethe Park (RM 14), and as a result, little further degradation is expected to occur. Downstream of RM 14, Pleistocene-age bedrock crops out in the bed of the channel at RM 9.5 just upstream of Watt Avenue. An abandoned channel fill that is controlling the local bed elevation at about RM 6 may erode in the future, but its effects on the vertical stability of the river upstream will be minimal.

Hydraulic analysis of the reach indicates that bankfull discharge from RM 0 to RM 13 is on the order of 50,000 cfs, increasing to 100,000 cfs between RM 13 and RM 18, and reducing to 50,000 cfs from RM 18 to RM 23.

Although the hydraulic analysis indicates that the levees will contain a discharge of 180,000 cfs, this conclusion should be viewed with caution because of uncertainties associated with the location of the cross-sections and the levee profiles.

Incipient motion analysis indicate that the bed material in the project reach is generally immobile at discharges less than 50,000 cfs. As discharge increases, the bed material is mobilized; but at some locations, the bed is immobile even at a discharge of 180,000 cfs.

Analysis of the vertical stability of the bed of the channel indicates that the bed is relatively stable under all of the flow scenarios, even though there are local areas of aggradation and degradation under each of the scenarios.

Sediment transport routings indicate that the bed material sediment yields to the Sacramento River under all of the flow scenarios are extremely low, ranging from a maximum of 1,724 tons in Scenario 4 to a minimum of 1,570 tons in Scenario 2. Under existing conditions (Scenario 1), the yield is 1,584 tons. Under all of the scenarios, the vast majority of sediment is in the size range of 1-8 mm.

Bank work index values indicate that on the basis of the integration of the flow duration curve, a threshold value for bank erosion is about 100. Utilizing the weighted average of various return period flood events, the threshold value is about 50. The difference among any of the four scenarios and the existing condition in the leveed reach are insufficient to increase the work index values above the threshold value of 50. For weighted average conditions, Scenarios 3 and 4 (which increase the storage in Folsom Reservoir) appear to reduce the potential for bank instability in the downstream 5 miles of the reach. Scenario 5 (the dry dam) increases the potential for bank instability in the lower 5 miles.

Based on the SRBPP criteria for protection of the levees, there are only 4 locations within the leveed reach that qualify for high priority status. These include RM 2.1L, RM4.8L, RM8.6R, and RM10.3R. Because of the risk to the levees and the fact that both sites are gaps in existing revetments, full bank rock revetment is recommended for RM2.1L and RM4.8R. Full bank rock revetment of stone dikes could be utilized at the other two sites. Approximately 1,500 feet of damaged revetments require rehabilitation.

Based on Lower American River criteria, additional bank protection needs were identified. These include:

- 1,400 LF requiring immediate protection (Type 1a);
- 9,000 LF requiring protection within 12 years (Type 1b);
- 5,000 LF of repair of existing revetments (Type 1c);
- 1,100 LF of bridge abutment protection; and,
- 2,500 LF of new bridge protection (Type 1a).

Within the project life, it is expected that a further 5,400 LF of bank protection will be required.

Evaluation of bridge pier scour potential at 18 bridges within the project reach using FHWA procedures indicated that under existing conditions (Scenario 1), there is significant scour potential at all of the bridges. The remainder of the Scenarios do not significantly alter the computed pier scour depths. Abutment scour estimates at four bridges indicate that there may be an abutment scour problem under existing conditions that is not exacerbated by the other Scenarios.

Scour analyses at 5 high priority bank protection sites identified by the Corps, DWR, and SAFCA for a 100-year flood event under existing conditions (Scenario 1), shows that the sites are influenced by pier and abutment scour processes at bridge crossings. Sites 3 and 4, located at RM4.40L and RM6.80L, respectively are also located in bendways and may experience bend scour from 9.5 (limited by armoring) to about 32 feet, respectively. All of the sites are susceptible to thalweg realignment. In addition to provisions for pier, abutment, and bendway scour, the protection at each site should extend to 3 to 5 feet below the deepest position of the channel bend.

