Working Paper on Restoration Needs

Habitat Restoration Actions to Double Natural Production of Anadromous Fish in the Central Valley of California

Volume 3

WORKING PAPER ON RESTORATION NEEDS

HABITAT RESTORATION ACTIONS
TO DOUBLE NATURAL PRODUCTION OF ANADROMOUS FISH
IN THE CENTRAL VALLEY OF CALIFORNIA

Volume 3

Prepared for the U.S. Fish and Wildlife Service
under the direction of the
Anadromous Fish Restoration Program Core Group

May 9, 1995

ORGANIZATION OF THIS WORKING PAPER

This is Volume 3 of three volumes that comprise the Anadromous Fish Restoration Program (AFRP) Working Paper on Restoration Needs. The contents of the three volumes are as follows:

> **Volume 1** describes how the WORKING PAPER was developed, explains the process envisioned for completing a final Restoration Plan, and summarizes the production goals, limiting factors, and restoration actions sections developed by the AFRP technical teams. Interested parties should read the letter from Dale Hall and Wayne White that appears at the beginning of Volume 1.
>
> **Volume 2** provides descriptions of Central Valley rivers and streams, summarizes information on historic and existing conditions for anadromous fish, identifies the problems that have led to the decline of anadromous fish populations, and identifies roles and responsibilities of state and federal agencies in managing anadromous fish. It also includes two key documents that were used by the AFRP Core Group and technical teams to develop the WORKING PAPER.
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> **Volume 3** includes the complete production goals, limiting factors, and restoration actions sections as submitted by the AFRP technical teams and edited by USFWS staff. Volume 3 also includes citations for all three volumes of the WORKING PAPER.

To request copies of this Working Paper, call the AFRP=s information line at (800) 742-9474 or (916) 979-2330 and dial extension 542 after the recorded message begins. You may also obtain copies by calling Roger Dunn, CVPIA Public Outreach, at (916) 979-2760 or by sending e-mail requests to roger_dunn@fws.gov. The Working Paper is available to be viewed and downloaded on the Internet at http://darkstar.dfg.ca.gov/usfws/fws_home.html.

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INTRODUCTION

This section consists of the reports from the eight technical teams. Five of these teams addressed chinook salmon and steelhead in each of the following areas: (1) mainstem upper Sacramento River, (2) upper Sacramento River tributaries, (3) lower Sacramento River and Delta tributaries, (4) San Joaquin basin, and (5) Sacramento-San Joaquin Delta. Three additional teams addressed (6) striped bass, (7) American shad, and (8) white and green sturgeon. The teams that addressed chinook salmon and steelhead, American shad, and white and green sturgeon organized their reports according to river systems.

Each report is presented in at least two sections, "Limiting factors and potential solutions" and "Restoration actions". The first of these sections describes factors potentially limiting the production of the species and gives an overview of potential solutions for each factor; the second section lists specific actions and describes the objective, location, and predicted benefits and provides details of implementation for each action.

A. CHINOOK SALMON AND STEELHEAD

Baseline Natural Production and Goals

Chinook salmon - The procedures described in Volume 2, Section IX, AGuiding Principles and Assumptions,@ were used to estimate restoration goals for chinook salmon (Table 3-Xa-1). The Core Group defined the restoration goal to be equal to, at least, twice the mean estimated natural production for the baseline period (1967-1991). It defined natural production during the baseline period to be that portion of production not produced in hatcheries and defined total production to be the sum of harvest and escapement. Only rough estimates of hatchery production and ocean and inland harvest exist for the baseline period, and then only for some Central Valley rivers and streams. Where estimates were not available or where they were known to be inaccurate, values for these parameters were assigned. The proportion of production produced in hatcheries was assigned based on available estimates (Dettman and Kelley 1985, 1986; Cramer 1990) and on the opinion of fishery biologists. Ocean harvest of Central Valley chinook salmon was assumed to be equal to the Central Valley Index. Inland harvest values were assigned as a proportion of escapement based on available harvest data (Mills and Fisher 1994, draft summaries of California Department of Fish and Game [DFG] 1991-1993 angler survey data) and the opinion of fishery biologists. In general, escapement estimates were taken from Mills and Fisher (1994). More specific sources of information considered for each river are listed as notes associated with production spreadsheets in Appendix A at the end of this subsection.

Opportunities exist to improve estimates of most of the parameters used to estimate the restoration goal, especially estimates of the proportion of production produced in hatcheries and ocean and inland harvest. The goals listed in Table 3-Xa-1 should be considered preliminary estimates.

Table 3-Xa-1. Escapement, harvest, and production data and preliminary estimated restoration goals for chinook salmon based on doubling of natural production.

Race and river[a]	Escapement	Harvest		Production		Goal[b]
		Instream	Ocean	Total	Natural	
All races combined	280,000	53,000	410,000	740,000	500,000	990,000
Fall run	220,000	40,000	340,000	610,000	370,000	750,000
Late fall run	15,000	5,500	24,000	34,000	22,000	68,000
Winter run	23,000	4,600	26,000	54,000	54,000	110,000
Spring run	13,000	2,400	19,000	34,000	34,000	68,000
Sacramento River						
Fall run	77,000	7,700	110,000	190,000	120,000	230,000
Late fall run	14,000	2,800	20,000	37,000	22,000	44,000
Winter run	23,000	24,000	26,000	54,000	54,000	110,000
Spring run	11,000	2,200	16,000	29,000	29,000	59,000
Clear Creek	1,600	160	2,700	4,500	3,600	7,100
Cow Creek	1,400	140	1,400	2,900	2,300	4,600
Cottonwood Creek	1,600	160	1,900	3,700	3,000	5,900
Battle Creek						
Fall run	18,000	1,800	31,000	50,000	5,000	10,000
Late fall run	1,000	200	1,500	2,700	270	550
Paynes Creek	90	10	110	200	160	330
Antelope Creek	190	20	240	450	360	720
Mill Creek						
Fall run	1,100	110	1,400	2,600	2,100	4,200
Spring run	800	80	1,300	2,200	2,200	4,400
Deer Creek						
Fall run	410	40	510	950	760	1,500
Spring run	1,300	130	1,800	3,300	3,300	6,500
Miscellaneous creeks	300	30	350	680	550	1,100
Butte Creek						
Fall run	420	40	490	951	760	1,500
Spring run	360	40	620	1,000	1,000	2,000
Big Chico Creek	240	20	230	500	400	800
Feather River	49,000	9,700	80,000	140,000	86,000	170,000
Yuba River	13,000	1,300	19,000	33,000	33,000	66,000
Bear River	100	10	110	220	220	450
American River	41,000	18,000	75,000	130,000	81,000	160,000
Mokelumne River	3,300	300	4,100	7,800	4,700	9,300
Cosumnes River	760	80	800	1,600	1,600	3,300
Calaveras River						
Winter run	410	480	590	1,100	1,100	2,200
Stanislaus River	4,800	240	5,800	11,000	11,000	22,000
Tuolumne River	8,900	450	9,500	19,000	19,000	38,000
Merced River	4,500	230	5,100	9,900	9,000	18,000

[a] Data for rivers without a race designation are for fall-run chinook salmon.

[b] Because of rounding errors, goal category numbers do not add up to twice the natural production category numbers.

Steelhead - Insufficient data are available to estimate natural production of steelhead in the Central Valley other than upstream of Red Bluff Diversion Dam (RBDD). The restoration goal for steelhead spawning upstream of RBDD is 13,000 steelhead per year (refer to Appendix B at the end of this subsection).

Upper Mainstem Sacramento River

Limiting factors and potential solutions - Population levels of chinook salmon and steelhead in the upper Sacramento River are at historically low levels. The winter-run salmon is listed as endangered; spring-run populations in the mainstem are less abundant than winter-run populations, but occur in tributaries to the upper Sacramento River at low levels. The commercial fisheries that depend on Sacramento River stocks have been curtailed to a considerable degree.

Actions that are needed include seasonal opening of dam gates at RBDD, releases of cold water from Shasta and Trinity dams from levels below the powerhouse intakes, removal of acid and metal from the worst portion of the discharge from Iron Mountain Mine Superfund Site, and avoidance of entrainment of juveniles at Glen-Colusa pumps and other diversions.

There is historical evidence that the salmon fishery was compatible with the basic components of the water projects during the 1940s, 1950s, and 1960s. During the 1950s, the combined population of all salmon runs on the upper Sacramento River probably exceeded one-half million salmon. Over the last two decades salmon escapements and harvests have declined. As water demands increased, the CVP grew, becoming less operationally flexible in providing water-related benefits to fish, wildlife, and associated habitats, especially during dry periods. This trend continued even with increased regulation.

By restoring operational flexibility to water projects, a reasonable balance can be achieved among competing demands for use of CVP water, including the requirements of fish and wildlife, agricultural, municipal and industrial, and power contractors. The Central Valley Project Improvement Act (CVPIA) calls for several fish and wildlife restoration activities, some of which are structural changes to the existing facilities. These changes (e.g., addition of a structural temperature control device at Shasta Dam) are especially valuable because they provide structural operational flexibility, allowing more needs to be met with the same amount of water.

With limited water supplies and high demand requirements for fish and wildlife, agriculture, municipal and industrial, and power production, complex water management solutions are needed. For fish and wildlife and associated habitat protection, the Central Valley Project (CVP) should attain operational flexibility to protect the salmon and steelhead populations. In drought situations, the salmon and steelhead runs should be protected at least 2 out of 3 successive years, thus ensuring the populations' maintenance, recovery, and resiliency and avoiding the decade-long recovery periods from cumulative mortality rates produced by the present water management operations.

Existing habitat conditions - The Sacramento River is the largest river system in California. The river's water resources yield 35% of the state's supply and the river's salmon and steelhead resource supplies the largest portion of the state's catch. The upper Sacramento River supports one of the largest contiguous riverine and wetland ecosystems left in the Central Valley even though the remaining riparian habitat is only 5% of the historical amount. The river ecosystem supports several federal- and state-listed endangered and threatened species and several species of special concern.

The flow of the Sacramento River is regulated by Shasta Dam where as much as 4.5 maf of water are stored during the wet season. River flow is augmented in average years by up to 1 maf of Trinity River water transferred by tunnel to Keswick Reservoir. The U.S. Bureau of Reclamation (USBR) owns and operates the Shasta and Trinity divisions of the CVP, which also includes Spring Creek Debris Dam, which is used for metering out toxic wastes from the Iron Mountain Mine, and RBDD, which diverts into the Tehama-Colusa Canal and the Corning Canal.

The upper Sacramento River extends from Keswick Dam to the confluence of the Feather River, a distance of 215 river miles. Other alterations of the river affecting this reach include: the Glen-Colusa Irrigation District's (GCID's) pumps, which divert approximately 1 maf of water per year; the Anderson Cottonwood Irrigation District's (ACID's) seasonal dam, which diverts approximately 150,000 af, May to October; hundreds of small riparian diversions; and displaced riparian forests along selected sections of the bank that have major flood-control and bank protection works from Red Bluff to the Feather River.

Habitat needs - The upper Sacramento River supports four races of chinook salmon and steelhead. Other native anadromous fish include white sturgeon (*Acipenser transmontanus*), green sturgeon (*A. medirostris*), Pacific lamprey (*Lampetra tridentata*), and river lamprey (*L. ayresi*). Nonnative anadromous fish include striped bass (*Morone saxatilis*) and American shad (*Alosa sapidissima*).

This subsection addresses six primary limiting factors affecting salmon and steelhead in the upper mainstem Sacramento River: 1) changes in the natural frequency, magnitude, and timing of flows; 2) water temperature changes; 3) passage at artificial migration barriers; 4) toxic discharges; 5) effects of hatchery stocks on natural stocks; and 6) loss of riparian forests and associated rearing habitat and water temperature moderation capacity. Specific issues for achieving restoration follow:

Changes in the natural frequency, magnitude, and timing of flows - Reservoirs have changed the natural flow regimes of the Sacramento River by changing frequency, magnitude, and timing of flow. Flows need to be established that support the life history needs of all four races of salmon and steelhead: spawning flows, stable flows for early life stages, outmigration flows, and flushing flows for sediment transport.

The Sacramento River functions as a water delivery canal for the CVP. Flows are regulated in large part by CVP water delivery operations. During the irrigation season, flows released to satisfy project purposes generally exceed flows needed to satisfy spawning and temperature control requirements. Critical periods for coordinating flows between fishery needs and water delivery needs include fall and early winter months to ensure that incubation conditions are adequate, late winter when there may be a need to reduce flows and increase storage for temperature control later in the year, and spring when temperature control plans and water contracting decisions are made for the next season.

The runoff and storage conditions in the project vary widely, requiring different types of operation. USBR generally operates the project in accord with a CVP Operations Criteria and Plan (USBR 1992) and the Biological Opinion for winter-run chinook salmon (National Marine Fisheries Service [NMFS] 1993).

The flow allocation process is now coordinated with the CVPIA (CVPIA; P.L. 102-575). Each year there is coordination among the fishery trustees (DFG, U.S. Fish and Wildlife Service [USFWS], and NMFS) and the CVP operators to select the flow regimes and flow changes meeting habitat requirements within the available water supply. Habitat considerations include prevention of stranding and isolation of redds and juveniles due to flow fluctuations, attainment of temperature objectives, and provision of experimental spring-time releases for facilitating outmigration. Consideration is given to balancing reservoir carryover storage needs for temperature control with flow needs for habitat. The project operators provide monthly forecasts to the fishery trustees and further coordination occurs throughout the year as hydrologic conditions change.

The benefits of pulsed flows need to be accurately determined to facilitate juvenile outmigration. This flow requirement can consume enormous quantities of water from supplies dedicated to fish and wildlife. Because of the high water cost, it is necessary to define the benefits through carefully designed studies of experimental spring-time outmigration flows. There may be a need for flushing flows for channel maintenance (e.g., to remove the harmful effects of sedimentation or growths of nuisance algae and oligochaetes that destroy salmon eggs). Presently, there is insufficient information to determine the timing and amount of the flushing flow. Until the recent drought, carryover storage was sufficient to produce spills from Shasta Dam at adequate intervals.

Water temperature changes - Reservoirs have changed the natural cycle of water temperature and blocked access to historical spawning areas. The temperature regulation is important to the restoration of winter-run, spring-run and, to a lesser degree, fall-run salmon. Late fall-run salmon, steelhead, and other anadromous fish are not threatened by temperature problems. Past instances of temperature-induced mortality caused major year class failures and losses, especially when poor runoff conditions were combined with heavy reservoir drawdowns.

The California State Water Resources Control Board (SWRCB), on behalf of the fishery trustees, requires CVP operations to provide the best temperature control attainable for all races of salmon and steelhead. In addition, it requires eventual installation of temperature control devices at Shasta Dam and at Whiskeytown Reservoir. The NMFS, under the Endangered Species Act, prescribes measures for temperature control for winter-run salmon.

Permanent remedies are needed to resolve the temperature problem through the installation of structural devices on all reservoirs releasing to the river, in combination with prudent reservoir management practices that leave sufficient carryover storage to maintain cold water reserves the following year. In the interim, the reservoir operations are reviewed by a temperature task force and recommendations are made to avoid possible losses of salmon and steelhead by the optimum budgeting and delivery of cold water reserves via the coldest available reservoir outlets. These actions are consistent with the intent of the Clean Water Act (Water Rights Order 90-5), Federal Endangered Species Act, and the CVPIA. Uncontrollable factors, such as extreme drought, will limit the ability to control temperatures even with temperature control devices.

The temperature regime of the middle Sacramento River below Tehama County is not significantly influenced by reservoir operations due to its distance downstream from the dam. The objectives of restoration activities that affect the temperature regime in the middle river include rerouting major agricultural drainwater discharges from the river into flood bypass channels and reestablishing large-tract riparian forests that increase humidity and moderate air temperatures. Further study and analyses are needed to quantify the benefits of these two actions. However, it may not be necessary to precisely quantify these benefits if these actions are taken for the overriding benefits of restoring riparian forest for wildlife and directing large pesticide and herbicide discharges away from the river.

Passage at artificial migration barriers -

Red Bluff Diversion Dam - Opening the RBDD gates eliminates delay in passage and blockage of adult salmon and steelhead, which can result in reproductive failure if the fish are unable to reach additional spawning habitat and the coldest available water. The open gates also eliminate concentrations of piscivorous fish (their upstream movement is blocked by the dam), which prey on juvenile salmonids disoriented by passage under the dam gates. A needed partial remedy to fish passage problems is installation of USBR's proposed research pumping plant, which will allow the diversion dam gates to be open from mid-September through mid-May. A final remedy will depend on results of pilot studies, evaluations of the research pumping plant, and further feasibility studies focusing on different sizes of pumping stations and/or ladder-type passage facilities.

Anderson-Cottonwood Irrigation District - The ACID's 75-year-old seasonal dam needs an updated fish passage facility and a water control device that adjusts the head on the canal without flash-board removal and related drastic stream flow reductions. The ACID's dam has several effects on salmon and steelhead: (a) adjustments to the flashboard dam according to stipulations in a USBR contract allow the district to order rapid and drastic changes in the river flow, thus causing fish stranding and redd dewatering; (b) high volume water releases from canal waste gates can attract and strand spawning adult salmon and steelhead; (c) there are occasional discharges of toxic herbicides to tributaries crossing the canal; and (d) inadequate fish ladders at the dam impair upstream fish passage.

Fishery restoration remedies are proceeding on a cooperative basis. The ACID is developing the necessary information to better operate and improve the facilities necessary to exercise its water right with minimum biological impacts, consistent with various litigation settlement agreements. A setting for the flashboards and canal drum gates was recently and successfully tested at river flows of 4,000-14,000 cubic feet per second (cfs). The setting can deliver the full water demand in the canal without requiring mid-season adjustment of the flashboards and not exceeding the safety of dam water surface elevation in the diversion pool at the main dam.

The canal system operating procedures have been revised to prevent major biological problems. Once the ACID has determined the level of remediation possible from operational changes and structural modifications, appropriate agreements need to be completed.

Keswick Dam - Keswick Dam routinely spills during powerhouse problems and floods. The spill attracts all races of salmon and steelhead into a stilling basin, isolating them from the river when spills cease. A more effective escape passage can be provided by installing a small stream channel through the bedrock at the outside corners of the basin. The spills occur intermittently with turbine load rejections, required safety checks of the gates, and rare flood releases. The basin also receives oil-laden discharges from the internal dam works.

Unscreened diversions - There are more than 300 separate irrigation, industrial, and municipal water supply diversions along the Sacramento River between Redding and Sacramento, diverting nearly 1.2 maf of water annually from April through October. These unscreened diversions may cause significant losses of juvenile salmon and steelhead rearing in these sections of the river during the irrigation and nonirrigation seasons. Flooding of rice fields during the nonirrigation season is presently under consideration, which would expose more rearing salmon and steelhead to unscreened pumps. According to The Resources Agency of California (1989), 10 million juvenile salmon and steelhead are lost to unscreened diversions annually.

Glen-Colusa Irrigation District - The GCID was organized in 1920 to take over the Central Irrigation District's diversion project, which had operated since 1905. Significant hydraulic changes have occurred in the river since installation of the existing fish screens in 1972. The entrance to the diversion has dropped about 3 feet in elevation, lowering water depths in the oxbow and decreasing the effective surface area of the screens. Decreasing surface area increases water velocity through the screens, killing juvenile salmon, steelhead, and other small fishes by impingement.

Bypass flows needed to allow juvenile fish to return to the river are insufficient, and reverse flows occur when drawdown in the intake channel exceeds the natural flow of the main channel of the river. Most fish entering the diversion during these periods are believed to be lost to predation.

Original screen design criteria did not call for screening out salmonid fry (less than 1.75 inches in total length). It is now recognized that these screens were never completely effective. DFG estimates an average annual loss of 7 million downstream migrating salmonids at this diversion.

Restoration of anadromous salmonid populations above Keswick Reservoir - The amount of chinook salmon and steelhead habitat lost upstream from Keswick and Shasta dams was enormous. Hanson et al. (1940) determined from extensive gravel surveys that more than 2.4 million square feet of spawning habitat in 187 miles of accessible rivers and streams capable of supporting a maximum run of 188,000 salmon were blocked to anadromous fish by the project. This area once provided substrate for natural spawning for approximately one-half of the total Sacramento River salmon run (Calkins et al. 1940, Van Cleve 1945, Azevedo and Parkhurst 1958). Restoration of fish access to historical spawning and rearing habitat currently blocked by Keswick and Shasta dams would provide an opportunity to augment natural production of anadromous salmonids and could extend the current reduced geographical ranges for chinook salmon and steelhead. If restoration is successful, anadromous salmonids would have access to historical spawning ranges above Keswick and Shasta dams, providing additional restoration opportunities.

Restoration of habitat above the dams would be a secondary objective explored if it proves unfeasible to double the natural production in Central Valley streams below Keswick and Shasta dams. Elements of a feasibility study to determine the potential for restoration would include, but not be limited to, a survey for suitable or restorable habitat above Shasta Dam; a survey for suitable or restorable habitat between Keswick and Shasta dams; examination of Keswick Dam fish trap to move adults above Keswick Dam; survivorship of juveniles through Keswick Dam turbines; and analysis of volitional fish passage, including fish bypass systems and trucking of fish to facilitate adult and juvenile migration past Keswick and Shasta dams.

Toxic discharges - The Sacramento River receives a variety of discharges that have created contamination and increased toxicity to fish and other aquatic life.

Metals - Due to waste from the Iron Mountain Mine, the Sacramento River has impaired water quality according to standards for metals established under the Clean Water Act (SWRCB 1992). The Iron Mountain Mine discharges a complex mixture of toxic metals from abandoned mine workings. The discharge enters the Sacramento River approximately 1 mile above Keswick Dam, polluting the river with dissolved metals and forming large deposits of chemical sediments.

Historically, fish toxicity is managed to the extent possible by metering waste from the Spring Creek waste reservoir and diluting it with releases from Whiskeytown and Shasta reservoirs. Dilution does not solve the problem. Normally, dilution capability is large in what is the largest reservoir and river complex in the state; however, during drought or operations at Shasta Dam to prevent downstream flooding, little or no dilution water exists. High concentrations of toxic metals have caused more than 40 documented kills of salmon and steelhead and more undocumented damage. Lower concentrations of metals that are fairly common in the river can result in reduced growth, disease resistance, and physiological problems.

During the last decade, the Iron Mountain Mine site has been on the U.S. Environmental Protection Agency's (EPA's) Superfund program. The main objectives of EPA and the fishery trustees in the Iron Mountain Mine clean-up include: (a) eliminate the water demand that the dilution of the toxic discharge places on the Shasta-Trinity Project of the CVP and (b) attain water quality objectives for toxic metals and contaminated sediments to protect the fishery resources of the Sacramento River from acute and chronic toxicity.

Protection of the Sacramento River fishery has been greatly improved by the actions completed to date under the EPA program, including diverting uncontaminated waters away from contaminated areas, capping an open pit mine, disposing of numerous large tailings piles, and piping the drainage from the portals to the major underground workings to a lime treatment plant that removes 98% of the metals and acid. The remaining necessary remedial actions still in the planning process include controlling pollution from the diffuse sources of copper still in the watershed, which causes pollution during large rainfall events, and cleaning up the chemical sediments in Keswick Reservoir (EPA 1994). Fifty years of discharging the metal-laden waste, which has a pH of 3, into Keswick Reservoir produced a deposit estimated to be 109,000 cubic meters in size and to contain metal levels exceeding those designated for hazardous waste and toxic to salmon fry and invertebrates in small amounts (DFG 1995). The location of a large portion of the deposits near the Spring Creek Powerhouse can mobilize deposits into the river under certain types of operations.

Bioaccumulative substances - Monitoring of dibenzofuran and dioxin concentrations in resident fish and pulp mill effluent should ensure compliance with the Central Valley Regional Water Control Board's (CVRWQCB's) basin plan (CVRWQCB 1990) and suitability of different fish species for sport and commercial uses.

Biostimulatory substances - Monitoring of nuisance algae growths and *Hydrilla*, with the possible use of infrared technology, is needed to determine when the river has reached its capacity to assimilate nutrients. Large sources of biostimulatory substances include nitrogen from municipal waste, pulp mill effluent, and trace elements such as iron from Iron Mountain Mine.

Effects of hatchery stocks on natural stocks - Effects of hatchery stocks on natural spawning stocks is unknown. There is a potential for competition to occur between hatchery-released and wild/natural juveniles in the Sacramento River. Biological interactions of hatchery-released fish with wild fish may include direct competition for food and space during the freshwater rearing phase (Steward and Bjornn 1990).

The extent of transmission of diseases or parasites from hatchery-released salmonids to wild stocks is largely unknown. Although disease outbreaks and epizootics are fairly common in hatcheries, direct transfer of these diseases to wild fish has not been clearly demonstrated. Steward and Bjornn (1990) state that there is little evidence of transmittance of diseases or parasites from hatchery to wild salmonids, although research on this subject is limited and the full impact of disease on supplemented stocks is probably underestimated.

Loss of riparian forests and associated rearing habitat and water temperature moderation capacity - Riparian forests have been removed because of bank stabilization projects that reduce rearing habitats and increase heat gain along the river.

Riparian forests - The continuing fragmentation of the remaining riparian ecosystem has been implicated in the decline of salmon and steelhead populations in the upper mainstem of the Sacramento River. The riparian habitat along the river is an integral part of this system, affecting erosion, deposition, and channel morphology.

The riparian ecosystem along the Sacramento River consists of a mosaic of habitat types of different age, species composition, and vegetative structure. From grasses, forbs, and willows sprouting on newly deposited point bars to thick stands of cottonwood, sycamore, and black walnut to high terrace valley oak woodland, the system is inextricable from the geomorphological processes of erosion and deposition. The vegetation structure in turn affects river morphology by promoting sedimentation during floodflows and influencing erosion rates and channel cutoffs. The resulting channel and floodplain configuration has a diverse array of instream habitat conditions that benefit salmon and steelhead populations.

Loss of riparian forest has many deleterious effects on salmonid populations. These include the loss of configurations suitable for creating spawning riffles; gravel from eroding banks for the creation of spawning riffles; wood debris that provides habitat for juvenile fish; and organic material for aquatic invertebrates,-cover, and shade.

Many factors have resulted in considerable reduction in the amount of riparian habitat along the Sacramento River. Conversion of riparian forests to agriculture is the principal reason for the decline. Completion of Shasta Dam fostered further conversions of habitat to agriculture as decreasing flood risks allowed the planting of orchards and row crops in the historical floodplain. Bank protection also fostered conversion of forests by reducing bank erosion and meandering. The CVP altered the river's natural flow regime and sediment transport characteristics, changing patterns of forest regeneration. Operation of flood control projects, primarily south of Chico, with their associated systems of weirs, levees, bypasses, and bank protection precludes the reestablishment of a dynamic riparian ecosystem. Other current and historical factors contributing to the degradation of the riparian system include timber and fuel harvesting and urban and residential development.

For most of the length of the river, many of these factors currently preclude the reestablishment of an active meander zone. North of Cottonwood Creek, for example, lack of flooding has disrupted the historical pattern of vegetative succession, resulting in a reduction in early successional stages of riparian forest. The

Sacramento River Flood Control Project directs floodflows away from the leveed main channel, leaving only small remnants of riparian habitat south of Colusa.

Between Chico Landing and Red Bluff, conditions still exist that could eventually support the reestablishment of a relatively continuous and viable riparian system. Unregulated tributary flows contribute to a hydrology that still bears some resemblance to the natural system. Active erosion and deposition is still occurring in many places, and remnants of the vegetation mosaic remain. Both USFWS and The Nature Conservancy have targeted this reach for riparian habitat acquisitions.

The riparian forest moderates temperature in shallows along the water's edge and in the sloughs and side channels that are preferred rearing habitat because of lower water velocities.

Another contribution of the riparian system to the health of fisheries is the spatial heterogeneity created by woody debris and overhanging vegetation (Schlosser 1991). Such habitat components may provide escape cover for salmon and steelhead fry.

Cut banks, regardless of the presence of overhanging vegetation, may be preferred by salmon and steelhead fry. A DFG study compared three pairs of natural cut bank and artificial rock revetment sites, finding about three times as many salmon and steelhead fry near the cut banks (DFG 1982). The survey also found a higher diversity of fish species not characteristic of salmon and steelhead streams at the rock revetment sites, suggesting increased salmon smolt predation and competition for food.

Spawning substrate - Gravel recruitment to salmon and steelhead spawning beds has been halted by Shasta Dam. The problem is most acute in the uppermost 15 miles of the river where there is an absence of tributary streams capable of providing gravel to the river. Many tributaries have been mined for decades, reducing bedload replenishment to the river.

To date, two basic types of gravel restoration projects have been conducted: direct engineered placement of gravel in the river bed by heavy equipment and stockpiling gravel on the banks where it can replenish the bedload under high flows. The gravel placement projects have demonstrated the following problems: (a) engineered riffles are placed during lower flow conditions, making them unstable at high flows and potentially causing mortality to the early life stages in the shifting gravel; (b) placements contain large depressions and unnatural irregularities that isolate and strand juveniles when the flows are ramped down to elevations below the constructed gravel deposit; and (c) the operation of heavy equipment in the river, while placing gravel, discharges sediment above protection standards of downstream municipal water supplies and natural spawning areas.

Placing gravel in areas where it will be distributed naturally by floodflows costs less and does not create biological and water quality problems. Because the gravel is replenished at high flow, the river has the capacity to dilute fine sediment and prevent it from depositing on downstream spawning riffles or exceeding water quality criteria. The gravel used for bedload replenishment at high flow does not have to be washed.

Tracer rock placed into stockpiles indicates significant distribution with flows of 20,000 cfs and complete distribution when the 1993 flows ranged between 30,000 cfs and 40,000 cfs.

To ensure sufficient gravel supplies for the river, aggregate management plans should be in the counties that have streams that are mined for gravel (California Department of Water Resources [DWR] 1994). Gravel mining operations have to be modified to prevent formation of migration barriers, destruction of spawning habitat, and removal of spawning sized-gravel that would otherwise recruit to the river. Mitigation measures include stopping all instream gravel mining or requiring the spawning-sized gravel to be reserved for fishery projects. Streams that need aggregate management plans include Clear, Cow, Cottonwood, Thomes, and Stony creeks.

Gravel surveys have been conducted near Keswick Dam to estimate the available gravel from the ACID's dam to Keswick Dam (Vogel and Taylor 1987, Bigelow 1994). Good spawning substrate is predominately composed of gravel and cobble (90-100%), 1-6 inches in diameter, with most 2-4 inches with scarce boulders or fines (Vogel and Taylor 1987). Bigelow's estimate of good gravel between Keswick and Jelly's Ferry was 1,149,000 ft^2 and Vogel and Taylor's was 1,170,000 ft^2. This suggests that at the current salmon and steelhead population levels, spawning habitat probably is not limiting.

Table 3-Xa-2. Limiting factors and potential solutions.

Limiting factors	Potential solutions
Instream flows	1. Regulate CVP flow releases to provide adequate spawning and rearing habitat 2. Avoid flow fluctuations to avert dewatering redds or stranding or isolating adults and juveniles 3. Consider all effects of flow on ecosystem
Water temperatures	Maintain water temperatures at or below 56°F to at least Bend Bridge to Keswick Dam except in extreme water years
Passage at artificial impairments is inadequate	1. Correct migration problems at RBDD 2. Correct fish passage and other problems at the ACID's diversion dam 3. Avoid entrapment of adults at Keswick Dam stilling basin

Limiting factors	Potential solutions
	4. Correct unscreened pump diversions 5. Correct problems at the GCID water diversions
Contaminants	Remedy water quality problems associated with Iron Mountain Mine and other toxic discharges
Effects of hatchery stocks on natural spawning stocks is unknown	1. Evaluate competitive displacement between hatchery and natural stocks 2. Evaluate displacement of natural stocks by hatchery stocks 3. Maintain genetic diversity in hatchery stocks 4. Evaluate disease relationships between hatchery and natural stocks
Loss of riparian forests	Restore and preserve riparian forests

Restoration Actions -

Action 1: Develop and implement a river regulation plan that balances carryover storage needs with instream flow needs based on runoff and storage conditions.

Objective: Actively regulate river flows and reservoir storage in the upper mainstem Sacramento River system to provide necessary habitat for the production of all races of chinook salmon, steelhead, and other anadromous fish, consistent with sound ecological management principles.

Location: Shasta-Trinity Unit of the CVP.

Narrative description: These flow recommendations balance instream flow needs for habitat with carryover storage needs for temperature control. They are also intended to stabilize flows during important winter-run chinook rearing and spring-run and fall-run chinook spawning periods immediately after the irrigation season. Recommendations are listed in Table 3-Xa-3[1].

[1] The algorithm described here does not account for the ramping down of flows at the end of the irrigation

The algorithm for flow is built on the minimum flow and carryover requirements established in the Biological Opinion (BO) for CVP and State Water Project (SWP) effects on Sacramento River winter-run chinook salmon (NMFS 1993) and Water Rights Order 90-5 stipulating minimum instream flows. The BO also requires a minimum instream flow of 3,250 cfs from October 1 to April 30 and temperature control operation from May 1 to September 30 (NMFS 1993).

The recommended flows are based on runoff from a critically dry year and on maintaining a stable release throughout the period. However, water project operations will require flow increases under wet runoff conditions to control downstream flooding, and flow decreases if the runoff is less than critically dry to produce conservation storage. The recommended time to address concerns with runoff drier than critically dry is January 15 when approximately 40% of the wet season runoff has occurred. The recommended flow reduction is 275 cfs to make up for the increment of lost runoff between a critically dry and extreme critically dry water year (driest 5% of record), thereby producing reservoir storage sufficient to reach the 3.0 to 3.2 maf target by April 30. Reducing the flow during the wet season can cause reductions in the wetted perimeter of the spawning grounds and result in stranding and dewatering of the salmon in immobile early life stages that cannot follow the receding water. Managing flow reduction at mid-January produces the least amount of stranding risk during the wet season; but there are still 10% of the late fall-run salmon and 40% to 60% of the fall-run salmon at immobile early life stages (Vogel and Marine 1991).

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season in early October or the ramping up at the beginning of the irrigation season in late April.

Table 3 Xa 3. Minimum recommended Sacramento River flows (cfs) at Keswick Dam for October 1 to April 30 based on October 1 carryover storage in Shasta Reservoir and critically dry runoff conditions (driest decile runoff of 2.5 maf) to produce a target April 30 Shasta Reservoir storage of 3.0-3.2 maf for temperature control [2]

Carryover storage (maf)	Keswick release (cfs)
1.9	3,250
2	3,250
2.1	3,250
2.2	3,500
2.3	3,750
2.4	4,000
2.5	4,250
2.6	4,500
2.7	4,750
2.8	5,000
2.9	5,250
3	5,500

The flow recommendations are based on historical operations of the water project. Future changes in water project operations could become an obstacle to implementing flow recommendations, especially changes that increase in the transfer of storage from Shasta Reservoir to off-stream reservoirs (e.g., San Luis Reservoir and other proposed projects). The transfer of storage during the early part of the wet season would reduce the probability of attaining the Shasta Reservoir storage target in April needed to provide temperature control. Even without changes in operations, the actual implementation of the flow regime is expected to vary from that proposed due to uncontrollable factors such as the quantity and timing of runoff. However, by basing the flow recommendations on critically dry runoff conditions, the proposed operation

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$$Flow = \frac{\dfrac{carryover - 3.2\ maf\ (target) + 2.5\ maf\ (inflow)}{211\ days}}{1.98 \times 10^{-6}\ maf/day},$$

should be able to maintain the balance between instream habitat and reservoir storage for temperature control.

Discussion: The river regulation program for Keswick and Red Bluff dams, during the May through September irrigation season, generally does not need to be integrated with any of the habitat requirements other than temperature and outmigration flows. The seasonal irrigation releases from the Shasta Trinity Unit of the CVP provide the flows needed for temperature control for winter-run chinook salmon, as described below for Action 5, upper mainstem Sacramento River.

The source of the flows on an annual basis includes Shasta and Trinity reservoirs and, to a smaller extent, Whiskeytown Reservoir. During the wet season, Shasta Reservoir supplies approximately 80% of the water (with the exception of Trinity Reservoir flood control releases) because most of the Trinity basin water export is concentrated in the dry season when the needs and financial returns are greater. During drought cycles, Trinity River water exports are reduced during the wet season such that it generally approximates 10% of the Sacramento River flow. During the dry season, the Shasta Reservoir still contributes an average of 75% of the Sacramento River flow with the balance coming from Trinity and Whiskeytown Reservoirs.

No algorithm exists that combines water year type, previous year carryover, and other variables such as weather and project operations to provide an end of water year carryover target. The decision-making process for allocating the water supply available to CVP contractors involves comparing the forecasted conditions resulting from drawing on storage during the existing water year with the risks of potential impacts in the following water year or years (USBR 1992). No current set rule curve or formal risk analysis has been established to make that comparison and decision. However, the current process, which has evolved through 6 years of continuous drought, forms a basis for the allocation decision.

An algorithm to provide reservoir storage targets is not recommended. Rather, as suggested in the BO, 1.9 maf should be the minimum carryover in critical operational conditions (NMFS 1993). The methodology used for determination of minimum carryover storage needs was an empirical, exploratory seasonal irrigation release from the Shasta Trinity Unit of the CVP to provide the flow needed for temperature control for winter-run chinook salmon, as described below for Action 5, upper mainstem Sacramento River.

It may be impossible to maintain a minimum carryover storage of 1.9 maf in the driest 10% of water years. If the 90% probability of exceedance runoff forecast projects critical or extremely critical hydrological conditions and the CVP operations forecast projects carryover storage levels in Shasta Reservoir below 1.9 maf at the end of the water year, USBR must reinitiate consultation with NMFS prior to the first water allocations announcement.

The river flow should be actively regulated to meet the ecological requirements of all the anadromous fish that coexist in the Sacramento River, especially species that have suffered the greatest declines. In addition, there is a goal of managing the river system at an ecosystem level, which includes all organisms that interact in those environments located throughout the Central Valley that are influenced by the Sacramento River and its reservoir system.

Minimum flow requirements should allow salmon and steelhead to successfully interact with the overall river environment. Justifications for the recommended minimum flows are described below.

Releases of 5,500 cfs would provide a stable river environment throughout the wet season when restricted to water years having high runoff and storage conditions. As poorer runoff and storage conditions occur, flows are reduced toward a minimum of 3,250 cfs (Table 3-Xa-3) to increase conservation storage for future temperature control.

Compared to lower flows, 5,500 cfs provides good spawning conditions in the reach directly below Keswick Dam, reduces the risk of redd superimposition, and increases the length of river with suitable spawning temperature. This flow also generally wets the width of the river channel, providing extensive rearing habitat to the riparian growth bordering the river and optimum cover for juvenile fish and increasing aquatic insect production.

A flow of 5,000 cfs is the lowest release that produces comparatively little change in wetted perimeter with increasing flows, which tends to reduce the risk of stranding juveniles and dewatering redds if flows are temporarily raised and then reduced.

At 5,000 cfs, salmon and steelhead are generally discouraged from placing redds in the thalweg because water velocities are too high. Locating the sensitive embryos in the thalweg can expose them to flood control releases that could scour them out of the redds or crush them in the bedload.

The downstream migrant salmon include fry and larger juveniles. Outmigration cues may include turbidity, flow, and smoltification. During dry low flow years, there is an observed tendency for juveniles to delay downstream movement in the river above Red Bluff (USFWS 1988).

The effects of flow on outmigration is uncertain. Experiments are needed to empirically develop the most effective pattern of springtime flows. One possible practice is to artificially augment and intensify turbid river flows produced by small to moderate natural runoff events that occur between January 15 and May 15. The river would be regulated in a pattern that produced by the storm to yield augmented test flows ranging between 20,000-40,000 cfs as measured at Bend Bridge for a duration of 3-4 days. The total volume of water allocated for these flow experiments would vary between 60-120 thousand acre-feet (taf) depending on water supply. The natural flow recession curve should be mimicked to avoid stranding; however, if it is prolonged, the river flow should be ramped down as specified in Water Rights Order 90-5 (SWRCB 1990).

Flood control operations are another feature of river regulation that may be altered to meet ecological requirements of the river if they do not interfere with the protection of life or property. To the extent possible, flood control operations should attempt to produce this range of flows to facilitate transportation of stockpiled gravel for spawning gravel replenishment. For example, operational flexibility may allow higher releases for shorter time periods to produce flows in the target range. These stockpiles should be replaced so they can wash into the river during high flows.

The loss of late fall-run chinook redds during certain types of flood control operations may be minimized by shortening flood release periods. When flood control releases extend for weeks beyond a storm period, late fall-run chinook begin to spawn on river flood terraces above the normal river channel where their redds become stranded when flood control operations cease. Flood control operations may, in some cases, be able to use a higher release for a shorter period of time that tracks closer to natural storm events, if it is the operational equivalent to lower releases for a longer period. However, this recommended approach recognizes the potential for increased orchard seepage throughout the lower Sacramento River (drowning of tree roots), which is normally controlled with lower releases for longer time periods.

<u>Predicted benefits</u>: The proposed plan provides the most productive and stable environment that can be attained under the reservoir storage, runoff, and project operation conditions during the water year.

Action 2: Develop a flow regime that imitates natural flow changes and avoids dewatering redds or isolating or stranding juveniles on monthly and daily rates of change.

<u>Objective</u>: Avoid flow fluctuations to avert dewatering redds or stranding or isolating adults and juveniles.

<u>Location</u>: Keswick Dam (river mile [RM] 307) to Princeton (RM 164).

<u>Narrative description</u>: Reducing the flows rapidly or during months when a large portion of any race is incubating can result in significant fish losses due to stranding and isolation. Small juvenile fish have limited ability to follow receding waters back to the river and the early life stages are completely immobile. The types of channel morphology that produce the largest losses are large flat terraces, shallow side channels, and shallow nearshore areas, all preferred rearing habitat for fry. Repeated flow fluctuations in these shallow habitats can cause significant cumulative mortality.

Water project operations require two basic types of flow reductions throughout the year: 1) short-term adjustments to accommodate changes in water demands and 2) seasonal adjustments that reduce the flows at the end of the irrigation season to begin storing wet season runoff (USBR 1992). There is a special problem associated with operation of the ACID's dam when flow reductions are made at Keswick Dam to accommodate adjustments of the flashboards (see action item for the ACID). To control damages to the fishery, different operational measures must be taken for the different types of flow reductions.

The short-term flow adjustments are limited to 15% in a 12-hour period (2.5% per hour) under the water rights for Shasta Dam (Water Rights Order 90-5) and the BP (NMFS 1993). In the years following the 1977 drought, low fluctuating flows between 3,000 and 6,000 cfs became a common occurrence during the wet season for the first time in the history of the project. Monitoring of these flow fluctuations revealed serious reductions in wetted perimeter of the spawning and shallow nearshore areas requiring slower ramping rates. The recommended ramping rates are 200 cfs per night when river flows are between 6,000 and 4,000 cfs and not more than 100 cfs per night at flows below 4,000 cfs where the largest rate of wetted perimeter reduction occurs (DFG 1992 and stipulations of NMFS BO). Salmon fry have been shown to be less susceptible to loss if the waters are receding during the night (Olsen and Metzgar, *Draft*) when there is reduced predator efficiency.

The seasonal flow adjustments are generally characterized by a flow reduction in fall at the end of the irrigation season when the weather cools and also during the time when temperature control releases are no longer needed. The best management practice to avoid significant reductions in the wetted perimeter of the spawning area during fall and winter is to maintain a flow above 5,000 cfs without any fluctuations (other than flood control). When limited reservoir water supply requires lower flows (Table 3-Xa-3 flow section) the best management practice is to establish as early as possible a flow that is the minimum that can be maintained throughout the incubation period without any fluctuation. This is similar to the Agreement concerning the Operation of the Oroville Division of the SWP (1963). Because the recommended flow schedule for the wet season is based on critically dry runoff, it ensures that the selected flow can be maintained throughout the incubation period in 90% of the water years.

Scheduling seasonal flow reductions to occur in the first week of October ensures that approximately 90% of the fall-run spawning activity occurs at a stable flow. Spring-run salmon are the only race consistently incubated at flows much less than they are spawned at because they all spawn during high irrigation releases and incubate at lower post-irrigation season flows, making their redds susceptible to dewatering at flows less than 5,000 cfs. After the irrigation season resumes in spring, the flows steadily increase to levels three to four times that during the normal wet season releases, eliminating risks to early life stages of late- fall-run, winter-run, and steelhead present at that time.

Predicted benefits: By integrating measures into the water project operation, losses due to stranding and isolation can be avoided for all of the races of salmon and steelhead except for spring-run chinook. Avoiding flow reductions during incubation prevents reductions in the interchange of surface flow to the intergravel environment of the redd, yielding larger healthier fry from the spawning effort (Reiser and White 1990). Stabilizing flows in the nearshore areas and side channels maintains the best rearing habitat available in the river.

Action 3: Complete an integrated instream flow incremental methodology study (IFIM) to refine a river regulation program that actively balances fishery habitat with the flow regime, including needs for adequate temperature, flushing flows, outmigration, channel maintenance, attraction flows, and maintenance of a riparian corridor.

Objective: Regulate CVP releases to provide adequate spawning and rearing habitat for salmon and steelhead and to minimize flow fluctuations to avoid dewatering redds and stranding or isolating adult and juvenile fish.

Location: Upper Sacramento River from Keswick Dam to Hamilton City.

Narrative description: Between 1985 and 1990, DWR and DFG carried out a cooperative study (Phase I report) to collect the hydrologic and physical data for an IFIM study of the upper Sacramento River between Keswick Dam and Hamilton City (DWR 1993). This study, together with other evaluations, represented the first phase of a process that should ultimately lead to a multiagency recommendation for modified flow releases from CVP projects to the upper Sacramento River.

The primary objective of the Phase I report was to present an estimate of the amount of habitat for fall-run chinook salmon available at various streamflows.

The fish habitat versus streamflow relationships developed in the Phase I report provide only part of the information needed to make flow decisions. Further work should integrate the following additional topics with the habitat model in order to make appropriate flow decisions: (1) habitat models for late fall-run, winter-run, and spring-run chinook salmon; (2) timing of chinook salmon life stages; (3) spawning and rearing locations; (4) water temperature; (5) tributary inflow; (6) water quality; (7) agricultural diversions; (8) redd dewatering; (9) adult and juvenile stranding; (10) changes in substrate due to recent gravel restoration work; (11) potential changes in cover due to riparian vegetation restoration plans; and (12) outmigration. Flow needs for other, sometimes competing purposes, such as for other wildlife species, water supply, power generation, and maintenance of Delta water quality, should also be considered in this process.

Predicted benefits: Defining and implementing the "optimum flow" for anadromous fish in the upper Sacramento River would be a major step in maximizing the river's capacity for natural fish production.

Action 4: Manage flow to restore riparian vegetation.

Objective: Consider all features of how flow influences ecosystem.

Location: Red Bluff at RM 242 to Chico Landing at RM 204.

Narrative description: With control of the Sacramento River, flow patterns no longer resemble the hydrology that helped to establish and maintain riparian forests. Because our knowledge of the dynamics of Sacramento River riparian forests is limited, we suggest the following actions:

- # Experimental springtime pulse flows to assist juvenile salmonid outmigration should also attempt to mimic historical patterns of flooding followed by decreasing spring flows; they also establish and maintain riparian vegetation. The present patterns increase rather than decrease flows in spring, but the succession of riparian plant communities is better facilitated by decreasing flows. Flushing flows are needed to manage sedimentation and are therefore beneficial to both fish and riparian communities.

- # A hydrologic model should be developed for a meander belt from Red Bluff to Chico Landing.

Discussion: Many factors have resulted in considerable reduction in the amount of riparian habitat along the Sacramento River. Agricultural conversion is the principal reason for the decline. Completion of Shasta Dam as part of the CVP fostered further conversions of habitat to agriculture as decreasing flood risks allowed the planting of orchards and row crops in the historical floodplain. Bank protection also fostered conversion of forests by reducing bank erosion and meandering. The CVP altered the river's natural flow regime and sediment transport characteristics, changing patterns of forest regeneration. Operation of flood control projects, primarily south of Chico, with their associated systems of weirs, levees, bypasses, and bank protection, precludes the reestablishment of a dynamic riparian ecosystem. Other current and historical factors contributing to the degradation of the riparian system include timber and fuel harvesting and urban and residential development.

For most of the length of the river below Colusa, many of these factors currently preclude the reestablishment of an active meander zone. The Sacramento River Flood Control Project directs floodflows away from the leveed main channel, leaving only small remnants of riparian habitat south of Colusa. Although the river is not meandering in these reaches, valuable habitat remains, providing benefits to salmon and other wildlife species and opportunities for improvement.

Predicted benefits: The reestablishment of a healthy riparian system along the Sacramento River would have several positive impacts on salmonid populations. These include: 1) maintaining channel configurations suitable for creating spawning riffles; 2) supplying gravel from eroding banks for the creation of spawning riffles; 3) supplying woody debris that provides habitat for juvenile fish and a source of organic material for aquatic invertebrates; 4) supplying a renewable source of shaded riverine aquatic habitat; 5) supplying terrestrial invertebrate food for juvenile fish; and 6) moderating the temperature regime of the river, particularly the near shore and backwater areas.

Action 5: Maintain water temperatures at or below 56^{o} F from Bend Bridge to Keswick Dam except in extreme low water years.

Objective: Develop a water management plan that will ensure USBR=s ability to provide cold water during critical months and budget cold water reserves in reservoirs to maximize survival during critical months.

Location: Keswick Dam at RM 302 to RBDD at RM 242.

Narrative description: Water temperatures in the Sacramento River are a major limiting factor to the maintenance of winter-run chinook salmon, spring-run chinook salmon, and, to a lesser extent, fall-run chinook salmon (NMFS 1993, USBR 1992, USFWS 1987, DFG 1992). By providing temperature control at Shasta Dam, it is possible to compensate for the spawning grounds now blocked by the dam that historically maintained winter-run and spring-run chinook salmon during summer. In addition, temperature control actions maintain fall-run chinook salmon by overcoming the delayed cooling of the river that the reservoirs cause in fall. The historical water project operations and temperature modeling demonstrate that the Shasta-Trinity Unit of the CVP has the capability of controlling water temperatures in the 60 miles of river between Keswick Dam and RBDD under typical runoff and storage conditions (USBR 1992).

Over the last 20 years, various scientific studies and regulatory actions have established that 56^{o}F is needed for successful incubation (Seymour 1956 as cited by DWR 1988, USFWS 1987, Water Rights Order 90-5, NMFS 1993). Controlling temperatures to a "daily" average of 56^{o}F on the longest length of spawning grounds that the storage and runoff conditions will allow requires the following actions:

- Attain optimal management of the cold water supply available in the reservoir system by installing and properly operating the Shasta Temperature Control Device and the temperature control curtains in Lewiston and Whiskeytown Reservoirs pursuant to Water Rights Order 90-5). Prior to installation of the device, operate the low level outlets that bypass the powerhouse bypass.

- For each race of salmon, establish a temperature compliance point that will attain 56^{o}F throughout the incubation period of each race as determined by available storage as shown in Table 3-Xa-4 pursuant to the BO (NMFS 1993).

- Conserve sufficient Shasta Reservoir storage by the end of the water year so that in the next water year at least 90% of the recorded runoff conditions will refill the reservoir to the point the cold water supply will yield a temperature of 56^{o}F in the river reach where 90% of winter-run incubation activity occurs (above Jelly's Ferry). Specifically, Shasta Reservoir should be operated to attain a minimum October 1 carryover storage of 1.9 maf under all runoff conditions except the driest 10% of the water years.

Table 3-Xa-4. Water temperature control points for winter chinook salmon in the upper Sacramento River as a function of operational environment (carryover + Shasta inflow from October 1-February 1 and on April 1) related to Bend Bridge (RM 258) and Jelly's Ferry (RM 267).

Operational Environment (maf) February 1	Operational environment (maf) April 1	Control point	Inclusive dates	Temperature (°F)
≥3.03	4.33≥	Bend Bridge	April 15 - September 30	≤56
≥3.03	4.33≥	Bend Bridge	October 1 - October 31	60
2.54≥ ≤3.03	3.17≥ ≤4.33	Bend Bridge	April 15 - August 31	56
2.54≥ ≤3.03	3.17≥ ≤4.33	Jelly's Ferry	September 1 - September 30	56
2.54≥ ≤3.03	3.17≥ ≤4.33	Jelly's Ferry	October 1 - October 31	60
2.38≥ ≤2.54	2.82≥ ≤3.17	Jelly's Ferry	April 15 - September 30	56
2.38≥ ≤2.54	2.82≥ ≤3.17	Jelly's Ferry	October 1 - October 31	60
<2.38	<2.82	Meet Delta water quality standard		

Water allocations in spring should be based on a 90% exceedance forecast to reduce the risk of over allocating water supplies and missing the carryover storage target (NMFS 1993).

- Attain optimal operations and planning of the annual cold water budget by using a temperature model on a daily time step model, monitoring temperature (Clean Water Act, Water Rights Order 90-5), and scheduling the Trinity River diversion to the Sacramento River to provide a temperature benefit.

- All existing and future discharges of municipal and industrial waste that could add heat to the river, as well as water projects that could reduce the flow of the river and increase its heat gain, must attain temperature objectives established in accordance with the Clean Water Act. Specifically the Basin Plan for the Central Valley Regional Water Quality Control Board provides that "temperature shall not be elevated above 56° F in the reach between Keswick Dam to Hamilton City and 68°F in the reach between Hamilton City and the I Street Bridge" (Sacramento). The reach below Hamilton City is a migration corridor and rearing area for salmon.

Discussion: Fisheries experts have identified water temperature in the upper Sacramento River as a critical factor in the decline of winter-run chinook salmon. During most years, winter-run chinook salmon are unable to spawn successfully below RBDD because of lethal temperatures (Hallock and Fisher 1985). In recent years, drought conditions have resulted in lethal temperatures above the dam as well.

Coombs and Burrows (1957) found that water temperatures between 43°F and 57.5°F are optimal for chinook egg development although a literature review conducted by DWR indicated that the optimum range of temperature for development through the emerged fry stage may be bound by 56°F on the upper end (Seymour 1956 as cited by DWR 1988). Water temperature of 62°F is believed to produce 100% mortality.

Water temperature in the upper Sacramento River varies with location and distance downstream of Keswick Dam, depending on hydrologic conditions and operation of the Shasta and Trinity Divisions of the CVP. Water temperatures between Keswick Dam and RBDD are influenced by meteorological conditions, tributary inflows, volume of water released from Keswick Dam, temperature distribution in the reservoir, the ratio of Spring Creek Power Plant release to Shasta Dam release, and depth of release from both Shasta and Trinity dams. Water released from Keswick Dam generally warms as it travels downstream during summer and early fall months.

The reservoir system provides large reserves of cold water that can be tapped in a planned fashion. During most years, cold lake water and large irrigation flows provide sufficient thermal mass and rapid travel time to prevent excessive heat gain in the first 40-60 miles below Keswick Dam. Thus, the project can maintain a temperature regime suitable for the spawning and incubation of salmon over an area that is roughly equivalent to that found in the mountainous reaches of the river system now blocked by the dam.

During the past 5 years, USBR, in coordination with the multiagency Sacramento River Temperature Task Group, has developed temperature operational plans for the Shasta and Trinity Divisions of the CVP. From 1987 to 1994 USBR has implemented plans to provide for temperature protection for winter-run chinook salmon while still meeting other project purposes (USBR 1992; pages 33-36). The task group meets annually to discuss operational alternatives, new objectives, biological information, and status of water temperatures. Once the task group has recommended an operation plan for temperature control, USBR then submits a report on the operation plan to the SWRCB generally on or before June 1 each year. Operational plans have included releases of water from upper and lower outlets at Shasta Dam, releases from the lower outlet on Trinity Dam, and manipulation of the timing of Trinity River diversions and Whiskeytown Reservoir flood control drawdown. The lower outlets on Shasta and Trinity dams have the ability to gain access to deep, cold water in the reservoirs. However, water released through the lower outlets is unavailable for hydropower generation, and power generation is not possible from upper level outlet releases on Shasta Dam. Warmwater releases from the upper level outlets have been made to conserve cold water in Shasta Lake for temperature control operations during late summer months and to induce winter-run chinook salmon to spawn as far upstream as possible.

Action 6: Raise RBDD gates during primary chinook adult and juvenile migration periods.

Objective: Provide unimpeded adult and juvenile passage past RBDD and decrease juvenile mortality associated with predation.

Location: RBDD, RM 243, Red Bluff, California.

Narrative description: This action requires raising the dam gates at minimum from September 15 to May 15 each year to benefit all chinook salmon runs and steelhead by providing unimpeded passage (Table 3-Xa-5). Raising the dam gates at RBDD is a proven, attainable technology that allows unimpeded fish passage in the Sacramento River at Red Bluff. The river returns to a natural configuration that avoids mortality of adult and juvenile salmon, provided protective measures are incorporated into the alternate water pumping system(s). The seasonal removal of the dam at Red Bluff allows fall-run and spring-run chinook salmon access to an additional 3 miles of habitat.

Table 3-Xa-5. Percent of adult and juvenile chinook salmon runs and steelhead passing RBDD from September 15 to May 15 (DFG 1991).

	Chinook salmon run				
Life stage	Fall[a]	Late fall	Winter	Spring	Steelhead
Adults	75%	100%	89%	19%	84%
Juveniles	89-64%[b]	74%	74%	100%	--[c]

[a] Juveniles includes only those emerging above the dam.

[b] Values represent wet and dry years.

[c] No estimate of juvenile steelhead passage has been made because of difficulty in differentiating from resident trout.

Discussion: Fish ladders at RBDD are inefficient at passing migrating adult salmon (Hallock et al. 1982; Vogel and Smith 1984; USFWS 1987, 1989, 1990; Vogel et al. 1988). This results in significant delays and blockage of upstream migrating chinook salmon and steelhead, causing increased spawning downstream in waters previously too warm for successful egg incubation. Delay at the dam can produce elevated stress conditions in the adult salmon, especially when water temperatures along their migration passageways approach the upper limits of their temperature tolerance. Radio telemetry studies to evaluate passage of adult salmon reported up to 40% of radio-tagged winter chinook and 33% of late fall-run chinook salmon were blocked by the dam (Hallock et al. 1982, Vogel et al. 1988).

Since 1987, USBR has raised the RBDD gates for a variable and significant portion (80%) of the nonirrigation season, allowing free passage of adults during that period. Upstream progress of late fall-run and winter chinook salmon as they approach and pass RBDD was monitored yearly from 1986 through 1991 by USFWS. Analysis of the data have shown that raising the RBDD gates during the nonirrigation season dramatically improves upstream fish passage (Northern Central Valley Fishery Resource Office, USFWS, Red Bluff, California, unpublished data).

Problems in passage of juvenile salmonids has also been reported (Vogel and Smith 1984; Hallock 1989; USFWS 1987, 1989, 1990; Vogel et al. 1988). A cause of mortality in juvenile chinook salmon is the dysfunctional predator-prey relation created by RBDD, largely from the Sacramento squawfish (*Ptychocheilus grandis*) (Vondracek and Moyle 1983, Vogel et al. 1988). The piscivorous nature of Sacramento squawfish, as well as its preference for salmonids, is well documented (Vondracek and Moyle 1982, 1983); however, it has not been systematically studied immediately below RBDD (Garcia 1989). The Sacramento squawfish is a native species that co-evolved in the river with chinook salmon and steelhead. In the natural free-flowing river setting, the predator-prey relationship between the Sacramento squawfish and the native salmonids is intact and has no significant effect on salmonid populations (Brown and Moyle 1981). Artificial structures, however, can provide increased feeding and ambush settings, creating an unnatural advantage for predators. Other piscivors present below RBDD include striped bass (*Morone saxatilis*), rainbow trout and steelhead (*Oncorhynchus mykiss*), and American shad (*Alosa sapidissima*), as well as numerous other fish and bird species.

The juvenile passage problem at RBDD is twofold: upstream movement of piscivorous fishes is obstructed by the dam, causing fish to accumulate downstream, and juvenile salmon are disoriented from passing under the dam gates or through the bypass system, making them vulnerable to predation or injury. Vogel et al. (1988) found that mortality attributable to physical injury from passage under the dam gates was negligible (at or near 0) and mortality due to passage through the Tehama-Colusa headworks fish bypass system was measurable (1.6-4.1%). To estimate total mortality during dam passage, Vogel simultaneously released known numbers of juvenile hatchery salmon immediately above and below RBDD. Fish released above RBDD were recaptured 16% to 55% less than those released below the dam in this experiment. Some releases of hatchery fish above RBDD have contributed 51% less to the commercial and sport harvest than releases below the dam (Northern Central Valley Fishery Resource Office, USFWS, unpublished data, 1991). Vondracek et al. (1991) estimated an annual loss of 1-6% to juvenile downstream migrants during passage at RBDD due to Sacramento squawfish predation; however, peak estimates of mortality in April and May were as high as 80%.

The installation of the new fish screening system may reduce entrainment and predation of those fish that are diverted into the Tehama-Colusa Canal forebay although the effectiveness of this new fish bypass system has only been partially evaluated (Big Eagle et al. 1993). More symptomatic of the extent of the predation are surface and *in situ* observations by USFWS's scuba divers of concentrations of Sacramento squawfish feeding immediately below the dam. This suggests a significant predation problem on juvenile migrants passing under the dam gates. New information suggests that more significant mortality may be associated with juvenile passage under the dam gates. Rotary-screw traps operated below RBDD during August and September 1994 experienced high levels of juvenile salmonid mortality (resulting from passage under the dam gates) in their catch. After the RBDD gates were raised in September, mortality became negligible (USFWS 1994). These preliminary findings are under further investigation but do suggest that juvenile mortality during passage may have other causes, or that predators are benefiting from prey already dead or injured. Predation also occurs in the Red Bluff Reservoir where there are populations of black bass and other predators, not typical of a riverine habitat.

It was recommended by Vogel et al. (1988) that measures to control predation by Sacramento squawfish should be developed at RBDD. Some of the suggested measures were to trap and remove Sacramento squawfish from the fish ladders, use physical methods to disperse Sacramento squawfish below the dam, develop a commercial or sport fishery for Sacramento squawfish, or reduce Sacramento squawfish holding areas below RBDD. The goal of trapping and developing commercial or sport fisheries for Sacramento squawfish would be to remove a portion of the accumulated squawfish below RBDD, which theoretically would increase juvenile salmon survival, thereby increasing the number of adult salmon returning to the river. Trapping Sacramento squawfish in the fish ladders would have little impact on numbers immediately below the dam as it removes Sacramento squawfish that have already left that area. New fishways, designed to improve salmon passage, might also improve Sacramento squawfish passage; however, this is speculative as the biological criteria for Sacramento squawfish passage have not been developed.

Commercial fishing was evaluated in 1989 (Leveen 1990). Leveen used traps and hook and line methods to capture Sacramento squawfish. He caught 620 Sacramento squawfish immediately below RBDD in an undetermined amount of time using hook and line methods, he also caught 20 salmon. In 660 trap-days, 3,423 fish (mostly hardheads) were captured, including Sacramento suckers (31), tule perch (16), and carp (2). Contamination of Sacramento squawfish flesh by high levels of dioxin from upstream pulp mills terminated the project. The levels are now reduced to the point they may not interfere with a commercial fishery, but the California Department of Health Services has not determined if the fishery is suitable for commercialization.

It is unlikely a sport fishery could remove enough Sacramento squawfish to make a measurable impact on juvenile salmon survival. Sacramento squawfish are more abundant at RBDD in spring (Vogel et al. 1988) but spring removal may only temporarily decrease their abundance. This is because Sacramento squawfish are highly migratory and would repopulate the area below RBDD. Hence Sacramento squawfish removal would be a continuous process. Additionally, a spring fishery would likely incur an unacceptable incidental catch of threatened winter-run salmon. Sacramento squawfish are most abundant in the tailrace area immediately below the dam gates where disoriented prey are available. Boats are unsafe in the swift tailrace water immediately below the dam precluding entry by sport anglers.

The best long-term solution for improving or eliminating the dysfunctional predator-prey relationship would be the removal of feeding habitat in Red Bluff Reservoir and below the dam by seasonally or permanently raising the dam gates during the nonirrigation season. This allows free passage of juvenile salmon and Sacramento squawfish in near natural river conditions where the native predator-prey relationship has sustained itself for thousands of years. This is a known technology with easily understood benefits.

Predicted benefits: Upper Sacramento River salmon populations declined an estimated 114,000 fish (57,000 fall-run, 17,000 late fall-run, and 40,000 winter-run chinook) between 1969 and 1982 because of passage problems at RBDD (Hallock 1987). These losses have reduced the sport and commercial fisheries by about 228,000 salmon a year. Raising the dam gates for 8 months per year benefits all adult and juvenile chinook salmon runs and steelhead because negligible mortality is incurred at the dam. Supplemental pumping that occurs during the gates-raised period can have an impact on salmon located along the bank unless managed properly. Allowing spring-run and fall-run salmon to spawn by not inundating the spawning bed should remove a mitigation obligation for the Red Bluff project specific to the Tehama-Colusa Fish Facility.

Action 7: Complete the process to find final solutions to passage problems at RBDD and improve passage conditions beyond opening the dam gates longer than 8 months.

Objective: Correct problems at RBDD.

Location: RBDD, RM 243, Red Bluff, California.

Narrative description: This action calls for finding solutions to passage problems that will benefit the fishery resource beyond opening the gates 8 months per year. During the 8 months of the year the gates are open, there are no fishery problems associated with the RBDD. The following is a recommendation summary, based on current literature findings, for actions needed to monitor and evaluate existing fish protection facilities and to provide additional data required to make defensible decisions regarding solutions to passage problems at RBDD:

- USBR should continue to monitor entrainment past the rotary drum screens to evaluate long-term screening effectiveness.

- USBR should continue to inspect the screens *in situ* (SCUBA) to evaluate the durability of the seals and accumulation of silt in front of screens.

- USBR should measure screening efficiency by exposing a known number of fish to the screens and then measuring the number bypassed to the river or entrained in the canal.

- USBR should make inspections of the screens during high flows with the release of a known number of juvenile salmonids into the forebay to determine the likelihood of impingement.

- USBR should evaluate predation on juvenile salmonids in the forebay and at the bypass of the rotary drum screens.

- USBR should evaluate trash deflectors in front of Tehama-Colusa Canal headworks to determine fish deflector qualities.