Seepage and piping problems in the levees will occur as the flows increase above 115,000 cfs. Stratification in levee foundation materials will further lower the factor of safety. Since average strength values were utilized in the slope stability analysis, locations with weaker soils will have safety factors below the Corps minimum values. Use of triaxial shear test data rather than direct shear test data used by the Corps, will also cause a reduction in the minimum safety factor. Analysis of the effects of sudden drawdown on riverward slope stability indicate that safety factors are marginal at 115,000 cfs and decrease at higher flows.

Qualitatively, the potential impact of any of the four alternative project Scenarios on the stability of the Sacramento River is dependent on the need for modifications to the Sacramento Weir. All four of the alternative Scenarios will increase the amount of flow (total volume and/or peak discharge) in the leveed reach of the Lower American River. This occurs because under existing conditions, significant flow loss takes place during the 100-year flood in the reach upstream of the levees. This reduces the amount of flow passing through the leveed reach. In addition, it is presumed that levees not meeting the freeboard requirements would be raised in conjunction with implementation of any of the alternative Scenarios. According to analyses performed by Murray, Burns, and Kienlen, without modification to the weir, increased flows in the leveed reach associated with the various Scenarios cannot be passed in the Sacramento River at stages below the current design stage for the NEMDC. Modifications to the weir would change the flow distribution between the mainstem Sacramento River and Yolo Bypass. If the weir is maintained at its current capacity, more flow will probably be forced downstream in the Sacramento River, which would increase flood stages and stress on the levees and channel bed. The potential for instability associated with the increased stress cannot be evaluated without more detailed information. Because of the relatively low sediment yield from the American River to the Sacramento River under all Scenarios (including existing conditions) changes in sediment transport characteristics associated with the Scenarios are believed to be insignificant.

# 6.0 RIPARIAN ATTRIBUTES

## 6.1. Historic Overview

The floodplain and associated riparian and wetland habitats (e.g., sloughs, ponds, backwaters) serve important functions in riverine ecosystem that benefit a large assemblage of aquatic and terrestrial species. Floodplain and riparian habitats along the lower American River provide seasonal shelter, spawning, and rearing habitat for native species such as splittail, chinook salmon, and steelhead. Floodplain and riparian habitats also provide an important source of organic material and energy to the aquatic ecosystem that directly or indirectly benefits many aquatic species. Consequently, historical changes in floodplain and riparian habitats and alteration of the physical processes that sustain these habitats, as described below, have likely contributed to long-term declines in aquatic productivity in the lower American River.

### 6.1.1. RIPARIAN HABITAT

Historical trends in riparian vegetation since 1850 reflect human modifications of the physical processes that shape the river and its floodplain. Prior to 1850, the riparian vegetation along the lower American River largely reflected the undisturbed geomorphic and hydraulic conditions of the watershed, in addition to vegetation management practices by native Americans.

Hydraulic mining from 1849 to 1886 caused major modifications in the geomorphology of the floodplain (Watson 1985; Corps 1997), which had major impacts on the vegetation. Since the cessation of hydraulic mining and the completion of upstream dams (i.e., Old Folsom Dam in 1893 and North Fork Dam in 1939, in addition to Folsom and Nimbus dam), downstream sediment transport has been virtually stopped (Corps 1997). Modification of flows due to the operation of Folsom Dam and Reservoir has probably led to a reduction in cottonwood regeneration, but otherwise has caused an increase in near-channel riparian vegetation (Watson 1985).

Channel constrictions together with commercial gravel extraction from the floodplain, have caused channel incision since the 1950s (Corps 1997; James 1997). Channel incision is generally associated with a lowering of the water table in the floodplain, which may reduce riparian vegetation survival rates. In addition, localized rapid lateral erosion rates and bank instability in recent years have removed vegetation (Resource Consultants and Engineers 1993; James 1997).

Prior to 1849, riparian vegetation along the lower American River formed extensive, continuous forests in the floodplain of the river, reaching widths of up to 4 miles (Sands 1985). Lieutenant George H. Derby (cited *in* Sands [1985]) prepared a map of the Sacramento Valley showing vast expanses of riparian forest along the major and minor streams of the Sacramento Valley. Approximately 775,000 acres of riparian forests were present in the Sacramento Valley in 1850. Approximately 98.5% has been lost, resulting in a remaining area of 12,000 acres (Sands 1985).