- USBR needs to develop the ability to make real-time observations of screen seating during screen replacement.

- USBR should evaluate the effectiveness of screens on the centrifugal pumps located in the right bank fishway.

- USBR should evaluate piscine predation in Red Bluff Reservoir.

- USBR should continue to turn off RBDD high-intensity lights to reduce predation.

- USBR should evaluate bird predation at RBDD.

- USBR should develop, with the cooperation of USFWS, NMFS, and DFG, standard operating procedures for monitoring, maintenance, and operation of fish protection facilities.

- USBR should continue to use gate 6 fish ladder as an interim measure until final resolution of RBDD's fish passage problem.

- USBR should evaluate entrance modification to the west fish ladder entrance to optimize hydraulics.

- USBR should develop delay versus percent fish ladder discharge models by run. Include any new data in model development.

- USBR should explore feasibility of an experiment to increase supplemental flows in the fish ladders and, if feasible, conduct this experiment.

- USBR should evaluate mortality of juvenile salmonids through the fishway civil works.

- USBR and the fisheries trustees should give proper consideration to the concerns of the community and their desire to keep Red Bluff Reservoir intact as long as a viable fishery can be assured.

- # USBR should develop delay versus percent fish ladder discharge models for upstream migrating steelhead.

- # USBR and the fisheries trustees should give proper consideration to the temporary remedy of the gates-out modification from September 1 to May 30, along with modification to fish ladders to improve adult passage.

Discussion: Fish passage studies have been conducted at RBDD since the early 1980s (Hallock 1981; Hallock et al. 1982; Vondracek and Moyle 1982, 1983; Vogel and Smith 1984, 1985; Vogel et al. 1988; USFWS 1987, 1989, 1990). These studies identified numerous problems associated with fish passage at RBDD. Raising the dam gates is a completely effective remedy that solves all fishery problems relating to the dam for all species of anadromous fish at all life stages. The fish entrainment problem associated with diverting water at RBDD through the ineffective louver and bypass system was essentially solved by installing a state-of-the-art rotary drum fish screen in 1990. This screen system has, so far, proven to reduce canal entrainment and mortality of downstream migrating juveniles to near zero when water is being diverted and the system is properly operated and maintained (Johnson 1991, 1993; Big Eagle et al. 1993; Johnson and Croci 1994). Though remarkable progress has been made, additional studies are required to satisfy decision makers as to the permanent approach for alleviating passage problems. With anadromous salmonid runs in serious decline, the studies must be started as quickly as possible to minimize their population recovery times and lost use of these valuable resources.

The Red Bluff Fish Passage Program was undertaken to solve identified causes of declines in anadromous fish populations attributed to RBDD. This was a 5-year study initiated in October 1983 to develop methods to improve upstream and downstream anadromous fish passage at RBDD. The program is a coordinated effort between USBR, USFWS, NMFS, and Department. USBR is the lead agency for the program and the other agencies are participants. The purpose was to identify specific problems and implement corrective measures. A final report was produced for downstream migrant and adult upstream passage (Vogel et al. 1988). The results of this report form the major basis for the recommendations under this action.

Predicted benefits: Upper Sacramento River salmon populations declined an estimated 114,000 fish (57,000 fall-run, 17,000 late fall-run, and 40,000 winter-run chinook) between 1969 and 1982 because of passage problems at RBDD (Hallock 1987). These losses have reduced the sport and commercial fisheries by about 228,000 salmon a year. During the 8 months of the year the gates are open, there are no fishery problems associated with the RBDD. Raising the dam gates is a completely effective remedy that solves all fishery problems relating to the dam for all species of anadromous fish and all life stages. However, current gates-up operation is a transient fix and final resolution of passage problems at RBDD that will fulfill water needs for domestic, agriculture, and wildlife are pending. The process must be expedited and brought smoothly to closure so that benefits can be realized by still-viable fish populations. As new questions arise, USBR and fisheries trustees must collaborate with the interested publics to answer their questions and concerns. Acting in good faith to share information and concerns will facilitate understanding and hasten the realization of restoration goals.

Action 8: Implement structural and operational modifications to eliminate stranding, toxic discharges, and passage problems for chinook salmon and steelhead and improve screens.

Objective: Correct problems at the ACID's diversion dam.
Location: Keswick Dam, RM 302, and the ACID's diversion dam, RM 299.

Narrative description: The ACID's diversion dam is a flashboard dam located on the upper Sacramento River near Redding, at RM 298.5. This was the first dam on the Sacramento River, completed in 1917. Approximately 175,000 af of water can be diverted annually to the ACID's main canal.

The dam is installed only during the irrigation season. Typical operations involve the installation of flashboards in the dam in early April and their removal in late October or early November. Installation, removal, and mid-season adjustment of the flashboards are coordinated with flow reductions in the Sacramento River provided by USBR at Keswick Dam.

High flows make it physically difficult to install and remove the flashboards in the dam using hand-powered methods that date to 1917. ACID has historically indicated that 5,000 cfs is the maximum flow at which personnel can safely remove or install the dam flashboards. On several occasion, however, the flashboards have been removed or installed at flows above 5,000 cfs.

Past flow reductions to accommodate mid-season adjustments can cut the river flow in half. Reductions have occurred in a matter of hours, dewatering redds and producing large losses of juvenile salmonids through stranding and predation in isolated pools. The flow reductions for the ACID have not been consistent with the water right permit conditions for operation of Shasta Dam.

Operational modifications have successfully avoided the need to adjust the dam last year at flows between 4,000 and 14,000 cfs. Adjustment of the dam for flows less than 4,000 cfs can be accomplished without changing the Keswick Dam release.

The canal system needs several standard operating procedures to prevent documented problems. These include limiting waste gate flows to levels that do not attract salmon and steelhead from the river and containing canal waters when toxic herbicides are present to prevent fish kills. The canal intakes at Bonnyview Pumps and the main dam require maintenance and routine inspection.

Further empirical work is needed before any operational remedy is shown to be effective under all types of water years and water delivery demands. Once the ACID has determined the level of remediation it can provide through operational changes, structural measures can be designed to achieve complete remediation.

The following actions are proposed or have been enacted to reduce impacts of the ACID's dam on the aquatic environment.

- Modify the dam so it is unnecessary to reduce Keswick Reservoir releases to accommodate flashboard adjustment. Once modifications are shown to be successful, an agreement can be reached clarifying the water rights settlement contract between USBR and the ACID.

- If changes in structure and operations produce only a transitory remedy for river flows less than 14,000 cfs, other more costly alternatives need to be evaluated, including installing large automatic drum gates on the dam, installing a large Archimedes screw pump station, or supplementing canal flows with water pumped from other sources.

- Modify catwalks at the ACID's dam to include a new and safer work platform on the dam.

- Modernize the removal method for the topmost flashboard.

- Investigate solutions to excessive releases from the canal to waste gates that attract adults into the wasteways where they are stranded when the gates are shut off.

- Modify fish screen at the headworks of the district's canal to improve structural strength.

- Reduce or eliminate toxic discharges to the river and tributaries after application of herbicides.

- Reduce or eliminate stranding of adult chinook and steelhead attributable to cross connections of the canal with tributaries.

- Improve fish ladders at the dam to allow adult fish passage.

Discussion:

Stranding - A safe catwalk and easier flashboard removal is required to allow flashboard extraction and replacement without changing Keswick Dam releases. The current catwalk is a safety hazard because of its slippery surface; footing could be improved by covering the surface with nonskid material. Flashboards are currently removed by stabbing them with a pike-pole and prying them loose, an inefficient procedure made more so by high flows. The uppermost flashboards could be modified to make their removal easier at high flows by pegs attached to the upstream face. Additionally, if the ACID's operations can be accommodated with fewer flashboards in place, creating a lower head, the dam would not be as sensitive to higher river flows.

Cross connection of the canal with tributary streams during the nonirrigation season allows adult fish to enter the canal when it carries storm water. Physical improvements will be necessary to eliminate this cause of stranding.

Toxic discharges - Improper application of herbicides to the canal waters results in toxic chemical concentrations in river tributaries. Procedures have been initiated to contain toxic chemicals in the canal.

Fish screens - The canal screen has limited structural strength that need reinforcement. When it becomes clogged with aquatic vegetation or when there are rapid changes in flows, there is a danger of failure. To avoid catastrophic failure of the screen, trip panels are present that break away before the structure fails, leaving the diversion temporarily unscreened.

Adult passage - The ACID's dam was a complete barrier to the upstream migration of salmon until a ladder was installed in 1927. Since completion of Shasta and Keswick dams in 1942 cut off all but 3.5 miles of the Sacramento River upriver of the ACID's dam, the need for fish passage has been to provide access to spawning habitat between the dams and allow passage to a fish trap at Keswick Dam that serves as a collection facility for Coleman National Fish Hatchery.

There are no passage problems for most adult fall- and late fall-run chinook salmon and most steelhead trout because dam flashboards are removed during the nonirrigation season when these fish are migrating. There are no known juvenile salmonid passage problems associated with the dam. The seasonal presence of the small dam has not created any congregations of predators or good predator ambush habitat similar to larger dams.

During the 6 months of the year the dam is present, it is a partial barrier to adult anadromous fish, including winter-run chinook. There are small fish ladders located on each bank of the river that are ineffective because they carry only 1-4% of river flow. Construction of modern effective ladders is possible.

At this time, progress on the needed fishery remedies is proceeding on a cooperative basis. The ACID is developing the necessary information to better operate and improve the facilities necessary to exercise its water right while minimizing impacts on the aquatic environment, consistent with settlement agreements resulting from previous litigation.

Predicted benefits: This project will avoid the unnecessary destruction of valuable salmon and steelhead in the Sacramento River. This includes avoiding loss of winter-run chinook salmon, a species that is listed as endangered by both the federal and state Endangered Species Acts.

Action 9: Construct escape channel from stilling basin to the Sacramento River at Keswick Dam.

Objective: Avoid entrapment of adults at Keswick Dam stilling basin.

Location: Keswick Dam, RM 302.

Narrative description: Keswick Dam is located at RM 302 on the Sacramento River approximately 9 miles downstream from Shasta Dam. The dam has no fish ladders and completely blocks further upstream passage of migrating adult salmon and steelhead.

Keswick Dam was designed as a flow control structure for the Sacramento River to stabilize uneven water releases from Shasta Dam. Its construction, with a spillway, fishtrap, and power plant (75,000-kilowatt capacity), began in 1941 and was completed in 1951. It is a concrete gravity structure 157 feet high with a crest length of 1,046 feet creating a 23,800-af reservoir.

Aside from receiving Sacramento River water released from Shasta Dam, the reservoir created by Keswick Dam also receives interbasin flows from the Trinity River. Water from the Trinity River Basin is diverted via the Clear Creek Tunnel through the Judge Francis Carr Powerhouse into Whiskeytown Reservoir. From here, Trinity River water can be diverted into Keswick Reservoir via the Spring Creek power conduit to the Spring Creek Power Plant.

The spillway located on the east side of Keswick Dam is used for flood releases and during power plant outages. During normal power plant operations, there is no flow through the spillway and the stilling basin below the spillway is elevated above the tailwater river channel by the spillway end sill and a rock bench. During normal power plant operation, the tailwater is lower in the river channel than the spillway end sill, isolating the stilling basin from the river channel.

During a spill, the spillway end sill and rock bench become inundated, connecting the stilling basin to the main river channel. In past decades, the spills attracted migratory fish into the stilling basin where they became trapped when the spills ended. Documentation of this phenomenon dates back to 1972. More recent occurrences include December 1990, February 1992, and September 1994. Although fyke weirs in the shared stilling basin wall are intended to allow free passage of stranded fish into the fish ladder, testing conducted in December of 1993 demonstrated that fish were also attracted into the stilling basin through these fyke weirs.

The incidental take statement in the BO (NMFS 1993) addressing the effects of the CVP on winter-run chinook salmon requires USBR to structurally modify the stilling basin at Keswick Dam to allow free passage of adult salmonids back to the Sacramento River. The proposed solution to this problem, agreed to by the NMFS, DFG, USFWS, and USBR, involves excavating a channel from the spillway stilling basin through the spillway end sill and rock bench. This modification eliminates fish entrapment in the stilling basin. The agencies also agreed USBR should develop an interim fish salvage plan to immediately remove trapped fish from the basin following spills until the escape channel is constructed.

Predicted benefits: Adult salmonids would have access back to the main river and would not be lost to the spawning population resulting from poor water quality within the basin or losses associated with handling during rescue attempts.

Action 10: Implement structural and operational modifications to eliminate entrainment at water diversions.

Objective: Increase survival of outmigrating anadromous salmonid stocks by correcting unscreened or inadequately screened water diversions.

Location: Numerous irrigation diversions on the Sacramento River from Redding to its confluence of the Feather River.

Narrative description: Numerous unscreened water diversions from the Sacramento River and Delta adversely affect outmigrating juvenile salmonids, including the endangered winter-run chinook salmon. An estimated 10 million juvenile salmonids are lost to unscreened diversions annually (The Resources Agency 1989). There are more than 300 separate irrigation, industrial, and municipal diversions along the Sacramento River between Redding and its confluence with the Feather River, diverting nearly 1.2 maf of water annually from April through October (The Resources Agency 1989). There are an additional 1,800 smaller diversions in the Sacramento-San Joaquin Delta, diverting approximately 1.6 maf annually (DWR unpublished report 1983).

Diversions cause losses of fish in three ways: 1) direct entrainment of fish into irrigation systems, 2) physical damage of fish through contact with poorly screened diversions or bypass structures (impingement), and 3) increased predation on juvenile salmon due to hydraulic conditions near the diversion. These types of losses can occur at inadequately designed or poorly installed screens as well as unscreened diversions.

The CVPIA authorizes USBR and USFWS to "assist the State of California in efforts to develop and implement measures to avoid losses of juvenile anadromous fish resulting from unscreened or inadequately screened diversions on the Sacramento and San Joaquin rivers, their tributaries, the Sacramento-San Joaquin Delta, and the Suisun Marsh". The CVPIA Unscreened Diversions Program (UDP) provides this assistance by administering funding and providing technical assistance for fish screen projects. The state's ongoing program and priorities have guided most of the site-selection processes. A UDP technical team composed of representatives from USFWS, USBR, DWR, NMFS, and DFG provides technical advice and ensures that the program meets the goals and intentions of the CVPIA.

Fish screen technologies have been proposed that use sound or electricity to guide fish away from pumps. Although these alternatives have not been fully developed or tested, they have not provided necessary levels of fish guidance. Alternative technology for fish screen projects will be funded under an Experimental

Unscreened Diversion Research Program funded in fiscal year 1995 by USBR's Miscellaneous Project Program Construction Appropriations.

The UDP includes an accelerated program designed to immediately fund screening projects during the development of a long-term fish screen program. The accelerated screening program moved ahead in fiscal year 1994 to spend $600,000 from the restoration fund on three fish screen projects and program administration.

Predicted benefits: These fish screen programs have a high probability of reducing the 10 million juvenile salmon lost annually to unscreened diversions. These programs will probably have similar benefits for other anadromous species.

Action 11: Implement structural and operational modifications to eliminate impingement and entrainment of juvenile salmon at the GCID's water diversions.

Objective: Correct problems at the GCID's water diversions.

Location: GCID diversion, RM 206, Sacramento River, near Hamilton City, California.

Narrative description: This action calls for implementation of the on-going program to modify fish screens and bypass channel to mitigate fully for the fishery impacts associated with operations of the GCID's Hamilton City Pumping Plant. On August 19, 1990, a three-party agreement between the DWR Reclamation Board, GCID, and DFG was signed to fund environmental documentation and supporting preliminary engineering for gradient restoration and fish screen replacement. A contract was signed with HDR Engineering to complete the environmental documentation and engineering analysis, with a preliminary draft of the engineering Feasibility Report completed during 1994. In addition, a draft environmental impact statement (EIS) and environmental impact report (EIR) are currently under review with final completion scheduled for early 1995. Six alternatives, in addition to a no-action alternative, are considered feasible. The recommended environmentally superior alternative, in the draft EIS/EIR, is the construction of a multiple "V" screen near the mouth of the oxbow with a pumped bypass to return fish to the river (Alternative B). The basis for selecting Alternative B was the project purpose of fish protection and the overriding importance of fish protection when considered in combination with other environmental impacts. The report concluded that Alternative B "would most likely offer the greatest protection to endangered winter-run chinook salmon and other fish species that use the Sacramento River near the GCID's Hamilton City Pumping Plant".

The draft EIR/EIS concludes that prior to construction of the preferred alternative, an alternative that may or may not be the "environmentally superior alternative", future lead and responsible agencies must weigh environmental considerations against other factors such as construction costs, socioeconomic costs, legal considerations, technical modifications and feasibility, and political considerations. It also concludes that several areas of controversy exist that would bear on selection of the ultimate preferred alternative. The following are recommended actions needed to resolve those controversies:

- USBR should determine the degree of predation as a cause of mortality in the intake channel and the relative impact of predation on downstream migrants, compared to other sources of mortality, such as impingement, entrainment, and sedimentation.

- DFG should evaluate the importance of strict adherence (versus slight deviations) to existing fish screening velocity criteria as a means of protecting fish.

- USBR should determine the number of juvenile fish actually entering the GCID's intake channel under a range of flow conditions.

- USBR should determine the frequency and severity of predation at slow-flow holding areas near the existing fish screens and in the existing bypass channel.

- USBR should determine whether predation in the GCID's oxbow exceeds natural predation rates in other parts of the Sacramento River.

- USBR should determine whether the Sacramento River has the eventual capability to meander in such a manner as to leave the GCID's oxbow stranded.

- USBR should determine the degree to which sedimentation would occur and extend upstream of any new fish screens built.

- USBR should determine the degree to which sedimentation would occur and extend upstream of a Gradient Restoration Facility (GRF).

- USBR should determine the probability of success that can be expected from bypassing fish through pumps.

- USBR should determine the amount of time that should be devoted to future study before committing to a long-term solution.

The draft EIR/EIS also concludes that prior to construction of the Preferred Alternative "some studies can be conducted that would provide additional, valuable information" including the following:

- USBR should develop two-dimensional mathematical models and physical models of the GRF in combination with new fish screens. The models should be designed to accurately depict existing and post-project instream conditions, including approach and sweeping velocities at the screens, water depths and velocities throughout the entire affected reach of the river, and areas of turbulence. Modeling should be accomplished over a reasonable range of flow conditions expected after construction.

- USBR should determine the swimming abilities of all fish species and important live stages occurring in the project area when such information is lacking. It is imperative that the screens and either pumps or GRF be designed to protect the most sensitive of the species in the area.

- USBR should correlate post-project water surface elevations with elevations of various habitats in the area. This must be accomplished so that hydrologic impacts on vegetation communities can be more accurately determined.

- USBR should determine whether the GRF, if selected, could cause a change in river course resulting in flow to another channel.

- USBR should evaluate screw pumps at the RBDD and at GCID, if selected, to determine their feasibility at screened diversions.

Discussion: Fishery impacts at the GCID site were identified in the 1920s by researchers from the then California Division of Fish and Game. Court action required GCID to install fish screens in 1935, which were almost immediately rendered ineffective by undermining from flood events. No subsequent attempts were made to alleviate the problem until DFG built the existing screen structure in 1972 with funding from the Anadromous Fish Conservation Act of 1965.

The screen facility built in 1972 consists of 40 rotary drums, 17 feet in diameter and approximately 8 feet wide. The drums, housed in a 450-foot-long concrete headworks, are located midway down the oxbow, immediately in front of GCID's pumping facility. Within the headworks are 10 fish bypass orifices that converge in a 60-inch pipe that empties into the lower oxbow. The bypass was designed to transport fish around a seasonal earthen dam installed by GCID to decrease pumping lift. The original contract signed by GCID and DFG required that 90 cfs be allowed to go through the bypass to facilitate fish passage.

Studies conducted by DFG during the mid-1970s revealed that the screening structure was not operating effectively and suggested that large losses of juvenile salmon were continuing to occur at the site. Specific deficiencies identified included ineffective bypasses, screen leakage, high screen face velocities, and high potential for predation. Several modifications were made to rectify the situation, including screen seals on the rotary drums and placement of culverts through the seasonal dam. Even with the modifications, however, fish losses were still high.

Beginning in 1970, river gradient changes began to adversely affect flows and water surface elevations at the fish screens. Gradual lowering of the river surface profile occurred from 1971 until 1983 when high waters caused significant changes. During this period, scouring of the main river channel resulted in an average surface elevation that was 3-3.5 feet lower than that existing before 1971. The result was to lower the water surface elevation at the face of the fish screens and increase the through-screen velocity. In addition, gradient profile changes resulted in bypass flows ceasing and often flowing in reverse direction. The inability to provide positive bypass flows of 90 cfs placed GCID in direct violation of its contractual obligations with DFG.

Discussions between GCID and DFG were begun in the early 1980s to investigate potential remedies to the lack of bypass flows. Deteriorating hydraulic conditions finally resulted in DFG installing a fyke trap in place of one of the rotary screens. The trap was first operated in spring 1985 as a salvage facility with minimal effectiveness. During 1986, GCID widened and deepened its intake channel, which served to restore bypass flows. Continued high screen velocities, coupled with screen deficiencies identified by the DFG studies in the mid-1970s, resulted in continued discussion between GCID and DFG about fishery impacts. GCID's application for renewal of its dredge permit in 1986 resulted in a number of conditions being imposed by the U.S. Army Corps of Engineers (Corps), among which was implementation of a study to define a state-of-the-art solution to the fishery problems. Paralleling the requirements of the Corps permit was a memorandum of understanding (MOU) between GCID and DFG to conduct studies to define solutions to fish passage and water supply problems at the diversion site.

The result of the joint GCID/DFG study was a feasibility report published in 1989 that recommended building an entirely new screening structure at the head of the existing intake channel. The recommendation was based on extensive review of alternative solutions that would provide protection to fishery resources while allowing water deliveries by GCID.

During 1989, winter-run chinook salmon were listed under the California and federal Endangered Species Acts as endangered and threatened, respectively. Federal status was upgraded to endangered in 1994. Historical record had demonstrated that fry and juvenile winter-run salmon were exposed at the GCID pumping site as early as mid-July, with a peak fry exposure during late August to early September. During 1991, the NMFS brought suit against GCID to prevent it from causing further losses of winter-run salmon. The BO issued by NMFS indicated that operation of the GCID facility was likely to jeopardize the continued existence of winter-run salmon. The lawsuit resulted in a federal court injunction preventing the GCID from pumping during periods of peak downstream migration of winter-run salmon. As the result of the injunction, a joint stipulation between GCID, DFG, and NMFS provided conditions under which GCID could continue to pump. The joint stipulation initially required that GCID submit a completed and adequate application for an incidental take permit pursuant to Section 10 of the federal Endangered Species Act. Subsequent submittals were deemed inadequate by NMFS on February 4, 1993. With passage of the CVPIA (P.L. 102-575), USBR has been given responsibility for screening at GCID. The original joint stipulations were amended in 1993 to reflect the new status of USBR. GCID was required to fulfill certain conditions under the direction of NMFS. GCID was required to ensure the full funding of environmental analysis, selection, design, and construction of acceptable measures to provide long-term protection to winter-run salmon. During the interim period, GCID was required to reduce pumping during the critical period of August 1 through November 30 to meet screen velocity criteria of 0.33 foot per second (fps) required by DFG. In addition, among other conditions, minimum bypass flows were required to provide adequate passage for juveniles back to the river.

Various fishery studies were conducted by consultants hired by GCID during 1990-1993. The results failed to clearly identify solutions to rectify the problem. However, during 1993 GCID modified the portion of the oxbow channel in front and downstream of the fish screens to provide positive flows and reduce predator habitat. During 1993-1994, GCID refitted, as a stated "interim solution", the existing screen structure with new fixed plate screens meeting the screen opening criteria required by DFG/NMFS. These modifications are currently undergoing evaluation.

Predicted benefits: Fish losses at GCID are potentially very large. At times, the GCID diverts up to 20% of the total Sacramento River flow at RM 206 (Hallock 1987). If we assume that juvenile salmonids are distributed proportionally to flow, then up to 20% of the juvenile salmonids passing RM 206 could come in contact with the fish protection facilities at GCID. Correcting problems associated with the fish protection facilities at GCID can improve the probability of survival of those juvenile salmonids that contact it.

Action 12: EPA will complete Superfund cleanup of Iron Mountain Mine by 1996.

Objective: Remedy water quality problems associated with Iron Mountain Mine and other toxic discharges.

Location: Iron Mountain Mine, Spring Creek Drainage

Narrative description: Fish will be protected from chronic and acute toxicity caused by the discharge of heavy metals in acid mine drainage. The discharge can and has produced major kills of salmon and steelhead, as well as sublethal exposures that cause injury to anadromous fish by reducing growth and interfering with migratory behavior (EPA 1992a, Sorensen 1991). Completion of studies and subsequent implementation of EPA remedies for the Iron Mountain Mine Superfund site are needed to attain the safe metal concentrations identified in the CVRWQCB's Basin Plan. Pollution control remedies are required at the Iron Mountain Mine portal discharges from remaining sulfide ore deposits inside the mountain, the discharges from tailing piles, other sources, and the metal sludge in Keswick Reservoir. Attaining the objectives requires close coordination with the state and federal agencies, fishery trustees, legal council, consultants, and the responsible party.

We endorse the ongoing process to remedy problems associated with mine drainage entering the Sacramento River. Specifically, the main objectives of EPA and the fishery trustees in the Iron Mountain Mine clean up include:

- Eliminate the water demand that the dilution of the toxic discharge places on the Shasta-Trinity Project of the CVP. The water demand can be several hundred thousand af of storage that is needed for all the other beneficial uses of the project, including fish and wildlife conservation and temperature control.

- Attain the water quality objectives for toxic metals and contaminated sediments in the basin plan to protect the fishery resources of the Sacramento River from acute and chronic toxicity.

Until the site is fully remediated, there are a series of interim operations needed to achieve proper dilution of Iron Mountain Mine effluents:

- USBR will operate the CVP according to the 1980 MOU signed by USBR, DFG, and SWRCB. Under the provisions of the Spring Creek MOU, USBR agrees to operate according to criteria and schedules to minimize the probability of an uncontrolled spill and catastrophic fish loss, provided that such operation will not cause flood control parameters on the Sacramento River to be exceeded or interfere unreasonably with other CVP requirements as determined by USBR. The water quality criteria established in the MOU exceeds the metal concentration levels specified by the basin plan and causes chronic toxicity because operating to such standards would increase the frequency of acute toxicity that could affect a large portion of the salmon and steelhead populations.

- Operate by the stipulations in the BO (NMFS 1993).

Discussion: Site Location (EPA 1992b) - The Iron Mountain Mine site includes approximately 4,400 acres of land that includes the mining property situated around the 3,000-foot-high mountain. The site consists of several inactive underground and open pit mines, numerous waste piles, abandoned mining facilities, and mine drainage treatment facilities. The drainage from inactive mines on Iron Mountain Mine represents the largest pollutant discharge to the Sacramento River. This discharge is at least equal to all the combined industrial and municipal discharges to the San Francisco Bay and Estuary System (EPA 1992b). The toxic discharge is created by the mine characteristics, together with the natural occurrence of nearly pure sulfide deposits, producing a unique chemical reaction that is nearly optimal for the production of acid mine waters. This mine water contains extremely elevated concentrations of copper, zinc, cadmium, and other metals known to be toxic to fish and wildlife. On occasion, fish kills (including salmon) have been documented in the upper Sacramento River due to Iron Mountain Mine wastes. More frequently, there are documented instances of metal concentrations that exceed chronic toxic levels considered "safe" to early life stages of salmon.

The wastes from Iron Mountain Mine are collected in the Spring Creek Reservoir, then metered out into the releases of clean water from Shasta and Whiskeytown Reservoirs to achieve the best water quality possible. However, due to the extremely large waste load (averaging over 1 ton of copper and zinc per day), it is not possible to attain water quality objectives for heavy metals and a less protective target has been established. In the past and occasionally during intense, winter storms, the dam spills introduces toxins into the river at uncontrolled rates that sometimes result in fish kills. These highly toxic conditions are exacerbated when flows from Shasta and Whiskeytown Reservoirs are not available for dilution due to other CVP constraints.

Operating the Sacramento County Diversion Dam (SCDD) during major flood events is complicated because releases from Keswick Dam may be reduced to meet downstream flood control objectives while Spring Creek is spilling. Water released for diluting spills may be in excess of any other CVP requirements, representing a loss of beneficial use of the water for other purposes.

Predicted benefits: Source control and water management actions will significantly reduce copper and zinc in the Sacramento River below Keswick Dam. Such reduction would result in metal concentrations that consistently meet water quality objectives and that have been determined to be safe for fisheries. The control actions are being designed to protect fisheries from chronic and acute toxicity during all but a one in 100-year flow. Successful completion of the superfund program will (1) protect all fish from acute and chronic toxicity, including physiologic problems and slow growth; (2) protect salmonid reproduction between Keswick Dam and Cottonwood Creek from toxicity; (3) restore salmon and steelhead production to compensate for losses caused by the discharge; and (4) make available the water supply in the Shasta-Trinity unit of the CVP for all the beneficial uses.

Action 13: Avoid potential competitive displacement of wild, naturally produced juveniles with hatchery-released juveniles by stabilizing hatchery production levels and implementing release strategies designed to minimize detrimental interactions.

Objective: Evaluate competitive displacement between hatchery and natural stocks.

Location: Coleman National Fish Hatchery, Feather River State Fish Hatchery, and Nimbus State Fish Hatchery.

Narrative description: There is a potential for competition to occur between hatchery-released and wild/natural juveniles in the Sacramento River. Biological interactions of hatchery-released fish with wild fish may include direct competition for food and space during the freshwater rearing phase (Steward and Bjornn 1990). The extent of competition is, however, dependent on the degree of spatial and temporal overlap and the basic concept of supply and demand (Steward and Bjornn 1990).

The precise level of competitive interactions between hatchery-produced and wild/ naturally produced juveniles in the Sacramento River is unknown due to the absence of detailed studies. However, when comparing current population levels to apparent historical carrying capacities, the degree of competition as they rear and migrate through the 200-mile reach of river is assumed to be minimal (USFWS 1993).

Management practices exist that will avoid the risk of excessive competitive interaction both now and in the future. The practices can be implemented now and include: 1) stabilizing the total amount of hatchery production basinwide at established production goals and 2) releasing hatchery fish in a manner that avoids competitive displacement of wild/natural fish to the greatest extent possible.

Production goals should be quantified for all hatcheries in the basin and held or "capped" at current established levels. An allowable overage (e.g., 15%) can be built into these caps to accommodate fluctuations in spawning population numbers. Capping of production in this manner at USFWS's Coleman National Fish Hatchery has been implemented to avoid potential competitive impacts on endangered winter-run chinook salmon (NMFS 1994). As river carrying capacity and hatchery-wild interactions become more fully understood, production goals will be modified to benefit survival of both hatchery-produced and wild/naturally produced fish.

All current release strategies throughout the Sacramento River should be evaluated at a greater level of detail to identify the potential occurrence of competitive displacement of wild/natural juveniles with hatchery-released juveniles. USFWS's 1993 *Biological Assessment on the Effects of Coleman National Fish Hatchery Operations on Winter-Run Chinook Salmon* cites Steward and Bjornn (1990) and McMichael et al. (1992) in recognizing that hatchery-produced salmonids could lower production of wild/natural salmonids through competition if 1) the carrying capacity of the river is exceeded, 2) hatchery fish are larger than wild fish, 3) hatchery fish are in place before wild fish emerge, 4) large numbers of hatchery fish are released, or 5) released fish fail to disperse.

Carrying capacity is not believed to be a factor due to the 200-mile length of rearing area and the fact that this reach historically supported at least two to four times the current number of salmon and steelhead. An assessment of current release strategies should focus on competitive interaction questions, including:

a) Are hatchery fish larger than their wild/natural counter-parts at time of release?

b) Are hatchery fish allowed to take up residency prior to the emergence of wild/natural fish?

c) Are large numbers of hatchery pre-smolts released in a short time-frame?

d) Do hatchery fish fail to disperse after release?

Releases from all hatcheries within the basin should be evaluated in terms of these questions. Release strategies should be implemented to avoid identified competitive interactions. Established monitoring programs for wild/natural juveniles should be continued to evaluate potential competitive interactions due to size or timing of releases (questions a and b). Additional in-river monitoring will be needed if there is evidence that the number of hatchery fish or a failure to disperse produces undesirable levels of competition with wild/natural fish (questions c and d). Monitoring program objectives include relative abundance estimates of natural/wild juveniles near hatchery release sites, pre- and post-release, and average weights or preferably length-weight relationships (i.e., condition factors) of natural/wild juveniles near hatchery release sites, pre- and post-release. Relative abundance estimates of wild/natural juveniles pre- and post-release may assist in determining the extent to which hatchery released juveniles displace wild/natural juveniles, while estimates of condition factors may give insight into levels of competition for available food supplies.

Although carrying capacities are currently not presumed to be limiting, they will be considered in establishing long-term release strategies. Also, release strategies involving pre-smolts and fry should always consider the estimated densities of wild/natural fish and attempt to utilize underseeded habitats (Hard et al. 1992).

Predicted benefits: The precise nature of competitive displacement of wild/naturally produced juveniles by hatchery-produced juveniles is currently not defined. However, the current low population levels of wild/natural fish lead us to believe existing impacts of competitive displacement are minimal. Implementation of the above-stated recommendations may further reduce the potential for any negative impacts and therefore may result in higher survivability of wild/naturally produced juveniles and smolts.

Action 14: Implement specific hatchery spawning protocols and genetic evaluation programs to maintain genetic diversity in hatchery and wild stocks.

Objective: Maintain genetic diversity in hatchery stocks.

Location: Coleman National Fish Hatchery, Feather River State Fish Hatchery, and Nimbus State Fish Hatchery.

Narrative description: Steward and Bjornn (1990) and Hard et al. (1992) provide in-depth discussions of the potential genetic impacts or risks hatchery programs may pose on wild populations. These genetic risks include 1) extinction, 2) loss of within-population genetic variability, 3) loss of between-population genetic variability, and 4) genetic differences between hatchery and wild stocks resulting from differential selection pressures in the hatchery environment.

Implementing specific spawning guidelines and maximizing the survival of the resultant progeny will limit founder effects, genetic drift, and inbreeding in the hatchery population.

It is extremely important, however, that genetic variance between the groups is initially low (Reisenbichler et al. 1992, Hindar et al. 1991) and survival of hatchery adults and resultant eggs and fry in the hatchery is maximized. If survival of eggs and progeny in the hatchery program is maximized, genotypes will not be lost due to low survival rates and maladaptive selection in the hatchery environment.

One of the main parameters used to assess the viability of a population is its effective population size (Bartley et al. 1992). Therefore, to minimize inbreeding and genetic drift, a mating scheme should be developed to maximize the effective population size for all fish collected as hatchery brood stock.

Genetic differences between hatchery and wild stocks can be held to a minimum by employing specific breeding guidelines to minimize allele-frequency differences between hatchery and wild fish (e.g., Meffe 1986, Reisenbichler et al. 1992, Hynes et al. 1981, Hindar et al. 1991, Simon 1991, Simon et al. 1986, Tave 1986, Bonneville Power Administration [BPA] 1994). Guidelines to maximize the effective population size, conserve genetic diversity, and minimize genetic differences between hatchery and wild stocks (as described by the above authors) should be implemented as follows:

- Use adults that are genetically similar to the corresponding wild/natural stocks.

- Incorporate large numbers of adults into the spawning program to more adequately represent all genomes present in the wild. Although a reduction in the genetic variability in hatchery stocks of Pacific salmon due to inbreeding is not well documented (Steward and Bjornn 1990), small population sizes in hatchery programs may lead to losses of within-population genetic variability through inbreeding depression and genetic drift (Waples 1991).

- Implement a "no selection" protocol. Consider <u>all</u> returning or collected fish as part of the population (i.e., avoid selection based on phenotypic characteristics or other criteria).

- Use jacks to ensure genes associated with all age classes are incorporated in the population at appropriate levels.

- Implement a 1:1 male-to-female spawning ratio (i.e., one time use of each adult, single pair spawning, unpooled gametes).

- To ensure full fertilization when the egg supply is severely limited or male gamete viability is known to be low, successively use two males for each egg lot (1 and 2; 2 and 3; 3 and 4, etc). This procedure utilizes the first of the pair (with mixing), followed by interval of 30 seconds, and then the immediate use of the second male.

- Use pairing schemes to avoid discarding of excess spawners on spawning days where one sex is more numerous than the other. This can be used on all populations, except those that are critically small.

- For critically small populations (i.e., winter-run chinook salmon) apply a splitting scheme. Divide eggs from each female into two lots and fertilize with gametes from two different males. Also, use each male twice, once with two separate females. This practice safeguards against the loss of genetic contribution from an individual producing viable gametes mated with an individual that produced nonviable gametes (USFWS 1993).

- Develop improved gamete cryopreservation techniques to permit later crossing of lines from different generations.

Additionally, programs should be developed to obtain baseline information on the genetic diversity of current hatchery and wild/natural stocks and evaluation programs should be developed to monitor changes in these diversity levels over time.

Predicted benefits: Implementation of specific spawning protocol will serve to minimize the potential genetic effects of hatchery programs on wild/natural stocks. Development of genetic evaluation programs will aid in assessing the success of the spawning strategies to maintain existing genetic diversity.

Action 15: Evaluate transfer of disease between hatchery and natural stocks.

Objective: Evaluate disease relations between hatchery and natural stocks.

Location: Coleman National Fish Hatchery, Feather River State Fish Hatchery, and Nimbus State Fish Hatchery.

Narrative description: Develop and implement strategies to minimize the risk of disease outbreaks in hatcheries, determine degree of prevalence of pathogens/disease in wild/natural stocks, and evaluate potential for disease transmission from hatchery fish or hatchery water supplies to wild/naturally produced fish.

The actual extent of horizontal transmission of diseases or parasites from hatchery-released salmonids to wild stocks is largely unknown. Although disease outbreaks and epizootics are fairly common in hatcheries, direct transfer of these diseases to wild fish has not been clearly demonstrated. Steward and Bjornn (1990) state there is little evidence of transmittance of diseases or parasites from hatchery to wild salmonids. Their literature review describes a number of studies suggesting diseases such as bacterial kidney disease (BKD) and infectious pancreatic necrosis (IPN) were not transmitted from infected hatchery fish to wild fish. However, they go on to state that research on this subject is limited and conclude the full impact of disease on supplemented stocks is probably underestimated.

Infectious disease is considered to be a normal component in the life history of hatchery-reared and wild/naturally produced salmonids in the Sacramento River due to their similar parental stock (free-ranging brood stock of mixed origin) and exposure to similar water supplies. Some incipient level of pathogens are natural and also probably essential for the development of proper immunological response to actual disease outbreaks (Hard et al. 1992). Unfortunately, hatchery-rearing conditions often render hatchery fish more susceptible to contracting and spreading disease and parasites in the confined, high-density rearing environment.

Most pathogens endemic to Sacramento River salmonids evolved with their salmonid hosts and are not recent introductions. Endemic pathogens that have caused significant health problems in Central Valley salmon hatcheries include infectious hematopoietic necrosis virus (IHNV), BKD, *Yersinia ruckeri, Flexibacter columnaris, Ceratomyxa shasta, Ichthyophthirius multifiliis,* and *Nanophyetus salmincola* (Cox 1993). Numerous other bacterial, parasitic, and fungal species have also been identified as being pathogenic to hatchery populations under appropriate conditions.

Exposing wild stocks to infected hatchery fish may result in mortality or disability or may have no effect. This ultimate result depends on several ecological parameters (e.g., proximity and exposure time) that influence the spread and pathology of diseases and the immune status of the fish. The reduced probability of contact between individuals outside the confines of the hatchery may reduce the potential for wild salmonids being infected by the hatchery fish (Steward and Bornn 1990).

Reducing the risk of disease outbreaks within a hatchery consequently can reduce potential transfer of disease to wild/natural stocks. To minimize the risk of disease outbreaks in hatcheries within the Sacramento River basin, management practices as modified from BPA (1992) should be implemented as follows:

- All phases of propagation, transfers, and distribution will follow recommendations similar to those of USFWS's Fish Health Policy (1995).

- All hatcheries relying on surface water where anadromous fish are in the headwaters above the hatchery should be equipped with state-of-the-art water sterilization systems (e.g., utilizing ozone, ultra-violet).

- Bird exclusion devices should be installed at all rearing facilities to avoid disease introduction and pond-to-pond transfer by predators.

- During hatchery operations, strict sanitation and disinfection procedures should be employed.

- Isolation, segregation, and quarantine practices should be employed when necessary.

Additionally, state and federal fish health centers and the National Biological Survey should devise programs to 1) ascertain the disease implications of hatchery effluent waters on wild/natural juveniles, 2) perform laboratory and *in situ* exposures of infected hatchery fish to uninfected wild/natural fish to gain an understanding of the kinetics of horizontal disease transmission, and 3) gather baseline information on the degree of prevalence of pathogens/disease in wild/naturally produced juvenile salmonid populations.

<u>Predicted benefits</u>: Implementing strict fish health policies and practices in Sacramento River basin hatcheries will reduce disease outbreaks within hatcheries and consequently reduce the potential for pathogen/disease transfer from hatchery-reared fish to wild/naturally produced fish.

Action 16: Create a 50,000-acre meander belt from Red Bluff to Chico Landing to provide gravel recruitment, large woody debris, moderate air temperatures, and nutrient input to the lotic system.

Objective: Restore and preserve riparian forests.

Location: Red Bluff at RM 242 to Chico Landing at RM 204.

Narrative description: Recreate an active meander belt and restore a continuous riparian corridor between Chico Landing and Red Bluff. The meander belt and corridor would encompass approximately 50,000 acres.

Protect and restore the Sacramento River riparian corridor and, by doing so, preserve important instream values. The riparian and associated meander zone affect the aquatic ecosystem by providing the majority of spawning gravel; creating a variety of preferred spawning areas (e.g., point bar riffles, chute cutoffs, multiple channel areas, and areas near islands); maintaining and improving the hydrologic diversity of the river channel; reestablishing and maintaining a diversity of substrates; supplying a continually renewable source of shaded riverine aquatic habitat, including large woody debris; and providing an important terrestrial food source.

The most feasible location for reestablishing a functional Sacramento River riparian ecosystem is in the reach between Chico Landing and Red Bluff. Along this stretch of the river, riparian vegetation influences erosion and deposition within the floodplain. In turn, these fluvial processes create the diversity of streamside vegetation and maintain its overall condition.

Riparian vegetation creates a buffer to decrease local flood velocities. This increases the deposition of suspended materials derived upstream from eroding banks. It is this erosion-deposition process that builds the middle terrace and eventually the high terrace lands that support high-terrace climax forest and agriculture. Overbank flooding is essential for the continued health of the riparian system. As silt and seeds are deposited during these overbank waterflow events, the native vegetation is rejuvenated.

The interplay between biological succession and hydrologic and geomorphic factors results in a mosaic of habitat types in the riparian zone. These types follow a chronological and topographic continuum from a bare sandbar, to young forests of cottonwoods and willows, to mature forests of older cottonwoods and other deciduous species, to a climax forest of valley oak. Mature riparian forests are typically 40-90 years old. A meander zone along the Sacramento River should include an unbroken band of the full continuum of these river-created habitats that are maintained by the river over time. By definition, young to mature forest exists where the river channel has been in the last 100 years. The movement of the river within this 100-year meander belt creates and maintains the rich mosaic of habitats. It is estimated that this 100-year zone encompasses approximately 13,000 acres between Chico Landing and Red Bluff.

The hydrologic regime is an integral part of the riparian corridor. A healthy and sustainable riparian corridor depends on both seasonal flow fluctuations and periodic flood events. Receding spring flows are required to ensure a moist alluvial substrate for the establishment of willows and cottonwoods at the edge of sandbars. During winter and early spring, higher flood flows are necessary both to ensure deposition on high terraces and to erode banks to provide sediment downstream. The overbank deposition of sediments is necessary to offset the bank erosion and maintain the equilibrium of erosion and deposition in the floodplain. Sustained releases from Shasta Reservoir at a level just below bankfull discharge (such as occurred in spring 1993) may cause considerable erosion of saturated banks; however, allowing the river to utilize the floodplain can reduce flow velocities and allow for sediment deposition.

Ongoing DWR studies indicate that while floodplain deposition in the Sacramento River riparian zone has decreased since the construction of Shasta Dam, the rate of bank erosion has decreased as well. This suggests the possibility of an overall balance between erosion and deposition.

Research needs associated with meander-belt establishment include:

- Ongoing erosion and deposition measurements, particularly during wet years (most available data have been collected in the dry years since 1986). Further data collection and analysis is necessary to adequately assess erosion and deposition rates along the Sacramento River.

- Modeling the dynamics of the geomorphic system and biological succession. Data on geology, erosion, sedimentation, hydrology, and channel morphology can be used in combination with vegetation studies to determine the proportion of plant communities that will be established over time in the riparian zone. This information will also be valuable in assessing the impact of different flow regimes on the dynamics of the riparian ecosystem.

Under Senate Bill (SB) 1086, a group of landowners, government agencies, and environmental interests have been developing plans for the institution of a meander zone along the Sacramento River. Their ongoing dialogue resulted in the blueprint for limited meander zone found in the *Upper Sacramento River Fisheries and Riparian Habitat Management Plan* (The Resources Agency 1989). Parallel with these efforts, The Nature Conservancy has purchased several tracts along the river, and USFWS includes the Sacramento River riparian corridor as part of the Sacramento River National Wildlife Refuge. Through the SB 1086 process, plans are currently being laid for the establishment of a legislated, locally based district to implement the establishment of a meander belt.

<u>Predicted benefits</u>: Creation of a 50,000-acre meander belt from Red Bluff to Chico Landing will restore natural processes to the river ecosystem, providing gravel replenishment for spawning habitat enhancement; large woody debris for fish cover; moderate air temperatures that should contribute to a lower, more stable river temperature regime; and nutrient and food input to the lotic system.

B. UPPER SACRAMENTO RIVER TRIBUTARIES

Clear Creek -

Limiting factors and potential solutions - Table 3-Xb-1 lists key limiting factors for salmon and steelhead in Clear Creek and potential solutions.

Instream flow - Clear Creek as a regulated stream system receives very little stream flow. Therefore, restoring habitat and achieving doubling of the salmon and steelhead populations in the stream will require higher flows. The increased flow regime must provide sufficient spawning, incubation, rearing habitats, and outmigration flows for salmon and steelhead, together with suitable temperatures and channel maintenance (prevention of riparian encroachment).

Water temperature - High water temperatures can be lethal to adult spring-run chinook and yearling steelhead that live in the creek during the dry season (U.S. Geological Survey [USGS] Water Quality Records, DWR 1986, USFWS 1991). Warmer temperature regimes favor development of warmwater fish populations (e.g., black bass and squawfish) that will prey on juvenile salmon and steelhead.

Whiskeytown Dam has several outlets that release water from different elevations and temperatures within the reservoir water column. Integrated management of water temperatures and flow rates of reservoir releases is necessary to attain the proper creek habitat requirements for spring-run chinook salmon and juvenile steelhead.

Gravel recruitment and extraction - Suitable spawning gravel is being reduced in Clear Creek as a result of blockage by Whiskeytown Dam and gravel mining in the lower stream sections below the dam. For the past decade, about 12% of the stream below Whiskeytown Dam was mined for gravel. Another 10% of the streambed is targeted for mining. The channel configuration in mined areas is braided and pitted. The braided sections are shallow and split the flow, causing adult passage problems. The excavation pits entrain and trap juvenile outmigrants when the water level goes up and down during spring storm periods that subject them to predation by bass and squawfish. During periods of high runoff, the excavation pits also trap new gravel, making it unavailable for fish spawning (DWR 1986, 1994).

Fish passage - McCormack-Saeltzer Dam, constructed in 1903 for gold mining and later agriculture, is located about 10 miles downstream from Whiskeytown Dam. Water (about 10 cfs) is diverted into the Townsend Flat water ditch under pre-1914 water rights and an additional water rights settlement contract with the USBR. The use of the water right has changed; most of the water right service area is subdivided for housing or mined for gravel, leaving little for agricultural or fishery use. Saeltzer Dam is a partial barrier to fish passage that is compounded by difficult passage areas in the bedrock stream channel immediately below the dam. Improving fish passage and implementing a recommended flow regime will open up spring-run chinook salmon and steelhead habitat and restore additional spawning capacity to the creek.

Land use - Approximately half the creek's watershed below the dam is composed of decomposed granite soils (DWR 1986). The steep slopes and erosive soils below Whiskeytown Dam add sedimentation problems to downstream spawning and rearing areas. These problems are exacerbated by reduced flushing flows and blocked gravel recruitment below Whiskeytown Dam.

Table 3-Xb-1. Key limiting factors for chinook salmon and steelhead in Clear Creek and potential solutions.

Limiting factors	Potential solutions
Instream flow	Implement integrated flow schedule providing for T° and riparian channel maintenance
Water temperature	Operate Whiskeytown Dam to provide temperature control
Gravel extraction	Restrict instream gravel mining and restore mined-out channel sections
Fish passage	Remove McCormick-Saeltzer Dam and find alternate water supply
Land use	Make land use practices compatible with salmon restoration by acquiring land in the watershed and implementing erosion control practices, a stream corridor protection plan, and other appropriate land use planning developed in a comprehensive resource management plan for the watershed
Whiskeytown Dam	Restore spawning gravel recruitment halted by the dam and stream channel sections disturbed by dam construction and compensate for the blockage and inundation of 12 miles of spawning habitat above the dam

Restoration actions -

Action 1: Implement an integrated instream flow schedule.

Objectives:

1. Provide adequate instream flows and channel maintenance flows for all life stages of salmon and steelhead.

2. Provide suitable temperatures for all life stages.

3. Provide channel maintenance flows.

Location: Whiskeytown Dam.

Narrative description: The recommended releases from Whiskeytown Dam to Clear Creek are 200 cfs from October to April and 150 cfs for the remainder of the year with variable spring-time releases depending on water year type. Annually, this flow regime represents an amount of water that is equaled or exceeded by the natural runoff of the creek at the dam site during 25-30% of the water years. During drought conditions, these recommended releases are reduced by 25%. These recommendations (DFG correspondence report 1993) are based on attainable temperature objectives and habitat requirements that were determined by an instream flow study (DWR 1986) and the Clear Creek hydrologic data at Whiskeytown Dam for 1923 to 1994 (USBR Central Valley Project Operations Hydrologic Data).

The recommended flows provide habitat and temperature requirements for fall-run and late fall-run chinook salmon and steelhead and, to a lesser extent, for spring-run salmon, which are presently extirpated from the stream. If the spring-run chinook salmon population becomes successfully reintroduced, it may require an even lower summer water temperature regime, necessitating increased flows. The releases are measured at Whiskeytown Dam to provide more precise temperature regulation and prevent harmful flow fluctuations.

A springtime flushing flow recommendation will be developed empirically to accomplish sediment removal, prevent riparian vegetation encroachment, maintain the proper channel configuration, distribute new spawning gravel, facilitate timely juvenile outmigration, and attract adult spring-run salmon and steelhead into the stream. The schedule and amount of flow would be determined by a series of experiments designed to intensify and augment a storm flow at strategic times. The flushing flow releases would not exceed the natural inflow into Whiskeytown Reservoir during the storm.

Implementing the recommended flows can be accomplished via a reoperation of the Keswick and Whiskeytown dams in a manner that does not affect the water supply of the Shasta-Trinity unit of the CVP. Because Clear Creek enters the Sacramento River a short distance below Keswick Dam, it can be used to convey a small portion of the large irrigation water supply needed in the river.

Clear Creek flows recommended during the wet season approximate the annual amount of natural runoff that is present or exceeded in 90% of the years of record (1923-1994 in USBR Central Valley Project

Operations Hydrologic Data). Drought years within the 10% of the driest years on record require flow reductions that approximate the natural runoff. During the dry season, the Clear Creek releases will be subtracted from the Keswick Dam releases, requiring no net change in release from storage, only a change in delivery route. The flow reductions at Keswick Dam during May through September are minor relative to the average river flow (approximately 1%) and will not affect the habitat or temperature regime of the Sacramento River. Specifically, the Keswick Dam releases would be reduced to approximately 85 cfs (the flow increment above the water right requirements).

The recommended flow schedule should be implemented as soon as possible because a significant amount of usable habitat, presently taken out of service, that can significantly contribute to the doubling goals.

<u>Related actions that may impede or augment the action</u>: The water rights permit for the project allows implementation of a new release schedule for Whiskeytown Dam at any time on mutual consent between the USBR and DFG (CVPIA does not affect water right permits). The reoperation of Whiskeytown Dam may require preparation of a Fish and Wildlife Coordination Act Report; however, it may not be needed prior to operational changes based on past practice.

<u>Agency and organization roles and responsibilities</u>: The U.S. Department of the Interior is responsible for providing the stream flows that ensure preservation of fish and wildlife and compensate for lost spawning areas above Whiskeytown Dam. DFG should recommend flow releases, and the fishery agencies must monitor the habitat restoration effort. The USBR and DFG must update the water right for the project by submitting a revised MOU to SWRCB.

A detailed operational plan describing the recommended flow regime, consisting of natural runoff from Clear Creek into Whiskeytown Reservoir, should be prepared by DFG, the USBR, and USFWS. It should include flow release adjustment procedures at Keswick and Whiskeytown dams and dry year flow regimes to ensure that Clear Creek flows do not exceed its annual natural unimpaired runoff.

<u>Potential obstacles to implementation</u>: A consequence of providing additional releases down Clear Creek is the translocation of power production from Spring Creek and Keswick power plants to the city of Redding power plant located at Whiskeytown Dam where there is less power potential (head). A timely resolution of this power production loss may not be possible.

<u>Predicted benefits</u>: By increasing the flows below Whiskeytown Dam, it is possible to add back approximately 5 miles of spring-run habitat and 10 miles of steelhead habitat and to reintroduce spring-run chinook salmon. If successful, another distinct and genetically viable population of spring-run chinook salmon and steelhead could become established in the Central Valley, which would reduce the probability of these species going extinct. In addition, the recommended flow releases can nearly double available fall-run and late fall-run chinook salmon habitat over that provided by the present releases. Clear Creek is one of two tributaries in the upper Sacramento River that can provide habitat for three races of salmon and steelhead.

Clear Creek's estimated production is 6,190 salmon and 13,052 steelhead (USFWS 1986, DWR 1985).

Action 2: Provide temperature control.

Objective: Operate Whiskeytown Dam to control temperatures primarily for steelhead or spring-run chinook salmon if reestablishment is successful.

Location: The reach of stream above the valley floor near McCormick-Saeltzer Dam.

Narrative description: Whiskeytown Dam has several outlets at different elevations that allow lower temperature water releases. The installation of the Oak Bottom temperature control curtain further assists in regulating temperature for Clear Creek. A remote-sensing temperature monitoring device is needed at the USGS gauge station at Placer Road Bridge to help project operators to actively control creek temperatures.

Temperature monitoring during several experimental flow releases demonstrated that temperature objectives for juvenile rearing (65° F), holding of prespawning adults (60° F), and egg incubation (56° F) are attainable (DWR 1986, DFG temperature data, USGS temperature data).

Related actions that may impede or augment the action: In a related action, DFG has proposed an amendment to the Water Quality Control Plan for the Central Valley Basin that establishes temperatures suitable for spring-run chinook salmon and steelhead in the foothill reaches of Clear Creek (DFG correspondence 1994). The CVRWQCB's staff is considering the recommended amendment pending further analysis.

Agency and organization roles and responsibilities: Roles and responsibilities are the same as those described for Action 1. In addition, the CVRWQCB will continue to analyze the temperature objectives for Clear Creek proposed by DFG.

Potential obstacles to implementation: Potential obstacles are the same as those as described for Action 1.

Predicted benefits: Temperature control makes the habitat usable for salmon and steelhead and recreates habitat similar to what is now blocked by Whiskeytown Dam. The expected temperature regime provided by the recommended flows will ensure that: 1) the first 10 miles of stream below the dam will be suitable for steelhead spawning and incubation and oversummering rearing of juveniles; 2) any reintroduced spring-run chinook salmon would be provided with suitable habitat for adult summer holdover, spawning, and incubation within the first 5 miles below the dam; and 3) suitable habitat would be provided for spawning, incubation, and juvenile rearing of fall-run and late fall-run chinook salmon within the first 8 miles of the stream above its confluence with the Sacramento River.

Action 3: Restrict gravel mining and restore degraded channel.

Objective: Eliminate the severe adverse effects of gravel mining.

Location: North State Aggregate and Sunrise Excavation Pits.

Narrative description: The adverse effects of instream gravel mining are documented (DWR 1994). Specific problems on Clear Creek include formation of a highly unstable braided and pitted channel that affects upstream passage and lacks sufficient gravel recruitment (DWR 1986). Purchase of the mined stream channel, along with that proposed for mining, would eliminate this problem.

Currently the U.S. Bureau of Land Management (BLM) is in the process of exchanging some of its lands for 900 acres of land bordering Clear Creek between McCormack-Saeltzer Dam and the confluence with the Sacramento River (Schmidt Estate and BLM February 1995 pers. comm.), which is consistent with the Record of Decision for the Redding Resource Areas Land (BLM 1993). Completion of the land exchange will place approximately 96% of the lands along the valley reach of the stream in public ownership, while in the foothill reach of the stream, all the adjoining lands are in public ownership.

After mined areas are transferred to public ownership, channel restoration projects such as the placement of a berm to deflect water from the pits, consolidation of braided channels, and installation of spawning riffles can begin. Plans and environmental documentation are completed for some of the initial channel restoration work.

Related actions that may impede or augment the action: The approved Surface Mine Reclamation Plan for the mined section of the creek is compatible with projects that restore the site for fish and wildlife uses. Restoration activities may be augmented by the Federal Forest Plan Option 9 program that includes Clear Creek watershed. Restoration proposals for labor-intensive projects have been submitted to this program for funding.

Agency and organization roles and responsibilities: BLM is implementing the land exchange with the assistance of DFG. Shasta County and the City of Redding are administering the Surface Mine Reclamation Plans that have requirements consistent with restoration of fish and wildlife habitat. Plans for public recreation in the watershed are the responsibility of the City of Redding, National Park Service, and BLM. The County of Shasta and the Corps are responsible for establishing conditions for any future proposed gravel mining activity in the lands near Clear Creek.

Potential obstacles to implementation: None, if the land exchange process proceeds as planned.

Predicted benefits: Approximately 12% of the anadromous fish habitat has been heavily mined for gravel but can be restored for spawning and rearing. An additional 10% of the stream can be exempted from gravel mining.

Action 4: Provide fish passage.

Objective: Provide access to stream habitat above McCormick-Saeltzer Dam.

Location: McCormick-Saeltzer Dam.

Narrative description: DFG has made a number of attempts to provide effective fish passage over McCormack-Saeltzer Dam (Saeltzer Dam) that have been largely unsuccessful to date. This is compounded by a difficult passage situation in the bedrock channel below the dam that could be improved by blasting a wider channel (project scheduled for 1995).

The most effective method of passing fish would be removal of the dam. The land at the dam site is now under the ownership of DFG. Although the dam can be used to segregate fall-run from spring-run salmon, that service is not relevant and can be provided by alternate means if necessary. To protect water quality and substrate, dredging of sediment behind the dam is needed. A project design and environmental documentation is already completed for this action.

The dam and diversion appear to be greatly oversized for the current water use serviced by the canal (i.e., much of the irrigation district lands serviced by this diversion have been urbanized and mined for gravel). There are alternate methods of supplying water, including groundwater pumping, contracting water from the ACID's canal, or piping water from Clear Creek using a smaller diversion. The proposal to exchange the dam for an alternate water supply was discussed with the owner-operators and in public meetings; the evaluation process is continuing.

Related actions that may impede or augment the action: The program could be augmented by the CVPIA water purchasing program by offering to purchase its pre-1914 water right and the USBR water contract. The landowners in the district may request the Natural Resources Conservation Service (NRCS) (formerly the U.S. Soil Conservation Service) to develop a water conservation plan for farm use and this program could identify alternate water supplies.

Agency and organization roles and responsibilities: DFG is responsible for documenting the fish passage problem. The SWRCB is responsible for responding to any complaints that the water right is not being exercised according to the rules for reasonable use and/or preventing environmental damage.

Potential obstacles to implementation: The water district serviced by the dam may choose not to enter into a water conservation program or not accept any alternate water supply.

Predicted benefits: Fish passage provides access to the only reach of the stream where water temperatures can be controlled by releases from Whiskeytown Dam during the dry season. Without access to this reach there would not be suitable habitat available for yearling steelhead or spring-run chinook salmon. There are educational benefits to allowing salmon and steelhead access to the upper reach where they could be observed at the Whiskeytown Environmental Camp. This facility is operated by the Shasta County Department of Education and the National Park Service to accommodate thousands of elementary school students annually with programs that include fishery issues.

Action 5: Prevent habitat degradation due to sedimentation and urbanization.

Objective: Develop an erosion control and stream corridor protection program for the creek.

Location: Entire stream.

Narrative description: The soils in the upper portion of the watershed consist of highly erodible decomposed granite that can degrade water quality and spawning substrate. A review of land management practices in the Clear Creek watershed is being conducted through the coordinated resource management process. The Western Shasta Resource Conservation District (RCD) formed a group of interested parties from private and government sectors and held several public meetings discussing fishery restoration plans. This collaborative process is directed at developing the land use practices for timber harvest, residential development, agriculture, mining, and road building that prevent sedimentation of the stream. The RCD will be initiating a watershed analysis in spring 1995 that will identify the scope and scale of watershed problems. The NRCS could, if funded, inventory and prioritize problem sites and design and implement treatment measures.

As urbanization of the land continues in the Clear Creek watershed, there is a need to preserve a wide, unfragmented corridor of riparian vegetation for fish and wildlife. The land exchange process being completed by BLM will produce a greenbelt along 98% of the stream. The stream corridor along the remaining private land should be protected under the Stream Corridor Protection Program (DFG 1993) adopted as an interim policy by both the city and the county. Part of the documentation for this program includes a complete mapping of Clear Creek with its riparian habitat and wetlands in a geographic information system format.

Related actions that may impede or augment the action: Almost all the land adjacent to the creek will be owned by public agencies that presently have land management objectives consistent with fishery restoration, wildlife conservation and public recreation. The land use activities on the remaining private lands should be consistent with the recently revised Shasta County General Plan (Shasta County 1993) that specifies special development and erosion control practices in the erodible Clear Creek watershed and protection of salmon spawning gravel in the creek.

Agency and organization roles and responsibilities: The land use activities on public lands must be managed in a manner that prevents degradation of the quality of either the water or the spawning substrate consistent with state and federal water quality laws. The land use activities on private land are conditioned in permits issued by Shasta County consistent with the provisions of the general plan. DFG, CVRWQCB, and the Western Shasta RCD review the proposed land use activities and advise the county on appropriate measures to conserve natural resources through the California Environmental Quality Act (CEQA) process.

Potential obstacles to implementation: None anticipated if all land management agencies follow current plans.

Predicted benefits: By establishing land use practices that decrease rather than increase the discharge of sediment to the stream, the restored sections of habitat will not be degraded by future land use practices. Effective source control of sediment discharge will also eliminate the need to operate sediment basins that interfere with fish passage and water quality protection. The decreased sediment loads will also increase the effectiveness of spring-time flushing flow releases from Whiskeytown Dam. Fish and wildlife values associated with the stream and its riparian vegetation will be preserved with the implementation of the Stream Corridor Protection Program.

Action 6: Restore lost gravel recruitment and spawning habitat.

Objective: Compensate for spawning gravel recruitment and spawning areas blocked by Whiskeytown Dam.

Location: Below Whiskeytown Dam, below McCormick-Saeltzer Dam.

Narrative description: The recruitment of spawning gravel to the creek is halted by Whiskeytown Dam, resulting in a 90% reduction in spawning habitat in the first 10 miles below the dam as indicated by a comparison of preproject and postproject spawning gravel surveys (DWR 1986, DFG 1971). This loss can be compensated for by artificially introducing quantities of spawning-sized gravel on a continuous basis.

During construction of Whiskeytown Dam, the stream below the dam site was mined for dam building materials, including boulders and rubble, reducing the quality of the habitat in this reach. Boulders can be placed in this section to restore habitat diversity.

The construction of Whiskeytown Dam also resulted in the blockage and inundation of approximately 12 miles of stream suitable for salmon spawning (U.S. Bureau of Fisheries 1940). The early surveys of the stream reach above Whiskeytown Dam indicated that less than 1% of the streambed was suitable for spawning, yielding an estimated capacity to support a run of approximately 700 salmon (U.S. Bureau of Fisheries 1940). These surveys did note that the stream was affected by mining wastes. There are historical records of a salmon run above the town of Whiskeytown prior to blockage by Saeltzer Dam at the turn of the century (DFG correspondence 1956).

Related actions that may impede or augment the action: Reintroduction of salmon and steelhead above Whiskeytown Dam is impossible because of insolvable fish passage issues for adults and juveniles. The preferred mitigation method when mitigation cannot be accomplished onsite, according to DFG and USFWS policies, is to compensate for those lost resources by creating new ecologically equivalent habitat as close to the site as possible. Mitigation could be achieved on the remaining 16 miles of stream below Whiskeytown Dam by managing flows, temperature, and spawning gravel so that the stream has the habitat with the capacity to support the same type and population size of anadromous fish as the historical habitat prior to blockage by dams.

Agency and organization roles and responsibilities: DWR, DFG, and USFWS need to formulate and implement a habitat restoration plan for Clear Creek below Whiskeytown Dam.

Potential obstacles to implementation: None are anticipated if all land management agencies follow current plans.

Predicted benefits: The replacement of a portion of the spawning gravel will restore and increase available habitat. Attainable increases in habitat using many years of gravel addition could range between 25% and 50%. This restoration action, along with the other actions proposed for Clear Creek, are expected to nearly double existing populations of salmon and steelhead.

Cow Creek -

Limiting factors and potential solutions - Primary land and water use activities in the Cow Creek drainage include timber harvest, livestock grazing, and hydropower production. Loss of habitat and water diversions are largely due to activities associated with livestock production. The Cow Creek watershed is in relatively good condition and measures to protect existing habitat from water diversion, cattle grazing, creekside development, and gravel extraction should maintain and preserve habitat conditions. Primary limiting factors for chinook salmon and steelhead are low fall and summer flows affecting attraction, migration, spawning, and rearing, caused in part by irrigation diversions. Irrigation diversions also affect steelhead by delaying or blocking adult upstream migration and the entrainment of juvenile migrants. Table 3-Xb-2 lists key limiting factors to salmon and steelhead in Cow Creek and potential solutions.