Prior to 1849, early settlers affected the riparian vegetation by removal of trees for construction and firewood uses, and riparian areas were probably converted to agricultural fields (Watson

1985). Removal of tall, old growth riparian vegetation most likely led to a reduction in shaded channel surface.

Two consequences of the hydraulic mining era affect the present riparian vegetation along the floodway of the lower American River. First, the floodplain of the river now lies considerably higher above the channel bottom than under natural conditions, in particular in the lower reaches. This results in a relatively deeper water table in the floodplain. Thus, while vegetation colonized the floodplain during the period of aggradation and the mature plants with deep root systems are vigorous today, little natural regeneration of the riparian forest is taking place (Corps 1998).

Second, the aggradation process also resulted in an inverted floodplain stratigraphy. Whereas in a natural river system, the coarsest sediments are located at the base of the bank and the finest at the top, the opposite is true along the lower American River. Here, the lower bank sediments are composed of silts and clays and the upper bank sediments are composed of sands and very fine gravels. The net result is that the berm surface tends to be composed of droughty sands (Corps 1998). Revegetation of the dry tailings has led to non-riparian grasslands and oak woodlands (Watson 1985).

In the 1920s, active gravel bars were scraped to obtain aggregate for cement production, and by 1940 bars as far downstream as Watt Avenue were affected (Watson 1985). These operations caused repeated destruction of the channel from 1900 to 1955.

Folsom and Nimbus dams effectively cut off all upstream sediment supply to the lower American River in 1955. In-channel sand and gravel mining, which continued into the early 1970s, also depleted the river's sediment supply. Improvement of the local levees along the lower American River between 1948 (south bank) and 1955 (north bank) probably also contributed to degradation by confining floodflows, thereby increasing flood depths and shear stresses along the bed and banks (Corps 1998). Reduction in the frequency and magnitude of high flow events may have led to degradation or loss of riparian vegetation in off-channel sites (Watson 1985). Also, reduction in the removal of vegetation from low bar surfaces by high flows has led to encroachment of riparian vegetation on the channel, which may contribute to immobilizing gravels (i.e., "armoring" of the bars) (Peltzman 1973). Although some increase in shaded riverine aquatic habitat may result, gravel that is tied up in this way may become unavailable to spawning salmonids (Peltzman 1973).

Modification of the spring and summer hydrograph resulting from the operation of Folsom Dam and Reservoir has likely affected the potential for regeneration of Fremont cottonwood. Flows resulting from the snowmelt runoff recession, which naturally occurred in May through July, have been shifted to August and September, beyond the seed dispersal period of cottonwood (Watson 1985). Cottonwood regeneration is critically dependent on the declining spring hydrograph (Scott et al. 1997). Cottonwoods are potentially the tallest streamside plant species. A reduction in the abundance of near-channel cottonwood likely has resulted in a reduction of shaded channel surface.

Increased summer base flows have resulted in an increase in riparian vegetation in sites peripheral to the active channel (Watson 1985), which can be observed by comparing 1937 aerial photographs to current photographs. The acreal extent of wetland vegetation in these "peripheral" sites, including sloughs and backwater channels, has probably increased.

Reductions in sediment supply also have plant substrate effects. Because no streams are tributary to the lower American River downstream of the sediment-trapping reservoirs, little sediment is available to develop new channel-margin habitat. Local contractions and expansions around bridge piers along the river are responsible for mobilization and then deposition of a few small gravel bars. In general, however, sediment transport capacity in the reach exceeds sediment supply and has resulted in the formation of an armored surface. Consequently, almost all sediment supplied to the reach by bank erosion upstream is moved downstream out of the system and is not deposited in the project reach to form new substrates for plant colonization (Corps 1998).