Water diversions - The only laddered dams and screened diversions are part of hydropower facilities. Agricultural diversions are unscreened, and ditches are unlined and poorly maintained. Nearly all the larger irrigation diversions occur within the tributary streams above the valley floor and generally do not limit chinook salmon migration to potential upstream spawning habitat (Harvey pers. comm.). The one possible exception to this is the concrete based flashboard diversion on North Cow Creek near Bella Vista (1.3 miles below Indian Oak Road) that presents a potential barrier. Irrigation diversions typically operate from April through October and can negatively affect stream flows important for fall-run attraction, migration, and spawning. Habitat surveys conducted by DFG in 1992 identified several permanent and temporary irrigation diversions in the various tributary streams, including 13 diversions in South Cow Creek, 10 diversions on Old Cow Creek, one on Clover Creek, and two on North Cow Creek. No surveys were conducted on Oak Run Creek. According to DFG, no summary data readily exist for information on diversion rights (i.e., ownership, magnitude, and duration).

Steelhead are directly affected by water diversion because they impede upstream migration of adults and entrain downstream migrating juveniles. Agricultural diversions and Pacific Gas and Electric Company's (PG&E's) hydropower diversions on South Cow Creek also reduce summer flows important for juvenile steelhead rearing. Colleen Harvey identified potential migration barriers to adult steelhead. All agricultural diversions are unscreened.

Livestock grazing - Livestock grazing has reduced riparian vegetation and eroded streambanks in the various tributary streams and in the mainstem Cow Creek. Sedimentation will continue to degrade the quality of spawning gravel in Cow Creek. Habitat surveys conducted by DFG in 1992 identified stream sections within the various tributaries where excessive erosion has occurred. Fencing these stream sections to protect the riparian corridor has been recommended for approximately 42,600 feet of stream on South Cow Creek, 45,600 feet on Old Cow Creek, 39,120 feet on Clover Creek, and 19,500 feet on North Cow Creek (Harvey pers. comm.).

Urbanization - Population growth in the towns of Palo Cedro, Bella Vista, Oak Run, and Millville is resulting in increased demand for domestic water and is affecting riparian habitat within the Cow Creek watershed (Reynolds et al. 1993). Creekside development projects will continue to threaten existing habitat conditions unless appropriate measures are taken to ensure that riparian corridors are protected. DFG has worked with Shasta County to address riparian concerns in its recently revised Shasta County General Plan (Shasta County 1993). The plan currently includes provisions to protect the riparian corridor within the watershed.

Gravel mining - Gravel mining occurred in North Cow Creek between Bella Vista and Palo Cedro near the confluence of Dry Creek. Gravel extraction has destroyed the riparian area and removed in-channel gravel. Chinook salmon spawning and rearing habitat have been adversely affected in this area. Currently, gravel mining in Cow Creek has ceased but its effects still remain. The recently revised Shasta County General Plan includes specific ordinances that currently prohibit gravel mining operations within the watershed.

Table 3-Xb-2. Key limiting factors for chinook salmon and steelhead in Cow Creek and potential solutions to those problems.

Limiting factors	Potential solutions
Instream flow	Work with water right holders to obtain agreement for additional flows
Adult passage	Work with water right holders to obtain agreement for improved passage at diversions
Entrainment	Screen diversions
Livestock grazing	Fence riparian corridors to exclude livestock
Urbanization and creekside development	Work with county and private land owners to develop a riparian corridor protection zone
Gravel mining	Eliminate instream gravel extraction operations

Restoration actions -

Action 1: Work with water right holders to obtain an agreement for adequate flows for fall-run chinook salmon migrations and spawning and juvenile steelhead rearing.

Objective: Provide suitable passage and early spawning flows for fall-run chinook salmon adults (particularly in dry water years) and adequate flows for juvenile steelhead rearing.

Location: South Cow, Old Cow, Clover, and North Cow Creeks and possibly Oak Run Creek.

Narrative description: Agricultural diversions on various tributaries and streams have reduced streamflows important for migration and early spawning of fall-run chinook salmon (primarily during dry years in mainstem Cow Creek and in South Cow Creek. Irrigation diversions and PG&E hydroelectric diversions on South Cow Creek have also reduced juvenile steelhead rearing habitat in the tributary streams, particularly during summer. DFG habitat surveys conducted in 1992 have documented the number and location of agricultural diversions on most of the main tributary streams that generally operate from April through October of each year. Thirteen agricultural diversion exist on South Cow Creek, ten on Old Cow Creek, one on Clover Creek, and two on North Cow Creek. No surveys were conducted on Oak Run Creek.

Related actions that may impede or augment the action: Some solutions depend on additional investigations. Although no IFIM studies have been conducted on Cow Creek, DFG has suggested that 50 cfs (measured at the Millville gauge) be maintained during October. This should provide adequate migration and spawning flows for fall-run chinook salmon until DFG has completed the instream flow studies to evaluate overall needs for migration, spawning, and rearing of anadromous fish.

Agency and organization roles and responsibilities: Additional investigations need to be carried out on all of the tributaries to examine current ownership and the specifics of the water rights. Specific canal maintenance programs need to be identified to minimize water losses. DFG should have primary responsibility for developing an agreement with water users to obtain the necessary flows for fall-run salmon and steelhead. DFG should also have lead responsibility for identifying specific canal maintenance programs. SWRCB should assist DFG in these efforts.

Potential obstacles to implementation: Diverters may oppose the suggested improvements or accepting liability or operation and maintenance costs. A reasonable plan will have to be negotiated between private diverters and responsible agencies to balance legitimate needs of agriculture, power generation, and fishery resources. Efforts to sort out water rights, gage and monitor stream flows, determine instream flow needs, and possibly purchase supplemental water will require funding and agency involvement. Adequate funding and staff must be available to DFG and SWRCB to cover these costs.

Predicted benefits: Obtaining additional fall flows from current water users will significantly enhance attraction, migration, and spawning habitat for fall-run chinook salmon, particularly in dry years. Additional summer flows will enhance steelhead rearing habitat, particularly with other actions taken to improve passage and reduce entrainment (see Actions 5 and 6). Projected benefits would be best addressed after an instream flow study is conducted to determine migration, spawning and rearing needs for all anadromous salmonids.

Action 2: Effectively screen agricultural diversions.

Objective: Prevent loss of juvenile steelhead due to entrainment.

Location: Various agricultural diversions in the tributary watersheds.

Narrative description: Agricultural diversions on Cow Creek are unscreened. The extent to which these diversions entrain juvenile steelhead is currently unknown; however, DFG conducted surveys on various Cow Creek tributaries in 1992 and found that diversions took nearly 50-100% of the available stream flow (Harvey pers. comm.). If the existing steelhead spawning and rearing habitat is enhanced through increased flows and passage improvements, then screening will be necessary.

Related actions that may impede or augment the action: Additional studies will be needed to identify diversions that significantly affect the fishery. Screening should be accomplished where instream flow and passage issues are resolved.

Agency and organization roles and responsibilities: DFG should have primary responsibility for conducting studies to identify diversions that require screening. DFG should also be responsible for identifying screening alternatives to reduce steelhead mortality. USFWS and the NMFS should support DFG.

Potential obstacles to implementation: The cost to screen private diversions will be objectionable to individual owners. This effort would have to find funding for screen installation and maintenance. Adequate funding would also be needed for fish screen design studies and agency involvement.

Predicted benefits: Effectively screening diversions will prevent the loss of juvenile steelhead and subsequently increase production.

Action 3: Improve passage at agricultural diversion dams.

Objective: Improve passage for adult steelhead and increase steelhead spawning and rearing habitat.

Location: Various agricultural diversions from Cow Creek above the valley floor.

Narrative description: DFG has identified several natural structures and agricultural diversions that may be potential migration barriers to adult steelhead (Harvey pers. comm.). Most water diversions in Cow Creek operate from April through October. Some diversions are temporary and may not be migration barriers; however, several diversion structures remain in place throughout the year and limit or impede migrating adults.

Related actions that may impede or augment the actions: Agency efforts have been successful in requiring PG&E to build a ladder at its hydroelectric diversion on South Cow Creek. The Olsen Hydroelectric Project on Old Cow Creek has also constructed a fish ladder.

Agency and organization roles and responsibilities: DFG, acting as the lead agency, should contact all water right holders to determine operating procedures and identify actions to rectify passage problems. Potential solutions include replacing dams with pumps, installing ladders, consolidating diversions, and temporarily removing dams. USFWS should support DFG.

Potential obstacles to implementation: Diverters may oppose suggested solutions for fish passage improvements or operation and maintenance costs. Cost for passage improvements may be prohibitive for private diverters. Alternative funding sources may be necessary for passage improvements. Adequate funding and staff must be available to DFG and USFWS to cover these costs.

Predicted benefits: Improving or providing passage at diversion dams will increase the usable holding, spawning, and rearing habitat for steelhead. Increased production will likely result from improved passage.

Bear Creek -

Limiting factors and potential solutions - Unscreened diversions in the valley reach are thought to be the major limiting factors. Natural flows are often less than the combined rights of the diverters, resulting in a total dewatering of the creek in the valley reach during critical periods for salmon. Table 3-Xb-3 lists limiting factors to salmon and steelhead in Bear Creek and potential solutions.

Table 3-Xb-3. Limiting factors for chinook salmon and steelhead in Bear Creek and potential solutions to those problems.

Limiting factors	Potential solutions
Flows	1. Provide an alternate source of water 2. Purchase existing water rights from diverters 3. Initiate legal action to provide instream flows
Entrainment	Build and operate fish screens on all diversions

Restoration actions -

Action 1: Restore instream flows.

Objective: Provide adequate instream flows to permit safe passage of juvenile and adult salmon and steelhead at key times of the year.

Location: Bear Creek from the Sacramento River to Bear Creek Falls.

Narrative description: In most years, and particularly dry years, flows in Bear Creek are insufficient and do not allow passage during spring and early fall mostly due to agricultural diversions. Precise volumes necessary for passage have not yet been defined.

Related actions that may impede or augment the action: Cooperative agreements have been implemented on Deer and Mill Creeks to exchange instream flows for groundwater during key times of the year with the intent of refining volumes and timing in future years. Such agreements that provide pumped groundwater in place of diverted stream flows could also be negotiated with the Bear Creek water right holders. Two additional avenues exist to achieve required flows: (1) purchase of an existing water right or (2) legal action.

Agency and organization roles and responsibilities: USFWS, DFG, DWR and water rights holders need to collaborate on solutions for this action to work. DFG should take the lead role to initiate negotiations with the water right holders.

Potential obstacles to implementation: None.

Predicted benefits: Recovery of the fall-run salmon on a sustainable basis requires a consistent guaranteed flow during the key migration periods, late summer and early fall. It is thus anticipated that achieving the specified flows is essential to meeting the specified recovery goals.

Action 2: Build and operate fish screens on all unscreened diversions.

Objective: Prevent losses of migrating juvenile fall-run salmon and steelhead into agricultural diversions.

Location: Sacramento River to Bear Creek Falls.

Narrative description: None of the agricultural diversions on Bear Creek are screened. If adequate flows are acquired, it will then be necessary to screen all remaining diversions during spring.

Related actions that may impede or augment the action: The success of this action depends on acquiring the necessary flows described in Action 1.

Agency and organization roles and responsibilities: DFG, with assistance from USFWS and DWR, should contact the diverters and begin implementing screening.

Potential obstacles to implementation: None.

Predicted benefits: Actions 1 and 2 must be accomplished with the anticipated benefit that salmon runs will return to, or exceed, DFG-estimated production and restoration goals.

Cottonwood Creek -

Limiting factors and potential solutions - Gravel mining on the valley floor has significantly reduced or eliminated available spawning area. In addition, poor land use practices are thought to have resulted in increased water temperatures and siltation and contributed to armoring of previously utilized spawning areas. Table 3-Xb-4 lists key limiting factors for salmon and steelhead in Cottonwood Creek and potential solutions.

Table 3-Xb-4. Key limiting factors for chinook salmon and steelhead in Cottonwood Creek and potential solutions to those problems.

Limiting factors	Potential solutions
Gravel	1. Restrict or eliminate gravel mining in important spawning areas through county zoning or state legislation 2. Rip and clean or reconstruct salmon spawning riffles on the south Fork Cottonwood Creek below Dippings at dam site and on lower Cottonwood Creek below the South Fork
Straying	1. Construct barrier to prevent fall-run chinook salmon from entering Crowley Gulch as the result of attracting flows caused by releases from the ACID
Water temperatures and siltation	1. Establish land use management practices in the watershed to restore and protect riparian vegetation and control erosion 2. Implement revegetation and erosion control program to restore lost riparian areas

Restoration actions -

Action 1: Protect and enhance spawning gravel.

Objective: Increase spawning opportunity.

Location: Valley sections of Cottonwood Creek.

Narrative description: Spawning gravel in the Sacramento River system is a limited resource, and Cottonwood Creek is one of the most important sources. Gravel has been mined in Cottonwood Creek for many years and has damaged spawning areas and significantly reduced gravel recruitment into the Sacramento River. Two major gravel mines operate on the creek near Interstate 5. Potential regulations to improve stream habitat include confining gravel extraction to off-stream terrace areas and mining only gravel of a size not used by spawners. Because some spawning gravels have become armored or compacted with sediment and unfit for spawning, a program is needed to rip and clean affected spawning riffles and to reconstruct additional riffles where possible.

Related actions that may impede or augment the action: Shasta and Tehama counties have enacted gravel mining ordinances that serve to protect critical spawning areas.

Agency and organization roles and responsibilities: DFG should continue to work with both counties in an effort to stop any new gravel extraction permits from being issued for streams supporting anadromous fish and to improve existing gravel extraction practices. DFG should also take the lead role in implementing spawning gravel rehabilitation where necessary.

Potential obstacles to implementation: None.

Predicted benefits: Reduction of instream gravel mining and rehabilitation of existing spawning riffles will produce long-term benefits to salmon in Cottonwood Creek and protect a valuable gravel source for the Sacramento River.

Action 2: Eliminate attraction flows in Crowley Gulch.

Objective: Eliminate mortalities from stranding.

Location: The ACID's waste gate at Crowley Gulch.

Narrative description: The ACID currently releases excess water into Crowley Gulch through a waste gate. Such releases have attracted adult fall-run salmon into a channel with no spawning habitat, which results in stranding.

Related actions that may impede or augment the action: Construction of a barrier at the mouth of Crowley Gulch will prevent adult entries and stranding.

Agency and organization roles and responsibilities: With support from USFWS and DWR, DFG should take the lead role in working with the ACID on this action.

Potential obstacles to implementation:

Predicted benefits: Eliminating adult mortalities at this site will provide additional fall-run spawners to the system.

Action 3: Improve land use practices.

Objective: Reduce water temperatures to improve holding, spawning, and rearing habitat and reduce siltation and sedimentation of existing spawning gravel.

Location: Mouth to upper end of watershed.

Narrative description: Incompatible land use practices such as overgrazing, road building, timber harvest, and development have resulted in watershed degradation. This degradation is believed to have resulted in increased water temperatures, siltation, and reduced spawning habitat. Regulatory actions need to be taken to control timber harvest, grazing, and road building need to eliminate additional damage to the watershed. In addition, active programs need to be implemented to restore riparian vegetation where necessary.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG should investigate and work with responsible agencies and stakeholders to facilitate watershed protection and restoration.

Potential obstacles to implementation: None.

Predicted benefits: Increased salmon productivity will result from decreased water temperatures and improved spawning areas.

Battle Creek -

Limiting factors and potential solutions - Table 3-Xb-5 lists key limiting factors for chinook salmon and steelhead in Battle Creek and potential solutions.

Hydrogeneration development - The primary factor that limits the potential production of anadromous fish above Coleman Powerhouse is stream flow. Bypass flows required by the Federal Energy Regulatory Commission (FERC) project license at PG&E's diversions are only 3 cfs on North Fork and 5 cfs on South Fork (Federal Power Commission 1976). Substantially greater flows will be required for salmon to reproduce successfully. All PG&E's diversions are unscreened and the effectiveness of the fish ladders is unknown. Additionally, the outflow from power generation facilities is generally greater than the creek flow. This causes some fish to stray toward the higher flow, and the fish may become stranded in the event of a powerhouse shutdown.

There is biological justification to implement restoration of Battle Creek on a long-term plan that can be phased in over 20 years. Because the residual populations of spring-run salmon and steelhead are so small, there is no need to immediately increase flows throughout the entire 41-mile stream system. The first phase of the project would confine the anadromous fish to a reach of stream that is large enough to meet habitat requirements of a growing population, yet small enough to increase spawning success by confining the mating pairs to a small enough area where they can find each other. Action 3 describes this initial restoration phase and recommended interim flows.

Agricultural diversions - There are two significant agricultural diversions on the mainstem of Battle Creek: the Orwick and Gover diversions. Only the latter is screened. However, the Gover diversion fish screen is located part way down the ditch and prevents only juvenile entrainment. Adults are often seen spawning in the canal and are presumed to gain access to the area below the screen by jumping over the screen (visual observation, DFG-Redding and USFWS-Coleman National Fish Hatchery (CNFH) and Northern Central Valley Fishery Resource Office).

Barriers to migration - Since the construction of CNFH, natural salmon and steelhead fall-run and late fall-run spawning in Battle Creek has for the most part been limited to the 5.7 miles from the mouth to the hatchery weir. CNFH personnel have expressed concern that substantial spawning of anadromous fish upstream from the hatchery water supply intake could result in disease organisms affecting hatchery production. During 1985-1989, as many as 10,000 fall-run spawners surplus to CNFH's egg-taking needs were released into Battle Creek above the hatchery weir to spawn naturally. Because of concerns for potential disease problems related to decomposing carcasses in the hatchery water supply, which is taken from the Coleman Powerhouse tailrace before the flow returns to Battle Creek, the fish ladders on PG&E's two lowermost diversions (Wildcat on the North Fork and Coleman on the South Fork) were purposely closed precluding migrations into the middle reaches of those streams.

Large boulders in the Eagle Canyon reach of North Fork Battle Creek create a probable barrier to upstream migration of salmon (Payne & Associates 1991a).

Disease control - An additional management consideration with introducing anadromous fish into upper Battle Creek is the increased risk of disease in CNFH. It is also possible to reduce disease risk to the hatchery by sterilizing the effluent from the large number of aquaculture facilities that discharge fish pathogens into upper Battle Creek with a proposed multimillion dollar ozone water treatment system. This system will ultimately facilitate reintroduction of anadromous fish into 41 miles of stream. Until then, hatchery disease risk can be managed by separating the hatchery water supply from the first 17 miles of upper Battle Creek using existing power canals along with some minor modification of the water delivery system for the hatchery. This action provides a low-cost interim action, opening up a 17-mile reach of stream that can support anadromous fish above the hatchery.

Table 3-Xb-5. Key limiting factors for chinook salmon and steelhead in Battle Creek and potential solutions to those problems.

Limiting factors	Potential solutions
Water flow	Increase bypass flows at PG&E diversions to quantities needed to provide near-optimum transportation, spawning, and rearing of anadromous fish
Upstream passage of adults	1. Allow passage at the CNFH weir 2. Modify the barrier in Eagle Canyon 3. Examine fish ladders at PG&E dams for effectiveness particularly during increased flows; modify as necessary
Entrainment	1. Effectively screen Orwick diversion 2. Effectively screen all PG&E diversions within the reach of potential anadromous fish distribution
Straying of adults	1. Effectively screen Gover diversion to prevent adult salmon from entering the ditch 2. Effectively screen tailrace at Coleman Powerhouse
Potential disease problems at Coleman National Fish Hatchery	Install water treatment facilities capable of completely removing disease organisms from the hatchery water supply. As interim solution, install bypass pipe from Coleman Powerhouse Forebay to Coleman Powerhouse tailrace channel

Restoration actions -

Action 1: Treatment of CNFH water supply.

Objective: Eliminate the potential for waterborne disease to adversely affect hatchery production.

Location: CNFH.

Narrative description: Personnel from CNFH have expressed concern that decaying carcasses of spawned-out chinook salmon upstream from the hatchery water supply intake could release disease organisms that might adversely affect hatchery operation. The hatchery water supply treatment should be improved so that it will completely remove disease organisms. Funds for sterilization of the hatchery water supply are currently appropriated through the USBR. Due to the enormous cost of the project, the construction is being accomplished in phases and the project is presently capable of treating only about 25% of the hatchery water supply. The final completion date is uncertain. Achieving the benefits of most other actions are contingent on complete treatment of the water supply. A lower cost interim solution is to deliver disease-free Coleman Canal water to the hatchery by installing a bypass pipe from the Coleman Powerhouse Forebay to the Coleman Powerhouse Tailrace channel that feeds the hatchery (Rectenwald pers. comm., CH2M Hill 1994). This bypass will be used only when the powerhouse is shut down during load rejection.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: USFWS and the USBR should seek budget augmentations or redirection so that the project will be completed in a timely manner.

Potential obstacles to implementation: Funding of the project depends on Congressional appropriations. Attempts to reduce federal budget deficits could delay necessary funding.

Predicted benefits: Providing a disease-free source of water to CNFH will likely increase hatchery survival. Additionally and probably most importantly, implementation of this action will support the endeavor for providing fish passage above the CNFH weir. Providing passage at this point will enable fish to gain access to approximately 41 miles of stream. This action, in concert with the other proposed actions, would increase anadromous fish runs by an estimated 4,500 fall-run, 4,500 late fall-run, 2,500 winter-run, and 2,500 spring-run chinook salmon and 5,700 steelhead trout. These estimates are based on the amount of potential spawning substrate in reaches where different species/races would be expected to spawn (Kondolf and Katzel 1991), the amount of substrate required per redd (Reiser and Bjornn 1979), and the professional judgment of DFG biologists.

Action 2: Allow passage above CNFH weir.

Objective: Increase available habitat for all salmonid runs and life stages.

Location: CNFH weir.

Narrative description: CNFH operates a weir at RM 5.7 that prevents passage upstream and directs fish into the hatchery. Currently, the weir is in operation from July through March. This prevents passage of nearly all fall-run and late fall-run chinook salmon and steelhead. Substantial superimposition of fall-run redds occurs in years when large numbers of fish return. During extreme high flows, salmon and steelhead are able to swim over the weir to spawn upstream (Coots and Healey 1966). In the late 1980s, fall-run fish were allowed passage above the CNFH weir when production goals were met. Currently, spring- or winter-run chinook salmon that reach the weir from April through June are allowed to pass upstream.

One of the main reasons for denying passage at the weir is to prevent spawned-out carcasses from introducing disease organisms into the hatchery water supply. CNFH diverts water from Battle Creek above the hatchery weir. Currently CNFH is developing facilities for treating its water supply.

Because CNFH is operated to compensate for blocking spawning grounds upstream from Shasta Dam, any partial or seasonal blockage at the CNFH weir for accommodating hatchery operations is an impact of the CVP and as such may require mitigation in accordance with Section 3406(b)(I) under "other impacts" of the CVP. Avoiding any blockage that interferes with the natural production of Battle Creek will reduce the mitigation obligations of the CVP.

Hankin (1991) determined that it is feasible to maintain both natural production and hatchery production in Battle Creek. Once the water treatment facilities are completed, fish should be allowed access to the creek above the weir. All spring-run and winter-run fish should be allowed passage. Passage of fall-run and late fall-run chinook salmon and steelhead should be evenly distributed throughout the run. The time and number of fish to place over the weir should be based on the estimated size of the run returning to the hatchery and hatchery production goals.

Related actions that may impede or augment the action: This action depends on completion of Action 1.

Agency and organization roles and responsibilities: The action will be implemented by USFWS once Action 1 is complete. Action 1 depends on funding to be obtained by the USBR.

Potential obstacles to implementation: Requires funding to complete Action 1.

Predicted benefits: Passage above the weir will provide approximately 41 miles of spawning and rearing habitat for chinook salmon and steelhead. Providing access to additional spawning habitat for fall-run will likely increase production for Battle Creek because it is believed that available spawning habitat below CNFH is utilized at capacity.

This action, in concert with the other proposed actions, would increase anadromous fish runs by an estimated 4,500 fall-run, 4,500 late fall-run, 2,500 winter-run, and 2,500 spring-run chinook salmon and 5,700 steelhead trout. These estimates are based on the amount of potential spawning substrate in reaches where different species and races would be expected to spawn (Kondolf and Katzel 1991), the amount of substrate required per redd (Reiser and Bjornn 1979), and the professional judgment of DFG biologists.

Action 3: Increase bypass flows at PG&E's hydropower diversions.

Objective: Provide streamflow of sufficient quality and quantity to provide adequate holding, spawning, and rearing habitat.

Location: All hydropower diversions on North Fork and South Fork Battle Creek.

Narrative description: Many different factors are considered when determining instream flow requirements at hydropower diversions, including hydrology, stream temperature, run timing, the relationship between streamflow and physical habitat available to fish, and the impact on power generation. Thomas R. Payne and Associates (1991a) evaluated the relationship between streamflow and physical habitat available to various anadromous fish life-history stages for several reaches of Battle Creek. While the following instream flows are subject to revision based on additional analyses, they are offered as an indication of the magnitude of flows needed to optimize anadromous fish production:

Diversion	Months	Flow (cfs)
Keswick	All year	30
North Battle Creek feeder	September-November	40
	January-April	40
	May-August	30
Eagle Canyon	May-November	30
	December-April	50
Wildcat	May-November	30
	December-April	50
South	May-November	20
	December-April	30
Inskip	May-November	30
	December-April	40
Coleman	September-April	50
	May-August	30

The restoration of anadromous fish in Battle Creek will be implemented in a phased approach. The optimum flows listed above will not be required until the population grows to a size sufficient to utilize all the available habitat. The initial restoration phase in the 17-mile reach between the Coleman fish barrier and Eagle Canyon Dam on the North Fork and Coleman Diversion on the South Fork will require the following interim actions:

1) Eagle Canyon Dam - Release 40 cfs from Eagle Canyon Dam from September 1 to April 1 and 30 cfs the remainder of the year. The source for the release would be all the springs diverted into the canal, plus a small amount of surface flow. Close the fish ladder all year.

2) Coleman Diversion - Release 50 cfs from Coleman Diversion from October 1 to February 1 and 30 cfs for the remainder of the year and close the fish ladder all year.

3) Wildcat Diversion - Close Wildcat Diversion to allow all the spring water to remain in the creek and avoid entraining juvenile outmigrants in the power canal.

4) Coleman Forebay - Deliver canal water to the hatchery through a bypass pipe from the Coleman Power Plant forebay to the plant's outlet (tailrace) channel.

The preliminary engineering cost estimate for the pipeline and work on the hatchery delivery system is $1,000,000. This interim effort would delay the need to install and operate an expensive ozone water treatment plant. This bypass represents a loss of power production with an estimated value ranging from $220,000 to $640,000 per year (including the recommended fish water release), depending on the runoff and power prices. The value of the fall-run salmon production exceeds $700,000 per year based on the commonly accepted median value of $100 dollars per salmon. The spring-run chinook salmon and steelhead production would increase the value of this production 3-10 times, based on existing values and the value of avoiding future listings under the Endangered Species Act.

This action item and actions 6, 7, and 8 are mostly reasonably the responsibility of PG&E to mitigate the adverse impacts of the Battle Creek Project. They will, however, be costly in terms of capital construction costs and lost power generation, and PG&E would be expected to resist being saddled with these costs. The Battle Creek Project is licensed by FERC (the present license expires July 31, 2026), which has the legal authority to order that the needed changes be implemented (Article 44 of the license).

<u>Related actions that may impede or augment the action</u>: All of the other actions are required to gain maximum benefit from this action.

<u>Agency and organization roles and responsibilities</u>: DFG, CVRWQCB, USFWS should seek PG&E cooperation in providing improved flows and temperatures below project diversions. If such an attempt should fail, the agencies should petition FERC to reopen the project license and direct the licensee to release the necessary flows.

Potential obstacles to implementation: Requires cooperation on the part of PG&E. Inadequate DFG and/or USFWS staff available to pursue and complete the needed regulatory actions.

Predicted benefits: Increased water releases, in combination with Actions 2 and 9, will make available approximately 41 miles of spawning and rearing habitat. The recommended flows will provide sufficient habitat for achievement of the identified restoration goals. This action, in concert with the other proposed actions, would increase anadromous fish runs by an estimated 4,500 fall-run, 4,500 late fall-run, 2,500 winter-run, and 2,500 spring-run chinook salmon and 5,700 steelhead trout. These estimates are based on the amount of potential spawning substrate in reaches where different species/races would be expected to spawn (Kondolf and Katzel 1991), the amount of substrate required per redd (Reiser and Bjornn 1979), and the professional judgment of DFG biologists. Phasing anadromous fish production into the first 17 miles of upper Battle Creek could produce 6,000 fall-run chinook salmon immediately, 1,000 spring-run chinook salmon by 2015, 1,000 steelhead by 2015, and reintroduction of a small population of winter-run salmon by 2015 (Rutter 1901, DFG 1966).

Action 4: Construct rack to prevent adult salmon from entering Gover Diversion.

Objective: Prevent loss of spawning adult fall-run chinook salmon.

Location: Head of Gover Diversion Canal.

Narrative description: The Gover Diversion, creek mile 5.3, is effectively screened part way down the ditch to prevent juvenile salmonid entrainment. However, in some years adult fall-run chinook salmon are observed in the ditch both above and below the fish screen (DFG, USFWS-CNFH, and Northern Central Valley Fishery Resource Office observations). It is believed these fish are able to jump over the fish screen or swim up the channels that convey excessive water back to Battle Creek. Fry produced in the ditch are presumed lost to diversion. A bar rack with openings not greater than 2 inches located at the head of the diversion has been suggested, along with some sort of barrier at the terminus of the waste gates.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG needs to cooperate with the ditch owner to develop an effective means to prevent adult salmon from spawning in the channel. DFG's screen shop in Red Bluff should investigate the site and develop suitable screening. If screening is not feasible, then DFG should discuss other options with the ditch owner such as implementing conservation measures to reduce the ditch flow during the spawning period.

Potential obstacles to implementation: Requires the ditch owner's cooperation.

Predicted benefits: Effectively screening this diversion from adult entry to the canal will prevent adult salmon from spawning in a location where reproduction will not contribute to population maintenance.

This action, in concert with the other proposed actions, would increase anadromous fish runs by an estimated 4,500 fall-run, 4,500 late fall-run, 2,500 winter-run, and 2,500 spring-run chinook salmon and 5,700 steelhead trout. These estimates are based on the amount of potential spawning substrate in reaches where different species/races would be expected to spawn (Kondolf and Katzel 1991), the amount of substrate required per redd (Reiser and Bjornn 1979), and the professional judgment of DFG biologists.

Action 5: Screen Orwick Diversion.

Objective: Prevent straying of spawning adult fall-run chinook salmon and prevent entrainment of juvenile salmonids.

Location: Head of Orwick diversion ditch.

Narrative description: The Orwick diversion, creek mile 7.3, is unscreened and would entrain adult and juvenile salmon if passage is afforded at the CNFH weir. DFG has constructed a screen, and it is ready for placement. However, it has not been installed because of a lack of cooperation by the land owner. Section 6021 of the Fish and Game Code requires the owner of a conduit to grant access for the installation and maintenance of the required screen.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG should pursue compliance with the law and complete installation of this screen.

Potential obstacles to implementation: Requires-cooperation by the landowner.

Predicted benefits: Effective screening will prevent adult fish from entering the diversion ditch where any spawning would not be productive and will ensure that juvenile salmonids are not lost to entrainment. This will increase escapement in future years.

This action, in concert with the other proposed actions, would increase anadromous fish runs by an estimated 4,500 fall-run, 4,500 late fall-run, 2,500 winter-run, and 2,500 spring-run chinook salmon and 5,700 steelhead trout. These estimates are based on the amount of potential spawning substrate in reaches where different species/races would be expected to spawn (Kondolf and Katzel 1991), the amount of substrate required per redd (Reiser and Bjornn 1979), and the professional judgment of DFG biologists.

Action 6: Screen tailrace of Coleman Powerhouse.

Objective: Prevent straying of spawning adult chinook salmon and steelhead.

Location: Outfall of Coleman Powerhouse.

Narrative description: Flows released from Coleman Powerhouse are generally greater than flows in the main creek channel above the powerhouse. The tailrace flow attracts upstream-migrating adult salmon where there is limited spawning habit and where the fish or the resulting spawn could be dewatered in the event of a powerhouse shutdown. This occurs only when fish are allowed to pass the CNFH weir.

DFG has constructed an effective barrier on the outfall of a lateral from Gover ditch (near the Riverview Restaurant) that could be used as a model.

This action item, as well as Actions 3, 7, and 8, is most reasonably the responsibility of PG&E to mitigate the adverse impacts of the Battle Creek Project. These action will, however, be costly in terms of capital construction costs and lost power generation, and PG&E would be expected to resist being saddled with these costs. The Battle Creek Project is licensed by FERC (the present license expires July 31, 2026), which has the legal authority to order that the needed changes be implemented (Article 44 of the license).

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG and USFWS should actively pursue development of the needed barrier through administrative or legal action.

Potential obstacles to implementation: Requires cooperation on the part of PG&E. Unavailable DFG and/or USFWS staff to pursue and complete the needed regulatory actions.

Predicted benefits: Implementing this action will prevent the loss of adults due to straying and increase the production in Battle Creek. This action, in concert with the other proposed actions, would increase anadromous fish runs by an estimated 4,500 fall-run, 4,500 late fall-run, 2,500 winter-run, and 2,500 spring-run chinook salmon and 5,700 steelhead trout. These estimates are based on the amount of potential spawning substrate in reaches where different species/races would be expected to spawn (Kondolf and Katzel 1991), the amount of substrate required per redd (Reiser and Bjornn 1979]), and the professional judgment of DFG biologists.

Action 7: Construct fish screens at the PG&E diversions.

Objective: Minimize loss of both adult and juvenile salmonids.

Location: All diversions except those upstream from North Battle Creek Feeder Diversion.

Narrative description: PG&E operates six diversions on Battle Creek within the reach of potential anadromous fish distribution, none of which are screened. Anadromous fish spawning could be expected to occur as far upstream as above North Battle Creek Feeder Diversion (to the Cross Country Canal) on North Fork Battle Creek and South Diversion on South Fork Battle Creek. Contingent on obtaining necessary flows and providing passage at the CNFH weir, these diversions should be screened to prevent the loss of adult and outmigrant salmon and steelhead.

Specific diversions that should be screened are prioritized as follows: 1) Wildcat Diversion, 2) Eagle Canyon Diversion (only if barrier described in Action 9 is modified), 3) Coleman Diversion, 4) Inskip Diversion, 5) South Diversion, and 6) North Battle Creek Feeder Diversion.

This action item, as well as Actions 3, 6, and 8, is most reasonably the responsibility of PG&E to mitigate the adverse impacts of the Battle Creek Project. (See the narrative description for Action 6.)

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: Screening is the responsibility of PG&E pursuant to Section 5980 et seq. of the Fish and Game Code and Section 18 of the Federal Power Act. DFG and USFWS should actively pursue construction of the needed screens.

Potential obstacles to implementation: Requires cooperation on the part of PG&E. Unavailable DFG and/or USFWS staff to pursue and complete the needed regulatory actions.

Predicted benefits: Effective screening will prevent loss of juvenile and adult fish to hydropower diversions. This in turn will increase production on Battle Creek.

This action, in concert with the other proposed actions, would increase anadromous fish runs by an estimated 4,500 fall-run, 4,500 late fall-run, 2,500 winter-run, and 2,500 spring-run chinook salmon and 5,700 steelhead trout. These estimates are based on the amount of potential spawning substrate in reaches where different species/races would be expected to spawn (Kondolf and Katzel 1991), the amount of substrate required per redd (Reiser and Bjornn 1979), and the professional judgment of DFG biologists.

Action 8: Evaluate the effectiveness of fish ladders at PG&E diversions.

Objective: Ensure that fish passage is occurring.

Location: PG&E dams.

Narrative description: All PG&E hydropower diversion dams have fish ladders that are assumed to work. However, the effectiveness of these ladders has not been tested. The current ladders were constructed to operate with the current bypass flows of 3 cfs (North Fork) and 5 cfs (South Fork). The increased flows (Action 3) required to restore anadromous fish production may affect their ability to pass or attract fish under the new flow conditions and their effectiveness will need to be assessed. Ladders that are determined to have poor or no passage should be modified or replaced. PG&E is responsible for the maintenance and operation of the ladders. DFG should monitor passage at the ladders. Ladders needing improvements should be fixed based on priority; those with no passage should be fixed first, beginning downstream and working upstream.

This action item, as well as Actions 3, 6 and 7, is most reasonably the responsibility of PG&E to mitigate the adverse impacts of the Battle Creek Project. (See the narrative description for Action 6).

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG, USFWS, NMFS, and PG&E should jointly inspect and evaluate the effectiveness of the ladders.

Potential obstacles to implementation: None.

Predicted benefits: Assessing the effectiveness of the fish ladders under the new flow regime will aid in determining passage problems. Doing this will enable real time action to resolve such problems. Alleviating passage problems will ensure utilization of holding, spawning, and rearing habitat for steelhead and for fall-, late fall-, winter-, and spring-run chinook salmon. This action, in concert with the other proposed actions, would increase anadromous fish runs by an estimated 4,500 fall-run, 4,500 late fall-run, 2,500 winter-run, and 2,500 spring-run chinook salmon and 5,700 steelhead trout. These estimates are based on the amount of potential spawning substrate in reaches where different species/races would be expected to spawn (Kondolf and Katzel 1991), the amount of substrate required per redd (Reiser and Bjornn 1979), and the professional judgment of DFG biologists.

Action 9: Improve fish passage in Eagle Canyon.

Objective: Facilitate movement of adult salmon and steelhead to habitat in north Battle Creek in and above upper Eagle Canyon.

Location: Eagle Canyon.

Narrative description: A bedrock ledge and boulders that have fallen from the canyon wall have created a probable barrier to upstream migration of anadromous fish through the Eagle Canyon reach of North Fork Battle Creek (Payne & Associates 1991a).

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG stream improvement personnel are planning to modify this barrier.

Potential obstacles to implementation: None.

Predicted benefits: Modification of the barrier will allow access to approximately 8.3 miles of holding, spawning, and rearing habitat.

This action, in concert with the other proposed actions, would increase anadromous fish runs by an estimated 4,500 fall-run, 4,500 late fall-run, 2,500 winter-run, and 2,500 spring-run chinook salmon and 5,700 steelhead trout. These estimates are based on the amount of potential spawning substrate in reaches where different species/races would be expected to spawn (Kondolf and Katzel 1991), the amount of substrate required per redd (Reiser and Bjornn 1979), and the professional judgment of DFG biologists.

Action 10: Examine the feasibility of establishing a spawning population of winter-run chinook salmon.

Objective: Increase the genetic diversity and current habitat of the endangered Sacramento River winter-run chinook salmon.

Location: Above CNFH Weir.

Narrative description: While winter-run are assumed to be extirpated in Battle Creek, an additional population that spawns in this stream would increase the possibility of recovery of the species and reduce the probability of the race becoming extinct. Presently, the entire spawning population depends on habitat conditions in the Sacramento River below Shasta and Keswick dams. During critically dry or consecutively dry years, it is unlikely that Shasta Reservoir will be capable of maintaining or providing the necessary cold water in the river to support winter-run chinook salmon (about 1 in 10 years). This race of salmon will continue to be imperiled by such situations and years of low rainfall and low water storage may delay their recovery. Reintroduction of winter-run chinook salmon into the Battle Creek drainage following implementation of this plan would allow them access to substantial flows in the upper creek. This source of water is capable of protecting incubating winter-run chinook salmon eggs and fry during severe drought years because of the cool water provided by springs in the drainage.

Related actions that may impede or augment the action: All of the other actions are required for this action to succeed at the earliest time possible.

Agency and organization roles and responsibilities: NMFS, USFWS, and DFG, through the winter-run recovery team, would direct such an effort. Implementation would be carried out by USFWS.

Potential obstacles to implementation: None.

Predicted benefits: A successful reintroduction of winter-run chinook salmon into Battle Creek will likely shorten their recovery period and allow delisting earlier than would occur by recovering a single population in the Sacramento River. This action, in concert with the other proposed actions, would increase the winter-run by an estimated 2,500 fish. This estimate is based on the amount of potential spawning substrate in reaches where winter-run salmon would be expected to spawn (Kondolf and Katzel 1991), the amount of substrate required per redd (Reiser and Bjornn 1979), and the professional judgment of DFG biologists.

Paynes Creek -

Limiting factors and potential solutions - Table 3-Xb-6 lists key limiting factors for chinook salmon and steelhead in Paynes Creek and potential solutions. Paynes Creek is primarily limited by instream flow that is directly related to precipitation. Sixteen seasonal diversions also have some impact on flows. Lack of adequate spawning gravel is also a limiting factor, although there are no known gravel extraction projects that would have altered natural recruitment.

Table 3-Xb-6. Key limiting factors for chinook salmon and steelhead in Paynes Creek and potential solutions to those problems.

Limiting factors	Potential solutions
Instream flows	1. Negotiate with diverters to release additional flows at key times 2. Purchase water rights or provide alternate source of water 3. Initiate legal action to provide instream flows
Spawning gravel	Construct spawning riffles and periodically maintain

Restoration actions -

Action 1: Restore instream flows.

Objective: Provide minimum instream flows to improve spawning, rearing, and migration opportunities.

Location: Mouth to upper end of watershed.

Narrative description: In general, flows in Paynes Creek are most affected by the lack of adequate rainfall. Benefits could be achieved by acquiring additional instream water from the seasonal diverters because these are minimal diversions; however, this action, by itself, probably would not significantly improve survival conditions. Paynes Creek is thus likely only an opportunistic resource dependent on natural rainfall conditions.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG should seek sources of additional water from diverters particularly in years with moderately low precipitation.

Potential obstacles to implementation: In years with low precipitation, it is likely that fish would not utilize the stream and any additional water supplied by diverters would be insufficient.

Predicted benefits: Consistent and adequate instream flow levels during the early fall and winter should provide the necessary conditions for fall-run salmon production increases. Fish population monitoring will provide data necessary to define IFIM study requirements and other studies deemed necessary to double the populations.

Action 2: Restore spawning gravel.

Objective: Increase spawning potential.

Location: Valley section.

Narrative description: No known gravel extraction projects or major dams have affected the volume or availability of natural spawning gravel. Thus, the addition of gravel and creation of riffles would potentially increase the productive capability of the creek over historical levels.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG should assume the role of coordinating the location and placement of additional spawning gravel to enhance the productivity of Paynes Creek.

Potential obstacles to implementation: None.

Predicted benefits: Improve spawning habitat and theoretically increase production.

Antelope Creek -

Limiting factors and potential solutions - Table 3-Xb-7 lists key limiting factors for chinook salmon and steelhead in Antelope Creek and potential solutions. Two diverters, the Edwards Ranch and the Los Molinos Water Company, have water rights for 50 and 70 cfs, respectively. Natural flows are often less than the combined rights of the two diverters, resulting in a total dewatering of the creek below the canyon mouth during critical periods for salmon. The average annual natural flow for 1940-1980, April through October, was 92 cfs.

Flows in Antelope Creek at the valley floor often split into three channels. The result of this split during spring is often insufficient water to support passage for adult and juvenile migration. No clearly defined channel has been identified, although human intervention (water diversions) may partially be the cause of the split (Harvey pers. comm.).

Table 3-Xb-7. Key limiting factors for chinook salmon and steelhead in Antelope Creek and potential solutions to those problems.

Limiting factors	Potential solutions
Agricultural diversions	1. Provide an alternate source of water to Edwards Ranch and Los Molinos Mutual Water Company 2. Purchase existing water rights from diverters 3. Initiate legal action to provide instream flows
Flow split	Define desired channel and construct flow control structure

Restoration actions -

Action 1: Restore instream flows.

Objective: Provide adequate instream flows to permit safe passage of juvenile and adult salmon at key times of the year.

Location: Edwards Ranch and Los Molinos Mutual Water Company diversion dam at the canyon mouth.

Narrative description: During most years, and particularly dry years, flows in Antelope Creek are insufficient to allow passage due, in part, to agricultural diversions. More precise volumes necessary for passage will be defined in future IFIM studies; however, until then, an estimated interim flow of 50 cfs seems reasonable to provide passage (Fisher and Harvey pers. comms.).

Related actions that may impede or augment the action: Cooperative agreements have been implemented on Deer and Mill Creeks to exchange instream flows for groundwater during key times of the year. Such agreements could be negotiated with the Antelope Creek water right holders. Required flows can also be achieved with: 1) purchase of an existing water right or 2) legal action.

Agency and organization roles and responsibilities: DFG should develop cooperative agreements with water right holders to gain access to alternative groundwater for the necessary flows during the critical times of the year. USFWS and DWR should support DFG's efforts.

Potential obstacles to implementation: Funding for wells and cooperation from water right holders are important to the success of this action.

Predicted benefits: Recovery of the spring-run, fall-run, and late fall-run salmon on a sustainable basis requires a consistent minimum guaranteed flow during the key migration periods. It is thus anticipated that achieving the specified flows is essential to meeting the specified recovery goals.

Action 2: Create defined stream channel.

Objective: Reduce infiltration losses and maintain flows to the Sacramento River.

Location: Antelope Creek at the canyon mouth.

Narrative description: Passage problems occur at the point where Antelope Creek splits into three different channels near the canyon mouth. Because of these split channels, much water is lost to infiltration, particularly at key times of the year. Restructuring the streambed for agricultural diversions is thought to have caused and is continuing to contribute to the flow splits. If additional flows are gained as the result of Action 1, it is important that any increases are not lost to infiltration. Two options are channel reconfiguration or construction of a permanent flow distribution structure.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG should cooperate with property owners and DWR to develop a solution. Actions that brought about this problem need to be identified and then remedied.

Potential obstacles to implementation: None.

Predicted benefits: Actions 1 and 2 must both be accomplished with the anticipated benefit that salmon runs will return to, or exceed, the baseline production and restoration goals.

Elder Creek -

Limiting factors and potential solutions - Table 3-Xb-8 lists key limiting factors for chinook salmon and steelhead in Elder Creek and potential solutions. The Corning Canal siphon, which crosses Elder Creek just west of Interstate 5, approximately 4 miles from its mouth, creates a barrier to migrating chinook salmon during low to moderate flow conditions. Blocking of adult fall-run chinook salmon by the siphon has been observed on several occasions since 1970. Spawning habitat is limited in the lower reaches of Elder Creek. Fall flows are inconsistent and the available spawning gravel is heavily silted.

The stream channel has been extensively manipulated with flood control levees and bank erosion control projects. The lower stream channel is a Corps flood control project maintained by DWR and Tehama County.

Table 3-Xb-8. Key limiting factors for chinook salmon and steelhead in Elder Creek and potential solutions to those problems.

Limiting factors	Potential solutions
Poor fish passage over Corning Canal siphon	Construct a fish passage structure over the Corning Canal siphon
Limited and heavily silted spawning habitat in lower Elder Creek	Adopt an erosion control ordinance to minimize sediment input and carefully plan and coordinate flood management activities to integrate fish habitat improvements whenever possible

Restoration actions -

Action 1: Construct a fish passage structure over the Corning Canal siphon.

<u>Objective</u>: Improve fish passage for chinook salmon and steelhead.

<u>Location</u>: Corning Canal siphon about 4 miles above the mouth of Elder Creek.

<u>Narrative description</u>: The Corning Canal siphon creates a barrier to migrating chinook salmon and steelhead under low to moderate flow conditions (DFG 1993). Because spawning habitat is limited in the lower reaches of Elder Creek and spawning gravel available there is heavily silted, this barrier probably has a significant impact on chinook salmon production. Construction of a fish passage structure over the siphon is estimated to cost about $250,000 (DFG 1993).

Related actions that may impede or augment the action: None identified.

Agency and organization roles and responsibilities: DFG, with USFWS support and in cooperation with the water districts that use the Corning Canal, will take the lead in designing and implementing this project.

Potential obstacles to implementation: Before this project can be constructed, an engineering feasibility report and environmental documentation are needed to evaluate this proposal and identify any alternatives. This work requires funding.

Predicted benefits: Improved fish passage in lower Elder Creek is needed to achieve any significant increase in anadromous fish production. No specific estimates of fish numbers are available.

Action 2: Adopt an erosion control ordinance to minimize sediment input into Elder Creek.

Objective: Reduce sediment input into Elder Creek.

Location: Elder Creek.

Narrative description: The stream channel of lower Elder Creek is confined within Corps flood control levees and there has been extensive bank erosion. The channel has been extensively manipulated by flood and erosion control activities in order to maintain channel capacity. Tehama County should adopt an erosion control ordinance to reduce erosion-causing activities and to minimize sediment input. Flood management activities should be carefully planned and coordinated with appropriate agencies (DWR, DFG, the Corps, the Reclamation Board, and Tehama County Flood Control) to improve the existing fish habitat. Specific fisheries habitat restoration projects can usually be included in flood maintenance operations at little additional cost. Because USFWS has recently purchased property near the mouth of Elder Creek, it may be possible to undertake fishery habitat restoration work in conjunction with development of the Middle Sacramento River Wildlife Refuge.

Related actions that may impede or augment the action: With anticipated reductions in state and federal funding it is likely that local government and land owners may play a bigger role in flood management work, such as removal of invasive vegetation or protection of eroding banks. This could make inclusion of fish habitat improvements more difficult.

Agency and organization roles and responsibilities: DWR, DFG, the Corps, the Reclamation Board, and Tehama County Flood Control should work together to make the flood management activities in Elder Creek more fish friendly.

Potential obstacles to implementation: Future agency personnel, local government, and land owners must be willing to work together to minimize fishery impacts of flood management activities.

Predicted benefits: There is significant potential that improved fishery habitat in lower Elder Creek will provide benefits for migrating juvenile salmonids. Maslin and McKinney (1994) found that many minor tributaries of the Sacramento River, like Elder Creek, are used as temporary rearing habitat by juvenile salmonids, which may or may not have been spawned there. Elder Creek is one of those tributaries for which there is anecdotal evidence of historical runs of chinook salmon and steelhead. Elder Creek has few fish today but may have high potential for restoration.

Mill Creek -

Limiting factors and potential solutions - Table 3-Xb-9 lists key limiting factors for chinook salmon and steelhead in Mill Creek and potential solutions. The most immediate restoration objective is to provide unimpaired passage for migrating adults and juveniles in the valley floor reach (DFG 1993). Blockage or delays in fish passage are attributed to insufficient flows in April, May, June, and October of dry years due to naturally occurring low flows and agricultural diversions. Inadequate fish passage conditions occur during high runoff events at Clough Dam and the middle of the three agricultural diversion dams on Mill Creek (DFG 1993).

Spawning habitat for fall-run in lower Mill Creek is limited due to a shortage of high-quality gravel. Additionally, total spawning habitat is reduced by the three dams.

Although poaching has been identified as a potential problem in the spring-run holding areas, there are no specific data as to its impact on Mill Creek. Potential poaching in the upper watershed is being addressed by DFG through a focused law-enforcement and education effort.

Residential development near Los Molinos is encroaching on Mill Creek's riparian corridor and has the potential, through cumulative impact, to significantly degrade the habitat of the lower creek.

Although the quantity and quality of upstream habitat does not appear to be limiting for the restoration of anadromous fish populations at this time, degradation of upstream habitat is evident in some areas. Siltation is primarily a problem in upstream spawning and nursery areas between State Highway 36 and Big Bend (The Resources Agency 1989). In addition to the erosion of naturally occurring land forms in Lassen Volcanic National Park, timber harvesting, grazing, and roads have at times been identified as primary sources of stream siltation (The Resources Agency 1989).

Mill Creek is presently closed to fishing on the valley floor. In the anadromous fish sections above the canyon mouth, it is open to a catch-and-release trout fishery from April through the middle of November.

During 1993, DFG amended its policy of managing a catchable trout fishery within the anadromous sections of Mill Creek to its present policy of excluding catchable trout from anadromous sections of the stream.

Table 3-Xb-9. Key limiting factors for chinook salmon and steelhead in Mill Creek and potential solutions to those problems.

Limiting factors	Potential solutions
Inadequate transportation flows on valley floor	Complete agreements presently under negotiation with water right holders to leave natural flow in stream in exchange for groundwater
Improve passage at Clough Dam	Remove Clough Dam and provide owners with an alternate means of obtaining irrigation water
Land use impacts in upper watershed	1. Preserve the largely pristine character of the upper reaches of Mill Creek through managing the watershed, limiting development, and discouraging public access to spring-run and steelhead holding and spawning areas 2. Complete a comprehensive watershed analysis to assess present land use management practices and identify needed changes
Armored spawning gravel on valley floor	1. Mechanically rip compacted gravel to improve spawning habitat and food producing areas 2. Engineer and construct spawning gravel beds
Degraded habitat on valley floor	1. Work with local government to ensure protective zoning or ordinances for the Mill Creek riparian corridor 2. Restore riparian vegetation along lower Mill Creek

Restoration actions -

Action 1: Improve transportation flows in the valley reach of Mill Creek.

Objective: Ensure that upstream migrating spring-run chinook salmon and downstream migrating juvenile spring-run and late fall-run chinook salmon and steelhead can migrate safely through the lower portion of Mill Creek.

Location: Mill Creek below Ward Dam.

Narrative description: Inadequate transportation flows during critical migration periods (April, May, June, and after October 15) have largely been alleviated due to negotiated agreements between the Los Molinos Mutual Water Company, The Nature Conservancy, water right holders on Mill Creek, and state agencies. Central to these agreements are minimum base flow requirements (approximately 25 cfs) and the flexibility necessary to adapt management of instream flows to fishery needs as identified by on-the-ground personnel. For example, DFG personnel can request flow pulses or higher base flows (up to the entire creek flow) if conditions warrant. The only limitation on providing the additional instream flow is the state's ability to replace the fish bypass flows during the irrigation season with groundwater.

Related actions that may impede or augment the action: Although the existing agreements have been successful in meeting critical flow needs, additional flow provided on a voluntary basis through private water rights would make the existing program more cost effective and efficient. A study to refine flow needs for fish passage is presently being conducted by DFG.

Agency and organization roles and responsibilities: The DWR monitors flow in the creek and operates the project wells. DFG monitors fish populations and passage conditions. Continued cooperation and flexibility in the Los Molinos Mutual Water Company operations is essential to the success of the exchange program.

Potential obstacles to implementation: Participation by agencies and water right holders in contractual arrangements for additional instream flows is voluntary and therefore not guaranteed.

Predicted benefits: This project guarantees spring-run chinook salmon access to upper Mill Creek in dry to critically dry years when instream flows might otherwise be limiting. Unimpeded upstream passage of spring-run will maintain the genetic integrity of this species in Mill Creek. Although the supplemental flows are focused on the restoration of the spring-run chinook salmon population, fall-run adults and downstream migrant late fall-run chinook salmon and steelhead also benefit.

Action 2: Remove Clough Dam.

Objective: Provide unimpaired passage where an existing structure presently obstructs migrating adults under certain flow conditions.

Location: Clough Dam, lower Mill Creek.

Narrative description: At higher flows, the fish ladder on Clough Dam is inadequate and causes significant delays for upstream migrants. The Los Molinos Mutual Water Company could provide an alternate source of water to replace water diverted at the Clough Dam. Delivery of water from the company's system would, however, require the construction of a siphon under Mill Creek. Replacing the dam with a siphon would require the cooperation and approval of the dam's owners.

Related actions that may impede or augment the action: Although a second ladder would help alleviate the problem, the preferred alternative is to eliminate Clough Dam altogether. Comprehensive watershed management will require integration of existing state and federal land use planning, laws, and regulations.

Agency and organization roles and responsibilities: DFG and DWR should work through the newly formed Mill Creek conservancy to initiate this project.

Potential obstacles to implementation: Until issues related to the removal of Clough Dam are resolved, a second fish ladder on Clough Dam would provide improved passage over a greater range of flows than presently exists.

Predicted benefits: Removal of Clough Dam would provide improved passage conditions for all anadromous salmonids in Mill Creek. Additionally, removal of the dam could result in the restoration of approximately 0.5 mile of fall-run spawning habitat.

Action 3: Protect and restore anadromous salmonid fisheries habitat and preserve the long-term productivity of the upper Mill Creek aquatic ecosystem through cooperative watershed management.

Objective: Identification of restoration priorities and protection of Mill Creek's aquatic ecosystem through cooperative land use management in the upper watershed.

Location: Mill Creek watershed above the Sacramento Valley floor.

Narrative description: Protection and restoration of the upstream holding, spawning, and rearing habitat for spring-run salmon and steelhead will require a cooperative ecosystem management approach. For Mill Creek, a comprehensive watershed analysis should first be used to evaluate the quality of anadromous fishery habitat and quantify the effect of existing land use practices. This information could then be used to assist in setting priorities for improving current habitat conditions and developing alternatives to present land use practices that are detrimental to the long-term productivity of Mill Creek's anadromous fish populations. Measures must be taken to improve management practices on state, federal, and private lands. Ecosystem management from a watershed perspective is the most promising approach to guiding restoration in the watershed and maintaining viable anadromous fishery habitat in upper Mill Creek.

Related actions that may impede or augment the action: Comprehensive watershed management will require integration of existing state and federal land use planning, laws, and regulations.

Agency and organization roles and responsibilities: To be successful, implementation of ecosystem management will require participation of all major landowners in the watershed and all federal and state agencies involved with managing resources in the watershed. A Mill Creek Conservancy is being formed that could play a large role in this process if it is successful.

Potential obstacles to implementation: Watershed management within the Mill Creek drainage is essentially voluntary and therefore will require the cooperation of all major stakeholders. Agreement on a common goal to protect anadromous fishery habitat is essential before the process can begin in earnest.

Predicted benefits: A coordinated resource management planning process focused on the protection of anadromous fish habitat in the upper watershed will assist in the protection of existing habitat and preserve the long-term productivity of the upper Mill Creek aquatic ecosystem.

Action 4: Improve salmon spawning areas in lower Mill Creek.

Objective: Increase available spawning habitat at selected sites in lower Deer Creek to accommodate increased runs of fall-run and late fall-run chinook salmon.

Location: Lower 8 miles of Mill Creek.

Narrative description: Some spawning areas in lower Mill Creek are armored with rocks or boulders too large for salmon to move. Often these are locked together by sediment. This project would rip compacted gravel areas on certain riffles to improve spawning conditions and increase food production. In a few selected areas, spawning areas would be engineered and constructed with graded gravel. In some cases, it may be desirable to engineer and construct hydraulic controls to decrease velocities so that suitable-sized gravel can accumulate.

Related actions that may impede or augment the action: Continued operation of the water exchange program identified in Action 1 will enhance the benefit of this proposed action.

Agency and organization roles and responsibilities: DFG and DWR have cooperated in constructing similar projects in Mill Creek in the past and should continue to do so in the future.

Potential obstacles to implementation: Because Lower Mill Creek is entirely located on private property, the cooperation of local landowners will be required for implementation of this project.

Predicted benefits: This project would provide additional spawning habitat for about 1,500 fall-run or late fall-run chinook salmon.

Action 5: Maintain and restore riparian habitat along the lower reaches of Mill Creek.

Objective: Maintain and restore riparian habitat along the lower reaches of Mill Creek to help maintain cool water temperatures.

Location: Lower 8 miles of Mill Creek, Tehama County.

Narrative description: The riparian corridor is integral to maintaining the ecological integrity of the lower creek system. Local land use planning and regulations need to create a buffer zone between the creek and new development. Additionally, state and federal agencies could work with local land owners and land owner groups to restore riparian vegetation.

Related actions that may impede or augment the action: None identified.

Agency and organization roles and responsibilities: A cooperative effort between the USBR, DFG, DWR, and local government has already been instituted that shows promise in defining and implementing a riparian buffer zone for lower Mill Creek. The first step, mapping of existing resources, was initiated by California State University (CSU), Chico, in spring 1994.

Potential obstacles to implementation: Protection of the lower Mill Creek corridor is largely a question of local land use planning, laws, and regulation and therefore is subject to the willingness of local government to address this issue.

Predicted benefits: It is impossible to predict specific increases in fishery habitat or fish numbers due to this project; however, fish survival should increase to the extent water temperatures are decreased in lower Mill Creek and insect drop from streamside vegetation is increased during late spring when downstream migrant salmon and steelhead are passing through the area.

Thomes Creek -

Limiting factors and potential solutions - Table 3-Xb-10 lists key limiting factors for chinook salmon in Thomes Creek and potential solutions.

Land use - Timber harvest, overgrazing, and road building cause excessive erosion and compaction of the soil. Poor land use practices worsened the effects of the 1964 flood that conveyed hundreds of tons of gravel from the head waters to the valley floor (DWR 1982). The flood raised the stream bed in the valley and now much of the water below Paskenta flows subsurface, reducing the amount available for salmon.

In some areas, gravel mining has caused incision of the stream channel (Gard 1994). The stream channel has been incised so greatly as to cause passage problems at the Corning Canal siphon. A similar situation may be occurring at the Tehama-Colusa Canal (TCC) siphon and bridge crossings.

Migration barriers (diversions) - Excessive streambed erosion has exposed the Corning Canal siphon creating a migration barrier under most flow conditions (Gard 1994). Gravel mining adjacent to the siphon is the likely cause.

No major dams exist, but two minor seasonal gravel diversion dams may act as migration barriers; one is located in Paskenta and the other near Henleyville. Several small pumps draw water from the creek. These may also cause predation problems.

Instream flows - As is typical of westside streams, suitable flows for salmon reproduction are occasional at best. Historical records of flows in Thomes Creek reveal that in only 18 of 36 years are flows adequate to support salmon spawning (DFG 1961). Today, this probably occurs less due to the flood of 1964.

Water diverted from the TCC into Thomes Creek has attracted salmon to the creek to spawn, only to have the redds dewatered when diversions ceased (Villa pers. comm.). The TCC was designed with a turnout structure to provide water to Thomes Creek for mitigation of the RBDD. Water was delivered to Thomes Creek via the TCC but not for fishery purposes.

Water quality - Paskenta township has had concerns over the quality of its drinking water and recommends no consumption.

Table 3-Xb-10. Key limiting factors for chinook salmon and steelhead in Thomes Creek and proposed corrective actions.

Limiting factors	Potential solutions
Land use	1. Modify gravel extraction methods 2. Modify timber harvest practices 3. Modify grazing practices 4. Stabilize areas of high erosion

Limiting factors	Potential solutions
Migration barriers	1. Replace Corning Canal siphon 2. Solicit assistance from water diverters
Instream flow	Develop release strategy for the TCC
Water quality	Conduct regular water quality monitoring

Restoration actions -

Action 1: Modify gravel mining methods.

Objective: Improve land use practices.

Location: Gravel mining areas.

Narrative description: As a result of gravel mining operations in Thomes Creek, particularly the Red Bluff/Valley Rock operation located 500 feet downstream of the Corning Canal siphon and the Thomes Creek Rock/Wolf Pit operation located a short distance upstream of Highway 99, the channels have incised 8-13 feet. Today, the top of the existing Corning canal siphon is 3 feet above the streambed elevation (Gard 1994). The exposed culvert is a migration barrier under most flow conditions. Similar effects have been noted at other portions of Thomes Creek, with 10 feet of incision at the TCC siphon, and concerns by California Department of Transportation about channel incision at bridge crossings. Other problems associated with gravel mining include increasing suspended solids, causing passage problems and stranding of fish into extraction pits.

Related actions that may impede or augment the action: If gravel mining persists in the current manner, more structural fixes will be needed in the near future. Therefore, eliminating the causes is essential for correcting the fish passage barriers. The Tehama County Planning Commission is currently in the process of reviewing and modifying gravel extraction permits in Tehama County. More favorable conditions for salmon could be obtained with modified permit regulations.

Agency and organization roles and responsibilities: USFWS and DFG should contact the Tehama County Planning Commission and the DWR.

Potential obstacles to implementation: New regulations will likely incur resistance from the gravel mining companies.

Predicted benefits: Reform in gravel mining practices will prevent future passage problems, reduce entrainment, decrease suspended solids, and keep existing habitat from becoming degraded or lost.

Action 2: Modify timber harvest practices.

Objective: Improve land use practices.

Location: Entire stream.

Narrative description: Erosion caused by timber harvest has caused much damage to the upper watershed (DWR 1982). Logging roads are also of concern.

Related actions that may impede or augment the action: More favorable timber extraction techniques need to be employed to reduce these impacts.

Agency and organization roles and responsibilities: The Mendocino National Forest needs to employ the most ecologically sound timber extraction practices and require private timber harvesters to employ such methods and to remediate any incurred damages.

Potential obstacles to implementation: Cooperation of timber harvesters and enforcement by the U.S. Forest Service (USFS) and the California Department of Forestry (CDF) are necessary for this action to succeed.

Predicted benefits: Reform in timber harvest practices will improve salmon habitat by controlling erosion, increasing riparian habitat, and providing food and shelter.

Action 3: Modify grazing practices.

Objective: Improve land use practices.

Location: Entire stream.

Narrative description: The effects of cattle grazing on salmon are well known (Armour et al. 1994).

Related actions that may impede or augment the action: Cooperative efforts with the Mendocino National Forest would prove beneficial for the improvement of grazing practices on public lands.

Agency and organization roles and responsibilities: Private ranchers in the area should be encouraged to utilize the best environmentally sound grazing practices. DFG, with support from USFWS, should start discussions with local ranchers and provide necessary budgets to fence out cattle and begin restoration actions. Riparian restoration plans may have to be developed for specific ranchers.

Potential obstacles to implementation: The success of this action depends on the cooperation of private ranchers.

Predicted benefits: Improved cattle grazing practices will reduce erosion, improve water quality, and increase riparian habitat.

Action 4: Stabilize areas of high erosion.

Objective: Reduce impacts of previous land use practices and improve habitat.

Location: Entire stream.

Narrative description: Incompatible land and water use practices (overgrazing, deforestation, road building, and gravel mining) in the past have caused serious erosion problems.

Related actions that may impede or augment the action: Success of this action depends on permanent correction and reform of past forest practices described in Actions 1, 2, and 3.