In the 1950s and early 1960s, gravel extraction activities were located immediately adjacent to the active channel upstream of the I-80, Howe Avenue and Watt Avenue bridges and at Arden Bar (Watson 1985). Settling ponds and mining pits have been captured by the river at all of these sites. These sites have functioned as sediment traps, and locally caused aggradation and bank formation. Gravel extraction from elevated terraces in the 1960s and 1970s (e.g., Sacramento Bar and Arden Bar) caused the formation of ponds and mounds of debris. These ponds are hydraulically connected to the river through percolation. While ponds left behind from mining have a well developed band of willow and cottonwood vegetation, which provides important habitat for avian and mammalian species (Sanders et al. 1985), the ponds may trap anadromous fish at high flows and ultimately result in mortality.

Since the 1970s, bank erosion and channel degradation have necessitated bank stabilization efforts. Both erosion and placement of rip-rap have caused removal of riparian vegetation and shaded riverine aquatic cover, although currently innovative bank protection techniques replace and enhance shaded riverine aquatic cover (Corps 1998).

Increasing numbers of exotic plant species are colonizing riparian habitats previously occupied by native species (Eva Butler & Associates et al. 2000). In particular, scarlet wisteria (*Sesbania punicea*) and Chinese tallow tree (*Sapium sebiferum*) - two recently introduced species - are rapidly spreading in riparian habitats. Other invasive exotic riparian species include arundo (*Arundo donax*), silver maple (*Acer saccarinum*), and black locust (*Robinia pseudoacacia*). These species are able to outcompete native riparian species such as willows (*Salix* species), white alder (*Alnus rhombifolia*) and Fremont cottonwood (*Populus* fremontii), but do not provide similar habitat values. The insect fauna of these species is expected to be much more limited, and may therefore affect the food supply of salmonids.

### 6.1.2. SHADED RIVERINE AQUATIC COVER

Shaded riverine aquatic (SRA) cover is the vegetation in the nearshore aquatic zone occurring at the interface between the river and adjacent woody riparian habitat. The principal attributes of SRA cover include: (1) an adjacent bank composed of natural, eroding substrates supporting riparian vegetation that overhangs and/or protrudes into the water; (2) woody debris in the water, such as leaves, logs, branches and roots; and (3) variable water depths, velocities, and currents (USFWS 1993). These attributes provide high-value feeding, escape, and spawning areas for regionally important fish and wildlife species. SRA cover is particularly important to juvenile salmonids because it locally moderates stream temperatures during the growing season and provides high-value resting and feeding areas, protection from predators, and shelter from high flows. SRA cover also provides important habitat for other native species (such as tule perch and Sacramento splittail) and non-native species (such as largemouth bass, smallmouth bass, and bluegill). River productivity is increased at all trophic levels by inputs of logs, branches, leaves, and detritus from overhanging vegetation and flooded streambanks and terraces. Living and dead terrestrial vegetation provides substrate and food for many species of aquatic invertebrates, which are in turn eaten by several fish species, including salmonids.

Available information is inadequate to describe historical trends in the extent, distribution, and quality of SRA cover along the lower American River. It can generally be assumed that the geomorphic and hydrologic conditions that affected riparian habitat also affected nearshore woody vegetation. In general, increases in floodplain elevation, incision of the streambed, and confinement of the river by levees resulted in a simpler shoreline with less diversity in depths and hydraulic conditions than existed historically. Bank protection has further degraded nearshore aquatic habitats and restricted the recruitment of instream woody material that would have naturally occurred as a result of bank erosion. Decreases in recruitment of large woody material and fine sediments resulting from construction of Folsom and Nimbus dams also contributed to historic declines in the quantity, quality, and diversity of nearshore habitat along the lower American River. This has been compounded by snag removal for navigation and recreation.

In 1997, Jones & Stokes used ASR's data to estimate the extent of natural and revetted banks, and to examine the relationships between the occurrence of instream woody material and the physical attributes of natural and revetted banks between river miles 3.9 and 9.2. In this reach, natural banks were the most common bank type, comprising 71% of the shoreline, while cobble and rock rip rap banks comprised 21 percent and 7 percent of the shoreline, respectively. In general, outside bends had lower concentrations of instream woody material than inside bends. The lowest concentrations of instream woody material occurred at outside bends where rock rip rap or river cobble riprap was the dominant bank material. Natural banks generally had higher concentrations of instream woody material that was larger in diameter and extended farther from shore than instream woody material found along rip rap banks.

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