Agency and organization roles and responsibilities: The NRCS, USFS, and CDF should provide the expertise to identify and prioritize specific areas that require rehabilitation.

Potential obstacles to implementation: Appropriate funding is required to accomplish this task.

Predicted benefits: Stabilization of areas having high erosion will reduce siltation and sedimentation of spawning habitat and holding pools. It will also help maintain the riparian corridor, which moderates water temperature and provides food and cover for juveniles.

Action 5: Replace Corning Canal siphon.

Objective: Improve fish passage.

Location: Corning canal crossing (RM 7).

Narrative description: The Corning Canal crossing has been identified as a fish passage problem (Gard 1994). Incision of the stream channel as a result of gravel mining has exposed the once-buried culverts.

Related actions that may impede or augment the action: USFWS's Ecological Services in Sacramento recently completed a Fish and Wildlife Coordination Act Report and supports replacing the siphon. The USBR is responsible for the funding. The project to replace the siphon is currently underway.

Agency and organization roles and responsibilities: Successful implementation of Action 1 is required to stabilize the streambed after the siphon is replaced.

Potential obstacles to implementation: If gravel mining practices are not improved, similar passage problems may evolve.

Predicted benefits: Replacing the Corning Canal siphon will permit fish passage at this point.

Action 6: Minimize diversion barrier usage.

Objective: Improve fish passage.

Location: Henleyville Diversion, Paskenta Diversion.

Narrative description: Two diversions, one in Paskenta and one in Henleyville, were noted in DFG's Anadromous Fish Restoration Program (1993) and may be migration barriers to spring-run chinook salmon and steelhead. It is suspected that these are migration barriers and that spring-run chinook salmon utilize the stream.

Related actions that may impede or augment the action: Spring-run and steelhead probably ascend the creek only in years with high precipitation, and it is unlikely these dams operate during this time.

Agency and organization roles and responsibilities: DFG and USFWS should encourage diversion operators to keep barriers out as long as possible or to allow some method of fish passage and to notify DFG if spring-run chinook salmon are observed. Additionally, DFG should monitor the stream for spring-run salmon.

Potential obstacles to implementation: It should be noted that these are probably problems only in years when adequate precipitation allows spring-run salmon to ascend the creek up to these diversions.

Predicted benefits: Providing passage at these points will aid spring-run and steelhead migration to historical spawning grounds.

Action 7: Develop release strategy for the TCC into Thomes Creek.

Objective: Improve instream flows.

Location: Tehama-Colusa Canal crossing.

Narrative description: The TCC has the potential to supply water to Thomes Creek for spawning salmon but has not been utilized for this purpose.

Related actions that may impede or augment the action: At times water has been supplied to Thomes Creek via TCC and has attracted salmon to spawn in the creek (Villa pers. comm.), but this water has been turned off in the past and redds were left dewatered and fish stranded.

Agency and organization roles and responsibilities: The USFWS, USBR, and DFG should contact the Tehama-Colusa Canal Authority to coordinate development of a water release strategy for the TCC into Thomes Creek. If water is supplied, a minimum flow should be maintained from October through May to ensure survival for all life stages. Until a minimum flow can be determined, 50 cfs should be released. This flow is a professional opinion (Ward pers. comm.).

Potential obstacles to implementation: If it is not possible to maintain a minimum flow, no water should be released during this time period.

Predicted benefits: Developing a water release strategy at TCC will: 1) provide for water needs of salmon and 2) ensure that salmon are not inadvertently drawn upstream to spawn, resulting in stranded juveniles.

Action 8: Conduct regular water quality monitoring.

Objective: Provide suitable water quality.

Location: Entire stream.

Narrative description: Recently, Paskenta township's drinking water source, Thomes Creek, has been declared unsafe, suggesting that water quality may not be favorable for salmon.

Related actions that may impede or augment the action:

Agency and organization roles and responsibilities: DWR or EPA should be contacted to monitor the water quality.

Potential obstacles to implementation: Funding for any water quality improvement projects could be a limiting factor for success of this action.

Predicted benefits: Monitoring water quality will assist in determining point sources of pollution so that remedial actions can be accomplished.

Deer Creek -

Limiting factors and potential solutions - Table 3-Xb-11 lists key limiting factors for chinook salmon and steelhead in Deer Creek and potential solutions. Habitat in the upper watershed is relatively intact, with numerous holding areas and an abundance of spawning gravel. Some spawning areas in lower Deer Creek are lightly armored but could be improved for use by fall-run chinook salmon.

Except for the lack of streamflows on the valley floor below the agricultural diversions, fish habitat throughout the drainage is generally of good quality. Water right holders on Deer Creek have recently expressed interest in cooperating with DFG to develop alternative water sources and to provide flows to meet fishery needs. Water users are concerned about the depleted status of the spring-run chinook salmon and are willing to work toward mutually acceptable solutions to restore the fishery. Flows necessary to provide unimpaired migration for adult salmon and steelhead are not accurately known but are estimated to be about 50 cfs for planning purposes (Harvey pers. comm.). A flow study by DFG is underway to better define these needs.

Inadequate flows for upstream passage is the most significant problem on Deer Creek. During low-flow periods, flows in Deer Creek below the lower diversion dam are, at times, inadequate for fish to pass upstream from the Sacramento River.

Spawning gravel in lower Deer Creek is adequate for present population levels of fall-run salmon. However, gravel rehabilitation at selected sites could increase available spawning habitat and would be needed in order to double spawning populations.

Protection and restoration of the upstream holding, spawning, and rearing habitat for spring-run salmon and steelhead will require a cooperative ecosystem management approach. Participants in a cooperative watershed management effort would include state, federal, and county agencies; private land owners; and land owner organizations. A comprehensive watershed analysis should be used to evaluate the quality of anadromous fishery habitat and quantify the effect of existing land use practices in the Deer Creek watershed. Such information could be used to help set priorities for improving current habitat conditions and to develop alternatives to present land use practices that are detrimental to the long-term productivity of Deer Creek's anadromous fisheries.

Juvenile spring-run chinook salmon and steelhead need protection from possible predation and competition from catchable-sized hatchery rainbow trout stocked in the headwater rearing areas. DFG no longer allows stocking of rainbow trout in the upper 3 miles of rearing habitat. Eliminating this planting location and shifting the trout allotment to above Upper Deer Creek Falls has alleviated any possible conflict between anadromous salmonids and the catchable trout stocking program.

Table 3-Xb-11. Key limiting factors for chinook salmon and steelhead in Deer Creek and potential solutions to those problems.

Limiting factors	Potential solutions
Inadequate transportation flows	Negotiate agreements with water districts and water right holders to pump groundwater at state expense in exchange for leaving up to 50 cfs of natural flow in stream for fish migration
Potential land use impacts in upper watershed	1. Preserve the largely pristine character of Deer Creek through cooperative managing the watershed, limiting development, and discouraging public access to spring-run and steelhead holding and spawning areas 2. Complete a comprehensive watershed analysis to assess present land use management practices and identity needed changes
Armored spawning gravel	1. Mechanically rip compacted gravel to improve spawning habitat and food-producing areas 2. Engineer and construct spawning areas with graded gravel
High temperatures	Negotiate land use agreements with Deer Creek Conservancy to protect existing riparian vegetation along lower Deer Creek and develop programs to restore riparian vegetation
Flood management activity	Plan and coordinate flood management activities carefully with appropriate agencies to integrate fish habitat

Limiting factors	Potential solutions
	improvements whenever possible

Restoration actions -

Action 1: Improve transportation flows in the valley reach of Deer Creek.

Objective: Provide improved flows in the lower 10 mines of Deer Creek to ensure that upstream and down-stream migrating juvenile spring-run and fall-run chinook salmon and steelhead can pass over three diversion dams.

Location: Valley reach of Deer Creek.

Narrative description: In dry years, water right holders may divert nearly the entire flow of Deer Creek during the critical migration period of May to early June. As a result, upstream migration of adult spring-run chinook salmon and downstream migration of juvenile salmon and steelhead can be impeded or entirely blocked. If low flows persist in the creek, water temperatures quickly exceed the tolerance range for these species. Supplemental flows will help restore the population of wild spring-run chinook salmon by allowing migrating adults to reach their spawning habitat and by providing transportation flows for the juvenile salmon and steelhead migrating to the Sacramento River.

An agreement, or agreements, will be completed between Deer Creek Irrigation District (DCID), Stanford-Vina Irrigation Company (SVIC), DFG, and DWR. Under the agreements, natural flow that would otherwise be diverted for irrigation would be left in the creek when requested by DFG to aid fish passage during critical migration periods. The DCID diversions would be replaced by groundwater. SVIC would replace diversions partially with groundwater and partially with improvements to its distribution facilities. Up to five wells would be built or refurbished in DCID, and SVIC would build an unspecified number of wells and line some of its canals. Stream hydrology suggests that supplemental flows would be needed about every 3 years.

Agreements to operate this project would be formalized under a long-term (minimum 15-year) contract. The agreements would guarantee the state certain stream flows, on request, but would not modify the water rights of the individuals or agencies. Pumping payment rates and other contract conditions could be renegotiated at the end of the contract, which could extend the agreements indefinitely.

Related actions that may impede or augment the action: Although the existing agreements have been successful in meeting critical flow needs, additional flow provided on a voluntary basis through private water rights would make the existing program more effective. A study to refine flow needs for fish passage is presently being conducted by DFG.

Agency and organization roles and responsibilities: The DWR monitors flow in the creek. DFG monitors fish populations and fish passage conditions. Continued cooperation and flexibility in the operations of DCID and SVIC is essential to the success of the diversions-to-wells exchange program.

Potential obstacles to implementation: Participation by agencies and water right holders in contractual arrangements for additional instream flows is voluntary and therefore not guaranteed.

Predicted benefits: By ensuring access during dry and critically dry years, this action would guarantee spring-run chinook salmon access to about 38 miles of suitable holding, spawning, and rearing habitat every year. Spawning populations of spring-run chinook salmon have declined 90% over the past three decades. Although it is recognized that transportation flows in dry years is only one of many factors that have reduced this population, this action will remove a major uncertainty in the restoration of spring-run salmon in Deer Creek.

Providing adequate transportation flows during spring of dry years would primarily benefit upstream migrating adult spring-run salmon; however, downstream migrant spring- and fall-run chinook salmon and steelhead would also benefit from these flows. The juvenile salmon and trout must be out of Deer Creek by late April or May during dry years to avoid elevated temperatures resulting from low flows.

Although this project is primarily focused on spring-run salmon, flow augmentation in fall of dry years to benefit out-migrating salmon and steelhead smolts would also benefit adult fall-run salmon. Thus, this project provides the potential to improve migration and spawning flows for fall-run adults after October 1 and to increase survival of downstream migrant yearling spring-run salmon and steelhead.

Action 2: Protect and restore chinook salmon and steelhead habitat and preserve the long-term productivity of the upper Deer Creek aquatic ecosystem through cooperative watershed management.

Objective: Reduce the effects of land use practices.

Location: Deer Creek watershed above the Sacramento Valley floor.

Narrative description: Protection and restoration of the upstream holding, spawning, and rearing habitat for spring-run salmon and steelhead will require a cooperative ecosystem management approach. For Deer Creek, a comprehensive watershed analysis should first be used to evaluate the quality of anadromous fishery habitat and quantify the effect of existing land use practices. This information could then be used to assist in setting priorities for improving current habitat conditions and developing alternatives to present land use practices that are detrimental to the long-term productivity of Deer Creek's anadromous fisheries. Measures must be taken to improve management practices on state, federal, and private lands. Ecosystem management taken from a watershed perspective is the most promising approach to guiding restoration in the watershed and maintaining viable anadromous fishery habitat in upper Deer Creek. To be successful, implementation of ecosystem management will require participation of all major land owners in the watershed and all federal and state agencies involved with managing resources in the watershed.

Related actions that may impede or augment the action: Comprehensive watershed management will require integration of existing state and federal land use planning, laws, and regulations.

Agency and organization roles and responsibilities: To be successful, implementation of ecosystem management will require participation of all major land owners in the watershed and all federal and state agencies involved with managing resources in the watershed. A Deer Creek Conservancy is being formed that could play a large role in this process if it is successful

Potential obstacles to implementation: Watershed management within the Deer Creek drainage is essentially voluntary and therefore will require the cooperation of all major stakeholders. Agreement on a common goal to protect anadromous fishery habitat is essential before the process can begin in earnest.

Predicted benefits: A coordinated resource management planning process focused on the protection of anadromous fishery habitat in the upper watershed will assist in the protection of existing habitat and preserve the long-term productivity of the upper Deer Creek aquatic ecosystem.

Action 3: Improve salmon spawning areas in lower Deer Creek.

Objective: To increase available spawning habitat at selected sites in lower Deer Creek to accommodate increased runs of fall-run and possibly late fall-run chinook salmon.

Location: Lower 10 miles of Deer Creek.

Narrative description: Some spawning areas in lower Deer Creek are armored with rocks or boulders too large for salmon to move. Often these have become locked together by sediment. This action proposes to rip compacted gravel areas on certain riffles to improve spawning conditions and increase food production. In a few selected areas, spawning areas would be engineered and constructed with graded gravel. In some cases, it may be desirable to engineer and construct hydraulic controls to decrease velocities so that suitable-sized gravel can accumulate.

Related actions that may impede or augment the action: Continued operation of the water exchange program identified in Action 1 will enhance the benefit of this proposed action.

Agency and organization roles and responsibilities: DFG and DWR have cooperated in constructing similar projects in Mill Creek and should be able to continue to do so on Deer Creek projects.

Potential obstacles to implementation: Lower Deer Creek is almost entirely located on private property, and therefore the cooperation of local land owners will be required for implementation of this project.

Predicted benefits: This project would provide additional spawning habitat for about 1,500 fall-run chinook salmon.

Action 4: Maintain and restore riparian habitat along lower reaches of Deer Creek.

Objective: To maintain and restore riparian habitat along lower reaches of Deer Creek to help maintain low water temperatures.

Location: Lower 10 miles of Deer Creek, Tehama County.

Narrative description: Negotiate long-term agreements with the Deer Creek Conservancy and other land owners to protect existing riparian vegetation along lower Deer Creek and develop programs to restore riparian vegetation.

Related actions that may impede or augment the action: None identified.

Agency and organization roles and responsibilities: A cooperative effort between the USBR, DFG, DWR, and local government has already been instituted that shows promise in defining and implementing a riparian buffer zone for lower Deer Creek. The first step, mapping of existing resources, was initiated by CSU, Chico in spring 1994.

Potential obstacles to implementation: Protection of the lower Deer Creek corridor is largely a question of local land use planning, laws, and regulation and therefore is subject to the willingness of local government to address this issue.

Predicted benefits: It is difficult to predict quantifiable increases in fishery habitat or fish numbers due to this project. However, fish survival should increase if water temperatures are decreased in lower Deer Creek and insect drop from streamside vegetation is increased during fall and late spring when downstream migrant salmon and steelhead are passing through the area.

Action 5: Conduct flood management activities.

Objective: Carry out required flood management activities with minimal damage to the fishery resources and riparian habitat of lower Deer Creek.

Location: Lower 5 miles of Deer Creek, Tehama County.

Narrative description: The objective of this action is to plan and coordinate flood management activities carefully with appropriate agencies (DWR, DFG, the Corps, the Reclamation Board, and Tehama County Flood Control) to protect existing fish habitat and to integrate fish habitat improvements whenever possible. DWR is responsible for maintaining flood channel capacity in the valley portion of Deer Creek, which is a leveed flood control project of the Corps. Salmon spawning areas in the lower 5 miles of Deer Creek have been damaged by flood control maintenance activities, when spawning gravel was removed from the stream channel to increase capacity and when spawning riffles were compacted by heavy equipment or simply covered by soil, sand, or silt. In some cases, the stream channel was leveled during this process so that no low-flow channel remained. This made upstream migration by adult salmon difficult or impossible.

More recent DWR flood management activities on lower Deer Creek have successfully increased channel capacity and repaired levee damage, while maintaining a low-flow channel to permit fish passage. Large boulders and stumps were placed to create scour holes and provide resting habitat. Compacted gravel areas on spawning riffles were ripped to improve spawning habitat. A boulder weir was placed across the channel immediately downstream of the Stanford-Vina Dam to restrict flow and raise the water surface about 2 feet. This caused a more favorable water surface elevation at the entrance to the two fish ladders. Specific fisheries habitat restoration or enhancement projects can usually be completed during flood maintenance operations at little additional cost.

Related actions that may impede or augment the action: With anticipated reductions in state and federal budgets, local government and land owners may plan a larger role in future flood management activities, such as limited removal of invasive vegetation or protection of eroding banks on private property. This could make inclusion of fish habitat improvements more difficult. DFG and other agencies should work with local land owners to exclude cattle from the creek channel, especially in important spawning and rearing areas. This will help to maintain the integrity of stream banks as well as protect fish habitat.

Agency and organization roles and responsibilities: DWR, DFG, the Corps, the Reclamation Board, and Tehama County should continue to work together to make flood management projects more fish friendly.

Potential obstacles to implementation: Future agency personnel, local government, and land owners must be willing to work together to minimize fishery impacts of flood management activities.

Predicted benefits: It is impossible to predict specific increases in fisheries habitat or increased numbers of fish due to this project; however, if we can reduce damages due to flood maintenance activities, and perhaps actually increase fishery habitat by these activities, this will contribute measurably to the overall goal of doubling anadromous fish populations in Deer Creek.

Stony Creek -

Limiting factors and potential solutions - Table 3-Xb-12 lists key limiting factors for chinook salmon in Stony Creek and potential solutions.

Table 3-Xb-12. Key limiting factors for chinook salmon in Stony Creek and potential solutions to those problems.

Limiting factors	Potential solutions
Stream channel blocked at the GCID's canal intersection	Install siphon under Stony Creek at intersection
Insufficient water flow for all life stages	1. Adjust management of Black Butte Reservoir 2. Positive operation of the constant head orifice at TCC 3. Reduce diversions 4. Conduct IFIM
Poor spawning habitat	1. Modify gravel extraction permits 2. Add spawning sized gravel 3. Excavate distinct stream channel
High water temperatures for all life stages	1. Excavate discrete stream channel 2. Develop riparian canopy
Entrainment of fish and reduction of instream flow at the constant head orifice	1. Terminate reverse operation 2. Develop replacement sources of water
Insufficient riparian habitat	Develop a plan to establish riparian corridor

Limiting factors	Potential solutions
Potential passage and entrainment at North Diversion Dam	Correct problems associated with fish passage and entrainment
Questionable water quality	Conduct water quality monitoring

Migration barriers

Glenn-Colusa Irrigation District (RM 3) - Major challenges for Stony Creek restoration are fish passage and water flow enhancement at its intersection with the Glenn-Colusa Canal. During the irrigation season, the GCID constructs a gravel levee across Stony Creek at RM 3 as part of the eastern sidewall of the canal. The barrier is usually in place from April through November. It is removed during winter to allow potential high flows to pass down Stony Creek to the Sacramento River. In past years, the barrier has been in place year round, preventing flow to the Sacramento River and hence precluding the movement of salmon into the creek. After the levee is constructed, juvenile salmon that have moved from the Sacramento River into Stony Creek for rearing become stranded in residual pools below the levee or are entrained into the canal above the levee. In spring 1994, the temporary levee was erected in late February and an estimated 5,000 to 10,000 juvenile salmon were left stranded in the creek (Maslin and McKinney 1994). Adult chinook salmon were observed spawning in Stony Creek only once, in 1982, since the GCID's levee has been in place (Reavis 1983). That was in a year with early and above-normal precipitation, when passage at the levee was possible.

Tehama-Colusa Canal (RM 12) - Temporary passage problems may be occurring when water is diverted from Stony Creek to the TCC. During 1992 and 1993, a temporary gravel training dike and diversion dam were created across Stony Creek so that water could be diverted into the TCC (Brown 1994). This causes fish passage problems and reduces flow downstream. Brown (1994) documented resident and outmigrating fish were entrained by this diversion.

The TCC is equipped with a siphon under Stony Creek. Stony Creek water is diverted into the TCC via reverse operation of a constant head orifice. The original purpose of this diversion was to provide water from the TCC to Stony Creek to enhance salmon production as partial mitigation for operation of the RBDD. It is ironic that the constant head orifice is now used to divert Stony Creek water into the TCC. TCC demand for Stony Creek water occurs in spring and fall and is a result of the recent change in operation of the RBDD to facilitate fish passage on the Sacramento River. The gates-closed period for the RBDD has been shortened to 4 months, leaving unmet irrigation demand both before and after.

The USBR has applied for a permanent diversion permit for this site. California Sport Fishing Alliance (CalSPA) filed a protest to this application. As a result of negotiations, CalSPA agreed to withdraw its protest if the USBR met certain conditions. Among these the USBR commitments is the formation of a task force, technical team, and work plan for development of a long-term fish, wildlife, and water use management plan for Stony Creek. The creation of the task force could be a pivotal event in the restoration of Stony Creek.

North Diversion Dam (RM 18) - Potential fish passage problems may occur at the Orland Unit Water Users Association's North Diversion Dam. No fish passage facilities exist at this structure. In a study conducted in 1981-1982, 30+ salmon and redds were observed downstream of the dam, suggesting passage problems (Reavis 1983). Nick Villa (pers. comm.) reports that the North Diversion Dam is a migration barrier under most flow conditions.

Black Butte Dam (RM 24) - Built for flood control in 1967, Black Butte Dam has no provision for fish passage. Secondary uses of Black Butte Reservoir include recreation and water storage for the Orland Unit Water Users Association and the CVP.

Stony Gorge Dam (RM 45) - Stony Gorge Dam, located 45 miles upstream from the Sacramento River confluence, was built with no fish passage facilities. The dam supports irrigation needs of the Orland Unit Water Users Association. Prior to the closing of Stony Gorge Dam, Stony Creek supported "very good" populations of chinook salmon (Clark 1929). Subsequently, the native runs have become extinct. Most of Stony Creek's historical salmon spawning most likely occurred upstream of RM 45.

East Park Dam (RM 63) - East Park Dam is located on Little Stony Creek, 18 miles upstream of Stony Gorge Dam, and has no fish passage structures. Investigations by Kondolf and Swanson (1993) indicate that much of the gravel recruitment to Stony Creek originated from Little Stony Creek.

Instream flow - Ideally, all diversions would be eliminated, allowing the stream to return to a natural state. However, this scenario would be difficult to achieve both politically and economically. It is felt that Stony Creek could contribute to doubling salmon in the Sacramento River system without removal of all dams or diversions. Contributions can be achieved below Black Butte Dam. Regulating water releases from Black Butte Dam and the Tehama-Colusa Canal will aid in ascertaining escapement goals. Considering the artificial nature of the stream below Black Butte Dam, utilization of this structure to enhance the remaining habitat is of utmost importance. A need exists to develop a water release schedule for Black Butte Dam to benefit salmonids, while not infringing on flood control capabilities. Stony Creek would also benefit from supplemental releases from the TCC, and a water release delivery schedule would need to be developed for that structure. Releases need to provide suitable flows for attraction, migration, spawning, incubation, rearing, and outmigration, while ensuring that fish or redds are not left stranded. An IFIM study should be conducted to determine the best flows.

Spawning habitat - Limited usable spawning gravel exists in Stony Creek. The Black Butte Dam precludes the recruitment of gravel to lower Stony Creek, and what remains is being removed or embedded by gravel mining operations. Based on surveys of Stony Creek in the past (Puckett 1969) and more recent informal ones by the USFWS, gravel for spawning is considered very poor but still usable. Additions of spawning-sized gravel to Stony Creek and improvement of gravel mining operations would benefit salmon production.

The creation of a discrete channel below Black Butte Dam would provide the best use of the available water. Historically, the portion of Stony Creek below RM 24 was broad, shallow, and braided (Kondolf and Swanson 1993) and probably did not support salmon spawning consistently. Black Butte Dam now blocks passage to the higher elevations, but it can also provide cooler water and damping of flow extremes to the downstream portion of Stony Creek and thus provide some salmonid habitat. Given time, the proper flow regime will, by itself, create and maintain an appropriate channel; however, this process can be greatly accelerated by the design and excavation of a creek channel.

A single creek channel would alleviate passage problems at various flows; increase water velocity as needed for attraction, spawning, incubation, rearing and emigration; reduce water temperatures; and aid in establishing a riparian corridor.

Diversions

Glenn-Colusa Irrigation District - Potential entrainment of juvenile salmon behind the GCID's levee exists, particularly in wet years. When sufficient creek flows exist, salmonids move up from the Sacramento River to rear in Stony Creek and can be found up to the GCID's canal crossing. Juvenile salmonids become entrained when closing of the levee occurs before they emigrate.

Tehama-Colusa Canal - Resident and outmigrating fish are entrained into the TCC when flows are diverted (Brown 1994). Potential for entrainment exists if salmon spawning were to occur above this point.

North Diversion Dam - Salmon have not been observed above the North Diversion Dam in recent years, so entrainment is unlikely at this time. However, if passage issues are resolved, the potential for entrainment then becomes an issue because this diversion is not screened.

Riparian habitat - Many areas are nearly devoid of riparian vegetation, especially near gravel mining operations. This is apparent at the Highway 32 bridge. In some areas, orchards grow up to the stream margins and cows graze at the stream bank. Some eroded banks have been riprapped. A riparian canopy and streamside vegetation would reduce water temperatures, lower sedimentation, and provide terrestrial insects as an additional food source for juveniles.

Water temperature - High water temperature is a potential limiting factor in Stony Creek for all life stages. Human influence on water temperature should be controlled or minimized to benefit anadromous fish. Human-related activities have reduced the riparian canopy and its associated thermal benefits. Additionally, impoundment of water behind reservoirs elevates water temperature. Reestablishment of a riparian corridor and lower level releases of water from reservoirs will assist in moderating water temperatures.

Water quality - Other factors that limit salmonid spawning and survival include high turbidity, agricultural chemicals run-off, low oxygen levels, and otherwise poor water quality. These issues need further investigation.

Restoration actions -

Action 1: Install siphon under Stony Creek for GCID's canal.

Objective: Provide all life stages of fish passage, and prevent entrainment of juvenile salmonids.

Location: GCID's canal (RM 3).

Narrative description: A major challenge for the restoration of Stony Creek is passage of fish and water flow through the Glenn-Colusa Canal. During the irrigation season, the GCID constructs a gravel levee across Stony Creek at RM 3 as the eastern sidewall of the canal. The barrier is usually in place from April through November. It is removed during the month. In past years, the barrier has been in place year round, preventing flow to the Sacramento River and hence precluding the movement of salmon into the creek. After the levee is constructed, non-natal juvenile salmon that move from the Sacramento River into Stony Creek for rearing become stranded if caught below the levee or entrained to the GCID's canal if above the levee. In spring 1994, the gravel levee was erected in late February and an estimated 5,000 to 10,000 juvenile salmon were left stranded in the creek (Maslin and McKinney 1994). Since the GCID's levee has been in place, adult chinook salmon were observed spawning in Stony Creek only once, in 1982. That was in a year with early and above-normal precipitation, making passage at the levee possible.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG should work with GCID to construct a siphon under Stony Creek. The construction of a siphon, including associated structures, is estimated to cost $3.4 million (CH2M Hill 1994). GCID is supportive and desires to pursue this option (Clark pers. comm.).

Potential obstacles to implementation: If funding is not provided, this action may not be possible.

Predicted benefits: Restoration of Stony Creek will not occur without resolution of fish passage and necessary flow releases at the GCID's canal. The success of all other recommendations depends on resolving these two major issues. If they are not resolved, a salmon run cannot be re-established in Stony Creek. In 1982, when fish and water had passage at GCID, 393 adult salmon were estimated to spawn in Stony Creek (Reavis 1983). Potentially 24 miles of salmonid habitat would become available if passage is allowed at this structure.

Action 2: Develop water management release strategy for Black Butte Dam.

Objective: Provide adequate water flows.

Location: Black Butte Dam (RM 24).

Narrative description: Built for flood control in 1967, Black Butte Dam does not include provision for fish passage. Secondary uses of Black Butte Reservoir include recreation and water storage for the Orland Unit Water Users Association. Black Butte Dam blocks access to historical spawning habitat for chinook salmon and steelhead in Stony Creek. Consequently, the only potential anadromous fish habitat is now below the dam. The Corps manages Black Butte Reservoir for flood control. Flood peaks have been reduced to a fraction of pre-dam values (from 70% for Q2 to 25% for Q50) (Kondolf and Swanson 1993).

Related actions that may impede or augment the action: Even though there has been a reduction in peak flow and the duration of flow has increased, releases could potentially have a negative effect on salmon. Prolonged flows at sufficient discharge could attract salmon to migrate up Stony Creek, only to be left stranded when the water is "turned off". Similar situations could occur at any life stage. An IFIM study should be initiated after implementation of provisional salmon restoration flows.

Agency and organization roles and responsibilities: DFG and USFWS must work with the Corps to better manage water releases from Black Butte Dam for salmonids. Historically, an average of approximately 50,000 af is released from Black Butte Reservoir from October to May of each year (Yaworsky pers. comm.). These releases could provide an average daily release of, at least, 150 cfs with higher spikes serving as migration cues. Professional opinions of the staff at the USFWS's Northern Central Valley Fishery Resource Office recommend a daily average of 150 cfs as sufficient flow for attraction, migration, spawning, incubation, rearing, and outmigration. The October to May dates coincide with fall-run and late fall-run salmon spawning and rearing.

Water releases from Black Butte Dam need to be coordinated with those from Stony Gorge and East Park Reservoir.

Potential obstacles to implementation: There should be no major obstacles to implementing this action.

Predicted benefits: A sufficient and timely flow of water in Stony Creek should encourage salmon to utilize the stream for spawning through outmigration. Up to 24 miles of spawning and rearing habitat could be made available.

Action 3: Develop water management strategy for TCC releases.

Objective: Provide adequate water flows.

Location: Tehama-Colusa Canal (RM 12).

Narrative description: Water for Stony Creek could be supplied via the TCC. The TCC was built with a turnout to provide water to Stony Creek for mitigation of fish loss caused by the RBDD (USFWS 1967).

Related actions that may impede or augment the action: Mitigation for the RBDD was to provide water to Stony Creek via TCC, at a minimum of 100 cfs per day and up to 500 cfs per day (USFWS 1967); this mitigation commitment has not been met. On occasion, water has been supplied to Stony Creek via the TCC (Kelly pers. comm.), but it was never intended to benefit anadromous fish in Stony Creek. The amount and timing of release would depend on those releases from Black Butte Dam.

Agency and organization roles and responsibilities: DFG should work with the USBR to develop trades or transfers of TCC water that could be made in an effort to obtain water higher up in the system (i.e., Black Butte Dam).

Potential obstacles to implementation: There should be no major obstacles to implementing this action.

Predicted benefits: Twelve miles of potential spawning habitat could be made available, providing habitat for many additional spawners.

Action 4: Modify gravel extraction permits.

Objective: Provide suitable spawning habitat.

Location: Entire stream.

Narrative description: Gravel mining should cease in Stony Creek. Black Butte Dam precludes the recruitment of new gravel, and mining is removing residual gravel.

Related actions that may impede or augment the action: Mining within the creek should be restricted to May through October, a time when salmon are less likely to be present in the stream. Access would be limited to only a few sites in order to protect the riparian habitat. Permits could be modified with provisions that ensure that gravel from 1 to 6 inches in diameter is left in the stream.

Agency and organization roles and responsibilities: Other sources of gravel for the current mining operations should be sought. Kondolf and Swanson (1993) identified gravel sources in the immediate area. Other potential gravel sources include the heads of reservoirs on Stony Creek or mining laterally to the creek channel. Mining permits could be purchased from extraction companies, or companies could be assisted in relocating operations. Discharge of fine sediments should be regulated with assistance from the Corps.

Potential obstacles to implementation: DFG should work with the permitting agency for gravel removal, the Glenn County Planning Commission, to complete preparation of a management plan for gravel mining aimed at reducing impacts on fish.

Predicted benefits: Reformed gravel mining activities will help to ensure that spawning-sized gravel remains in the stream, sedimentation of existing gravel is reduced, riparian habitat is protected, and moderate water temperatures are attained.

Action 5: Add spawning gravel to the Stony Creek.

Objective: Provide suitable spawning habitat.

Location: Below North Diversion Dam (RM 18), below TCC (RM 12), or other.

Narrative description: Suitable spawning habitat for salmon is lacking in Stony Creek. Black Butte Dam prevents recruitment of new gravel, and mining companies are removing or embedding the existing spawning gravel. Because of this, spawning-sized gravel needs to be placed in the creek. Placement of gravel below the North Diversion Dam is selected because passage at this dam is questionable and any gravel placed above the North Diversion Dam could eventually settle into the reservoir. The last evidence of spawning salmon in the creek was just below the diversion dam, suggesting potential for successful spawning (Reavis 1983). Another option for the placement of gravel is below the TCC. This site is selected because in years that Black Butte Reservoir is unable to supply a sufficient amount of water, diversions could be made from the TCC.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG should work with the Glenn County Planning Commission. Permits could be modified to require mines located on the creek to leave gravel of 1-6 inches in the river or provide gravel for reintroduction to the streambeds.

Potential obstacles to implementation: The success of this action depends on the success of Action 4, modifying or eliminating gravel mining in the streambed.

Predicted benefits: Providing spawning-size gravel should increase the usable spawning area and increase the survival of eggs produced in this stream.

Action 6: Develop a distinct creek channel.

Objective: Provide suitable spawning habitat.

Location: From Black Butte Dam downstream.

Narrative description: The creation of a distinct creek channel below Black Butte Dam would provide the best use of the available water for spawning chinook salmon. Historically, the portion of Stony Creek below Black Butte Dam was fanlike, shallow, and braided (Kondolf and Swanson 1993) and probably did not support spawning salmon. With appropriate management of the reservoirs now extant on Stony Creek, this reach could provide spawning and rearing habitat for fall-run and perhaps late fall-run chinook salmon.

Related actions that may impede or augment the action: A distinct creek channel would alleviate passage problems at various flows. Increased water velocities are needed for attraction, migration, incubation, rearing, and outmigration; regulated lower water temperatures are necessary; and the establishment of a riparian corridor is required. Well-defined creek channels exist below Black Butte Dam and in the area of the Highway 32 bridge resulting from the effects of the dam and gravel mining, respectively (Kondolf and Swanson 1993). Nonnatal rearing habitat occurs in the lower 3 miles of the creek (Maslin and McKinney 1994, Brown 1994), and care should be taken to avoid negatively affecting this function.

Agency and organization roles and responsibilities: DFG and USFWS and other appropriate agencies need to coordinate and fund channel restoration. It is an established technology (Rosgen 1991). It would require substantial excavation and revegetation activity within the existing streambed.

Potential obstacles to implementation: Funding, coordination, and cooperation between key organizations and land owners are important to the success of this action.

Predicted benefits: Some of the benefits in developing a distinct creek channel include alleviating some passage problems, moderating water temperatures, enhancing the riparian corridor, sorting substrate, and cleaning gravels.

Action 7: Develop plan to establish riparian corridor.

Objective: Provide suitable water temperature.

Location: From Black Butte Dam to mouth.

Narrative description: A riparian corridor of native vegetation needs to be established. Because of gravel mining operations, many areas along the stream are nearly devoid of riparian vegetation. This is apparent at the Highway 32 bridge. Exotic plant species such as false bamboo have taken over many disturbed areas. In other areas, orchards grow up to the stream margins and cows graze at the stream bank. Eroded banks have been stabilized with riprap. A riparian canopy would help moderate water temperature, control erosion, and increase terrestrial insects for juvenile salmonids. A healthy riparian corridor will also provide diverse habitat and help maintain lower water temperatures. A plan needs to be developed for the establishment of a riparian corridor. Included in the plan should be provisions for protecting existing riparian habitat, planting native species, removing exotic species, developing a distinct creek channel, and modifying Black Butte Dam releases.

Related actions that may impede or augment the action: All of these provisions should be considered for the creek below Black Butte Dam, and some may be worthwhile to consider above the reservoir. The Nature Conservancy has an office near the mouth of Stony Creek and may have an interest in becoming involved. Additionally, land owners need to be educated on the benefits of riparian corridors and how to establish and maintain them.

Agency and organization roles and responsibilities: DFG and USFWS need to develop a comprehensive technical plan to establish riparian corridors and coordinate riparian corridor rehabilitation and acquisition with private land owners.

Potential obstacles to implementation: Funding and available agency staff could be limiting factors in successfully completing this action.

Predicted benefits: Developing a plan to establish a riparian corridor will help moderate water temperatures and enhance and preserve the existing salmonid habitat. The increase of riparian habitat will also benefit other fish and wildlife.

Action 8: Discontinue diversions into the TCC.

Objective: Alleviate passage problems, ensure adequate flows, and prevent entrainment.

Location: Tehama-Colusa Canal (RM 12).

Narrative description: Temporary passage problems occur when water is diverted from Stony Creek to the TCC. During 1992 and 1993, a dam was created across Stony Creek so water could be diverted into the TCC via reverse operation of the constant head orifice. This affects fish passage and reduces downstream flows. Brown (1994) documented entrainment of resident and outmigrating fish by this diversion. This diversion was temporarily permitted for 1992 and 1993. The USBR has applied for a permanent diversion permit. CalSPA protested this application. As a result of negotiations, CalSPA agreed to withdraw its protest if the USBR met certain conditions. Passage problems are likely, and water for attraction, migration, spawning, and rearing of salmonids in Stony Creek is lost. Diverting water into the TCC entrains resident and outmigrating fish and would undoubtedly entrain juvenile salmon.

Related actions that may impede or augment the action: Among USBR's commitments is the formation of a task force and technical team, as well as a work plan for development of a long-term fish, wildlife, and water use management plan for Stony Creek.

Agency and organization roles and responsibilities: DFG should coordinate the formation of a task force to manage the restoration of Stony Creek. Unmet demand for this seasonal water should be met through other means, otherwise alleviated, or left unmet.

Potential obstacles to implementation: None.

Predicted benefits: Cessation of this diversion would make more water available for fish in Stony Creek, alleviate potential passage problems, and eliminate salmonid entrainment at this site.

Action 9: Correct problems associated with North Diversion Dam.

Objective: Provide fish passage for all life stages, provide adequate flows past dam, and prevent entrainment.

Location: North Diversion Dam (RM 18).

Narrative description: The North Diversion Dam is considered to be a migration barrier under most flows (Nick Villa, DFG, Rancho Cordova, CA, per. comm.). The magnitude of the passage problem needs to be evaluated. A possible mechanism to allow fish passage at the North Diversion Dam would be to raise the gates as early as possible, preferably at the beginning of October. Flow is most critical from October to May, and diversions should be kept to a minimum. Raising the gates would allow fish easier access to additional spawning habitat. If passage problems persist, a fish ladder could then be constructed. If fish do spawn above the North Diversion Dam, the potential for entrainment would exist.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: Entrainment could be reduced if diversions were kept to a minimum. DFG should initiate discussions with the USBR to minimize diversions from December until February, the time at which most fry would hatch and then emigrate from this section of the stream. Screening the diversion is also an option that must be evaluated.

Potential obstacles to implementation: None.

Predicted benefits: Potentially, 6 miles of stream will become available for spawning if passage is ensured.

Action 10: Develop plan to assess water quality.

Objective: Ensure adequate water quality for all life stages.

Location: Entire creek.

Narrative description: The water quality of Stony Creek is poor. Toxicants from agricultural runoff, elevated turbidities from gravel mining, and rubbish are just some of the problems.

Related actions that may impede or augment the action: Water quality may be a larger limiting factor than expected.

Agency and organization roles and responsibilities: A plan should be developed to assess water quality and develop solutions. DWR or EPA should conduct an assessment of Stony Creek.

Potential obstacles to implementation: None.

Predicted benefits: Assessing water quality will provide an indication of creek health, identify problems, and define cleanup solutions.

Action 11: Conduct an IFIM study.

Objective: Determine preferred water flows for all life stages.

Location: From Black Butte Dam to mouth.

Narrative description: Management of minimum flow releases from Black Butte Dam are necessary for anadromous fish production.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG and USFWS should conduct an IFIM study to determine the proper amount and timing of water released by Black Butte Dam and the TCC.

Potential obstacles to implementation: None.

Predicted benefits: An IFIM study will estimate the required flows necessary to sustain anadromous fish production.

Big Chico Creek -

Limiting factors and potential solutions -

Loss to flood and agricultural diversion - A significant problem affecting the Big Chico Creek anadromous fishery results from diversions at the M&T Ranch pumps located at the end of a forebay just downstream of the Chico-Mud Creek confluence (Paul Ward, DFG, Red Bluff, and Paul Maslin, CSU, Chico, pers. comms.). The five unscreened pumps at this diversion have a combined pumping capacity of approximately 135 cfs, which often exceeds the creek flow. The resultant reversal of flow in the lower 0.75 mile of creek would be expected to divert outmigrant juveniles and make it unlikely that upstream migrating adults will find the creek. (See discussion under "Upstream passage of adults".) Even when the creek is not reversed, these unscreened pumps are believed to take many juvenile salmon, both from Big Chico Creek and from the Sacramento River, because many juveniles move into the lower ends of Chico, Mud, and Rock Creeks for rearing (Maslin and McKinney 1994). The M&T Ranch has been cooperating in trying to find alternative water and leave the pumps off at critical times (Herringer pers. comm.). However, data obtained by Julie Brown (pers. comm.) and Maslin and McKinney (1994) show that critical times are more extensive than originally thought and vary from year to year.

At the Five-Mile Recreation Area (Bidwell Park), a 1963 Corps flood control project splits Big Chico floodflows into three channels. This project provides flood protection for the city of Chico. Box culverts were designed to limit the maximum flow that can pass down Big Chico Creek and Lindo Channel to 1,500 cfs and 6,000 cfs, respectively. Flow in excess of 7,500 cfs spills over an open weir through the Sycamore Diversion into Mud Creek. DWR is currently investigating whether the high-flow split still meets design capacity. A base flow split was also designed into the 1963 flood control project. The combined width of the box culverts in the Big Chico channel is 20 feet. A low concrete weir, with a 12-foot-wide notch at the same elevation as the bottom of the Chico box culverts, was constructed across the channel leading to the

Lindo Channel box culvert and Sycamore weir. This design was intended to split 12/32 of base flow down Lindo Channel, leaving 20/32 in Big Chico Creek. Unfortunately, design of the flow control structures creates an upstream stilling basin during flood events. This causes gravel to fall out above the diversion, creating a gravel bar that blocks subsequent low flow to Lindo Channel unless gravel is mechanically removed following each high water event. Because of variability in size and shape of the gravel bar, the minimum total flow that still has some spillage down Lindo Channel varies. Lindo Channel has often ceased to flow while total flow was still in excess of 200 cfs, sometimes trapping adults and downstream migrants several times during a single season.

Upstream passage of adults - When flow is reversed in the lower 0.75 mile of Big Chico Creek by The M&T Ranch pumps, upstream migrating adults are unlikely to find the creek. (See discussion under "Loss to Agricultural diversion".)

At about Stream Mile 13, in Upper Bidwell Park, Big Chico Creek has cut through the Lovejoy Basalt into softer marine sandstone, causing jumbles of house-size boulders to tumble into the channel, making upstream passage of salmonids difficult. The Iron Canyon fish ladder, built in the late 1950s to facilitate fish passage through this zone, has been severely damaged (Ward pers. comm.), delaying or preventing upstream migration in low-flow years and thereby forcing the adult spring-run salmon to hold or even oversummer downstream of the ladder where temperatures, human harassment, and poaching are serious problems.

The Five-Mile Recreation Area flood control project also delays or impedes upstream movement of adults. Downcutting (approximately 8 ft) immediately below the Lindo culvert has resulted in fracturing of the concrete apron, making fish passage difficult in situations other than high flows.

Poor spawning habitat in lower creek - The Five-Mile Recreation Area flood control project also impedes gravel movement downstream. Only reduced amounts of relatively small gravel pass the Big Chico box culverts, very little gravel passes through the Lindo box culverts, and no gravel passes over the Sycamore weir. Poor gravel recruitment and absence of flushing flows have resulted in armoring, compaction, and siltation of spawning gravel throughout the Chico channel. Cleaning of One-Mile Pool (a swimming pool in the Chico Channel) during summer low flows creates turbidity and silt build-up downstream, causing further deterioration of gravels. Present downstream siltation levels during pool cleaning exceed standards set up by the CVRWQCB. Lindo Channel is scoured to bedrock from the weir to the Longfellow Bridge, but still has good spawning gravel further downstream. The high flow volume of diverted Chico Creek floodwater has scoured essentially all gravel from Mud Creek downstream of the Sycamore Flood Diversion Channel.

Marginal summer holding temperatures - There is some evidence that temperatures in the summer holding reach for spring-run salmon adults, from Iron Canyon to Higgin's Hole, may approach critical levels in late summer, particularly in low-flow years (Ward pers. comm.). It is not known if summer temperatures currently average higher than existed historically when salmonids were more abundant in the creek. Possibly human-induced changes in the upper watershed (such as logging, development, grazing, and road building) may have altered base flow and summer temperatures. Because holding temperatures are marginal, any human harassment of the adults would be especially detrimental. Currently prime holding areas are in private ownership, with limited access. Future development of the land, resulting in greater public access, could have serious consequences for spring-run chinook salmon in Chico Creek.

Degraded rearing habitat in Mud and Rock Creeks - The principal anadromous fisheries reach of Mud Creek, from Highway 99E downstream, has been straightened, levied, and kept free of riparian vegetation by annual controlled burns or herbicide applications to facilitate its function as a flood diversion channel. Consequently, shade and cover are scarce, contributing to critically warm temperatures in late afternoons from mid-April through early May in most years. The high volume of diverted Chico Creek floodwater has also scoured this reach of Mud Creek to bedrock or clay, prohibiting salmonid spawning and further reducing diversity for rearing. To add to the problem for fish, existing regulations pertaining to riparian protection and waste disposal are poorly enforced with respect to Mud and Rock Creeks. Hazardous materials are often clandestinely dumped from bridges, particularly in Mud Creek, and some land owners along Rock Creek have damaged or eliminated riparian vegetation by bulldozing, burning, or spraying (Maslin pers. comm.).

Rock Creek has not been modified as a flood channel, but in several reaches has been straightened and levied to maximize agricultural land. These straight, canal-like reaches provide far less habitat for rearing salmonids than do unmodified reaches. Rock Creek receives sporadic inputs of agricultural overflow water between Highway 32 and West Sacramento Avenue. Under certain conditions, this may facilitate outmigration of juveniles.

Both creeks dry to intermittent pools as summer approaches. In years with adequate late-season precipitation, this occurs in May, by which time most juvenile salmon have outmigrated. In low precipitation years, the creeks dry down earlier and many young salmon, particularly fall-run juveniles, are trapped in isolated pools and ultimately devoured by avian predators.

Table 3-Xb-13. Key limiting factors for chinook salmon and steelhead in Big Chico Creek and potential solutions to those problems.

Limiting factors	Potential solutions
Loss to flood and agricultural diversion	1. Substitute an alternative source of irrigation water for that currently supplied by the M&T Ranch pumps or move the pumps to the river and screen them 2. Split low flows between Big Chico Creek and

Limiting factors	Potential solutions
	Lindo Channel
Upstream passage of adults	1. Repair the Iron Canyon Fish ladder 2. Repair the Lindo Channel weir and fishway 3. Substitute an alternative source of irrigation water for that currently supplied by the M&T Ranch pumps or move the pumps to the river and screen them
Marginal summer holding temperatures	Preserve from development and disturbance the primary summer holding area for spring-run chinook salmon to minimize additional stress
Poor spawning habitat in lower creek Degraded rearing habitat in Mud and Rock Creeks	1. Replace spawning gravel in the channels modified for flood control 2. Improve cleaning procedure at One-Mile Pool 1. Revegetate denuded stream reaches 2. Restore a protected riparian strip

Restoration actions -

Action 1: Substitute an alternative source of irrigation water for that currently supplied by the M&T Ranch pumps.

Objective: Prevent loss of juvenile salmonids and permit sufficient attraction flows for adults.

Location: Just downstream of the Chico-Mud Creek confluence.

Narrative description: Four options exist: 1) the pumps could be moved to the river, set up to have bypass flow, and screened; 2) a siphon could be installed to carry Feather River water across Butte Creek and the pumps eliminated; 3) the irrigation water could be replaced with groundwater and the pumps eliminated; and 4) effluent from the Chico Municipal Sewage Treatment Plant, although inadequate for total needs, could be discharged into irrigation canals to supply water needs during low demand periods and to supplement other sources at high demand periods. Because versatility in water delivery systems permits water from the M&T Ranch pumps, Butte Creek, the Feather River, or the Chico Municipal Sewage Treatment Plant to be delivered to a range of users, and because all sources except the sewage plant have their own share of problems with anadromous fisheries, the problem should be approached on a regional basis, rather than a watershed basis. A combination of options 1, 2, and 4 would probably provide the best long-range management for anadromous fisheries in Big Chico Creek, Butte Creek, and the Sacramento River. DFG is currently negotiating with water users to determine the best overall solution. Active pursuit of this negotiation should be continued by DFG, DWR, USFWS, the USBR, the M&T Ranch, and Western Canal Water District (WCWD).

Related actions that may impede or augment the action: Improvement of the pumping situation at the mouth of Big Chico Creek would positively affect all actions that concern Big Chico Creek and its tributaries; therefore, it should be a priority.

Agency and organization roles and responsibilities: DFG is currently negotiating with water users to determine the best overall solution. Active pursuit of this matter should be continued by DFG, DWR, USFWS, the USBR, the M&T Ranch, and the WCWD.

Potential obstacles to implementation: Costs of building a siphon, pumping groundwater, or moving and screening pumps could be an obstacle.

Predicted benefits: The present loss to these pumps of juvenile chinook salmon from both the Big Chico Creek fishery and the Sacramento River fishery would be prevented or at least reduced; Chico Creek adults would have an increased chance of finding the creek. Recent estimates of the numbers of adult salmon entering Chico Creek do not exist, but 26 adults were observed during a spring-run survey conducted in 1993. This number could reasonably be expected to at least double, as Chico Creek historically supported thousands of spring-run, fall-run, and late fall-run chinook salmon (Yoshioka pers. comm.).

Action 2: Repair the Iron Canyon Fish ladder.

Objective: Facilitate movement of adult spring-run chinook salmon and steelhead to favorable summer holding habitat.

Location: Iron Canyon upstream of Salmon Hole (Upper Bidwell Park).

Narrative description: The severely damaged Iron Canyon fish ladder should be repaired. The responsible agency is DFG, which plans to complete this project in summer 1995.

Related actions that may impede or augment the action: This action would be augmented by Action 5 (constructing a fishway at the Lindo Channel box culvert at the Five-Mile Diversion).

Agency and organization roles and responsibilities: DFG plans to complete this project in summer 1995.

Potential obstacles to implementation: Cost of the project may be an obstacle.

Predicted benefits: More rapid movement through this area, particularly in years of low flows, will reduce stress and increase survival of spring-run salmon and steelhead adults.

Action 3: Split low flow between Big Chico Creek and Lindo Channel.

Objective: Minimize trapping and subsequent loss of both adult and juvenile salmonids from periodic dewatering of Lindo Channel.

Location: At the divergence of Big Chico Creek and Lindo Channel.

Narrative description: Two options exist for maintaining a minimum flow down Lindo Channel: 1) existing gates in the Big Chico box culverts at Five-Mile Diversion could be modified to permit operation under hydraulic head and adjusted as needed by city personnel to keep a suitable flow split and 2) city personnel could mechanically remove gravel deposits after each storm event. Because of infiltration losses in both channels at times when groundwater is low, a minimum of 75 cfs should be maintained in Big Chico Creek during March through May to facilitate upstream passage of adults. In critical low-flow years, sufficient water would not be available to maintain flow in Lindo Channel and fish would be lost. Unfortunately, flood control considerations preclude simply cutting off one channel or the other.

Related actions that may impede or augment the action: This action would be augmented by Action 8. If DWR determines the amount of riparian vegetation compatible with flood passage and salmon survival in Mud Creek, this information might be used or modified for Lindo Channel.

Agency and organization roles and responsibilities: The responsible agencies are the City of Chico and California DWR.

Potential obstacles to implementation: The need for gravel removal after storm events may be an obstacle.

Predicted benefits: Because many spring-run chinook salmon and steelhead juveniles and some adults travel by way of Lindo Channel, their survival would be enhanced. Survival of fall-run and late fall-run salmon redds and rearing fry in Lindo Channel would also be improved.

Action 4: Replace spawning gravel in the channels modified for flood control.

Objective: Improve spawning habitat for fall-run and late fall-run chinook salmon.

Location: In both Big Chico and Lindo Channels from the Five-Mile Diversion downstream through the city of Chico.

Narrative description: Gravel trapped at the Five-Mile Diversion stilling basin should be sorted and cleaned if necessary and moved to strategic locations downstream. This action should be executed by the Chico Parks Department and overseen by DFG.

Related actions that may impede or augment the action: This action could be augmented by Action 6 (improving of the cleaning procedure of One-Mile Pool) if gravel from Five-Mile Diversion was added downstream of One-Mile Pool

Agency and organization roles and responsibilities: This action should be executed by the Chico Parks Department and overseen by DFG.

Potential obstacles to implementation: Costs of personnel and equipment required to sort, clean, and move the gravel could be obstacles.

Predicted benefits: Spawning success will be improved for fall-run and late fall-run chinook salmon.

Action 5: Repair the Lindo Channel weir and fishway.

Objective: Facilitate upstream passage of spring-chinook salmon and steelhead from Lindo Channel.

Location: At the Lindo Channel box culvert at the Five-Mile Diversion.

Narrative description: The downstream apron should be regrouted and a fishway constructed.

Related actions that may impede or augment the action: This action would be augmented by Action 3 (splitting flow between Big Chico Creek and Lindo Channel).

Agency and organization roles and responsibilities: Planning and execution of this action should involve a collaboration between DFG, DWR, and the Corps.

Potential obstacles to implementation: Cost of building the fishway could be an obstacle.

Predicted benefits: Fewer adult spring-run chinook salmon and steelhead will be lost in Lindo Channel.

Action 6: Improve cleaning procedure at One-Mile Pool.

Objective: Reduce siltation of downstream spawning and rearing habitat.
Location: One-Mile Dam in Chico.

Narrative description: The following alternative approaches have been presented to the city (Swanson 1994): 1) remove the swimming pool and dam and restore the natural stream and 2) modify the dam and divert stream flow during pool cleaning.

Related actions that may impede or augment the action: None known.

Agency and organization roles and responsibilities: The responsible group for this action is the city of Chico.

Potential obstacles to implementation: Costs of modifying the dam for diversion during cleaning and public protest over removing the pool are potential obstacles to implementation.

Predicted benefits: Spawning success of fall-run and late fall-run chinook salmon would be enhanced because many spawn downstream of One-Mile Dam. Slight improvements in rearing habitat would also be expected.

Action 7: Preservation from development and disturbance of the primary summer holding area for spring-run chinook salmon.

Objective: Obtain title or conservation easement on land adjacent to primary summer holding pools for spring-run chinook salmon. This is especially important considering the marginal summer temperatures and possibility of residential development in those areas. Additional disturbance would cause significant mortality.

Location: Higgin's Hole downstream to the upper end of Bidwell Park.

Narrative description: Preservation can be accomplished by purchase of a conservation easement or purchase of the land.

Related actions that may impede or augment the action: None known.

Agency and organization roles and responsibilities: The USFWS and DFG should collaborate with local land owners and private conservation groups such as The Nature Conservancy in achieving this goal.

Potential obstacles to implementation: Costs of acquiring the land and the landowners's unwillingness to sell are potential obstacles to implementation.

Predicted benefits: This action would have minimum benefit in the immediate future, but is essential for continued long-term production of spring-run chinook salmon and steelhead in Big Chico Creek.

Action 8: Revegetate denuded stream reaches and restore and maintain a protected riparian strip.

Objective: Expand the usable habitat, provide habitat diversity and cover from predators, and shade to keep the water cooler in late spring.

Location: All Central Valley reaches of Rock and Mud Creeks, with special attention given to the reach of Mud Creek from the confluence of Sycamore Creek to the junction of Mud and Big Chico Creeks and the reach of Rock Creek from the Nord-Cana Highway to the Nord-Gianella Road.

Narrative description: Restore and maintain a natural riparian corridor. An educational campaign to dispense knowledge about the value of small tributaries as salmon habitat, coupled with more stringent enforcement of existing prohibitions on dumping and riparian destruction, should help significantly to preserve and restore tributary habitat. Recruitment of school groups and local conservation groups for cleanup, riparian planting, fencing, and other restoration projects would contribute both to education and direct restoration. Critical stream reaches might be preserved by purchase of conservation easements.

Related actions that may impede or augment the action: This action would be augmented by Action 9 (replacing gravel in the flood-diversion reach of Mud Creek), which would help to increase the overall habitat quality and diversity.

Agency and organization roles and responsibilities: Cooperation between DFG, DWR, and local conservation groups is essential. DWR will have to determine the amount of riparian vegetation compatible with flood passage and salmon survival in Mud Creek. Butte County must cooperate to allow that amount to remain while maintaining the channel.

Potential obstacles to implementation: Enforcing conservation laws may be difficult if there is a shortage of enforcement personnel.

Predicted benefits: Trees, roots, and stumps at the stream edge create eddy currents during flood. The eddies scour out the deep holes the young salmon need for survival in dry years. The trees also shade the stream, contributing to lower stream temperatures, while the roots and fallen branches provide cover for juveniles to escape from predators. Resultant habitat diversity supports many forms of aquatic foods, while terrestrial insects, falling into the water from overhanging vegetation, also contribute to the food base. Recruitment of school groups and local conservation groups for cleanup, riparian planting, fencing, and other restoration projects would contribute both to education and direct restoration.

Action 9: Replace gravel in the flood-diversion reach of Mud Creek.

Objective: Expand the usable habitat and provide habitat diversity for rearing salmon and their prey.

Location: The reach of Mud Creek from the confluence of Sycamore Creek to the junction of Mud and Big Chico Creeks.

Narrative description: Continual additions of gravel are required to compensate for scouring by the diverted Chico Creek floodwater. Gravel replacement would be necessary after each 10-year or larger flood event.

Related actions that may impede or augment the action: This action could be augmented by Action 4 (removing gravel trapped in the Five-Mile Diversion stilling basin and moving it to strategic locations downstream) if some gravel is placed in the flood-diversion reach of Mud Creek. This action would also be augmented by Action 8 (revegetate denuded stream reaches and restore and maintain a protected riparian strip).

Agency and organization roles and responsibilities: Responsible agencies are Butte County and DFG with supervision from DWR to ensure that flood transport capacity is not compromised.

Potential obstacles to implementation: Costs of continuous maintenance may be an obstacle to implementation.

Predicted benefits: Gravel replacement in Mud Creek would increase habitat diversity for rearing and permit adults straying into the creek to spawn successfully.

Future research needs - Further study is needed to determine if human-induced changes (such as logging, development, grazing, and road building) in the Big Chico Creek upper watershed may have altered base flow and summer temperatures, thereby making it hazardous for oversummering adult spring chinook salmon.

Thermographs have been installed by DFG at strategic points in Big Chico Creek to evaluate holding habitat for spring-run adults. Temperature data needs to be gathered over a number of years, preferably spanning both wet and dry periods.

Considering the paucity of available data for Big Chico salmonids, installation and monitoring of an adult counting device and a trap for outmigrants are needed.

Both Big Chico Creek and Lindo Channel receive storm drain runoff from the City of Chico, with its associated load of litter and pollutants. While this has not been implicated as a problem to the fishery, it should be monitored to ensure that no problem arises.

An investigation of the relationship of foothill diversions to downstream flow volume and water temperature in Mud and Rock Creeks would help with management decisions for those tributaries.

Butte Creek -

Limiting factors and potential solutions - Habitat needs within the Butte Creek system are complex and vary by area and time of year. Passage at dams and diversions, instream flows, and water temperature are the factors of most concern. Water rights in all of Butte Creek above the Western Canal Dam were adjudicated in 1942 (Butte Creek Judgment and Decree No. 18917). Additional issues that are more site specific include poaching, land development, and recreation (Table 3-Xb-14).

Table 3-Xb-14. Limiting factors for chinook salmon in Butte Creek and potential solutions to those problems.

Limiting factor	Potential solutions
Instream flows	1. Negotiate with PG&E to provide a minimum of 40 cfs below Centerville Diversion Dam at all times 2. Negotiate with water rights holders at Parrott-Phelan diversion (Diversion 50) to purchase or trade for right to water diverted from West Branch of Feather River (approximately 105 cfs), possibly as part of trade for relocation of M&T pumps on Big Chico Creek 3. Purchase existing water rights from diverters 4. Acquire water rights by replacement with Feather River water delivered through the Western Canal system as part of

Limiting factor	Potential solutions
	removal of up to five dams resulting from the proposed Western Canal siphon project 5. Adjudicate water rights and provide state Watermaster Service for the entire reach of Butte Creek on a year-round basis in conjunction with the existing adjudication 6. Initiate legal action to ensure adequate instream flows
Adult passage	
Centerville Diversion Dam	1. Remove Centerville Diversion Dam, Forks of the Butte Dam, and Butte Creek Head Dam 2. Build and maintain ladders over the Centerville Diversion Dam, Forks of the Butte Dam, and the Butte Creek Head Dam
Natural barrier 0.5 mile below Centerville Diversion Dam Durham Mutual Dam	1. Build and maintain fish ladder 2. Physically modify barrier to facilitate passage Build new high-volume fish ladder to replace existing ladders
Western Canal Dam	Remove dam and install siphon
Adams, Gorrill, McGowan, and McPherrin dams	1. Remove dam and provide alternate sources of water as part of Western Canal siphon project 2. Build new high-volume fish ladders if dam cannot be removed
Sanborn Slough bifurcation	Establish operational criteria for flow split either through existing legally binding agreements or as part of overall Butte Creek water

Limiting factor	Potential solutions
	right adjudication
White Mallard Dam	Replace existing fish ladder with new high-volume fish ladder
White Mallard Duck Club outflow	Install culvert and riser at the point that the outflow meets Butte Creek to eliminate straying
Drumheller Slough outfall	Rebuild and maintain existing culvert and riser at the point Drumheller Slough meets Butte Creek to eliminate straying
Butte Slough outfall	1. Develop operational criteria to provide continuous passage at outfall gates from February through June and October through December 2. Modify flap gates to allow upstream passage of adult salmon
East-West Diversion Weir	1. Establish operational criteria for timing and volume of flow splits between East and West Barrows 2. Install high-volume fish ladder
Sutter Bypass Weir #2	1. Establish operational criteria to specify dates of installation and removal of weir 2. Install high-volume fish ladder
Nelson Slough	Establish operational criteria to specify time and volume of flows through Nelson Slough
Sutter Bypass Weir #5	1. Establish operational criteria to specify time of installation and removal of weir 2. Install high-volume fish ladder

Limiting factor	Potential solutions
Sutter Bypass Weir #3	1. Establish operational criteria to specify time of installation and removal of weir 2. Install high-volume fish ladder
Sutter Bypass Weir #1	1. Establish operational criteria to specify time of installation and removal of weir 2. Install high-volume fish ladder
Juvenile Passage	
Durham Mutual Dam	Install fish screens on both diversions
Western Canal Dam Adams, Gorrill, McGowan, and McPherrin dams	Remove dam and install siphon 1. Remove dams and provide alternate sources of water as part of Western Canal siphon project 2. Install fish screens on gravity and pumped diversions if dams cannot be removed
Little Dry Creek pumps	Install fish screens
Sanborn Slough bifurcation	Install fish screen
White Mallard Dam	Install fish screen
Butte Slough outfall gates	Maintain positive flow into Sacramento River from October through December and January through June

Limiting factor	Potential solutions
Sutter Bypass, Butte Slough to Sacramento River	Investigate and screen diversions as necessary
Poaching	Increase enforcement effort throughout portion of Butte Creek accessible to anadromous salmonids
Land Use	1. Develop and enforce land use plans that create buffer zones between the creek and development 2. Develop watershed management plan

Restoration actions - The following action items are generally prioritized relative to their overall value for restoring habitat and enhancing anadromous fish production. Those actions having the same primary number configurations are considered of equal priority (e.g., ***1***[a] vs. ***1***[b]). Those actions having the same primary numbers and subletters (e.g., ***3[a]***[1] and ***3[a]***[2]) are also of equal priority. The subnumerals (e.g., 3[a]***[1]*** and 3[a]***[2]***) are meant to act only as action identifiers, not indicators of priority. However, differences in primary numbers and/or subletters are indicative of differences in relative priority (e.g., ***1***[a] vs. ***2***[a] or 3***[a]***[1] vs. 3***[b]***[1]). Many action items are interdependent and could therefore change in priority, depending on completion of other actions or additional information.

Action 1(a): Obtain rights to approximately 105 cfs of water from Parrott-Phelan Diversion.

Objective: Provide adequate instream flows for all life stages of salmonids.

Location: Parrott-Phelan Diversion.

Narrative description: Flow requirements within the Butte Creek system are a generic problem; however, they must be considered relative to site-specific requirements within the overall system and also by changing conditions during the year. There are generally no baseline studies to define fishery flow requirements within Butte Creek. The value of any additional water is increased by its location in the system. Additional water to increase instream flows includes a possible trade of rights to waters diverted by PG&E from the West Branch of the Feather River for power generation. The rights are currently owned by M&T and Parrott Ranches near Chico; however, alternate sources of water may be available as the result of a possible relocation of the M&T pumps, currently located on Chico Creek. Relocation of the M&T pumps, coupled with an increased capacity, would allow about 105 cfs of West Branch Feather River water to remain in Butte Creek. Rights acquired at the top of the anadromous portion of Butte Creek, such as the rights to water diverted from the West Branch, are more valuable in resolving the overall issue than those that enter further down in the system.

Related actions that may impede or augment the action: DFG currently has an application before the SWRCB's Division of Water Rights to convey some recently acquired water rights from above the Western Canal to the Sacramento River. The water rights in priority, time, and volume generally are not available during the period most important for fishery needs. However, an important issue could be resolved relative to changing the point of use to the Sacramento River.

Agency and organization roles and responsibilities: DFG, DWR, and USFWS should plan and carry out baseline studies to define fishery flow requirements within Butte Creek. They should define base fishery flows by location and time of year and acquire rights to the defined amounts. Passage of the required amounts of water through the system to the Sacramento River must be guaranteed.

Potential obstacles to implementation: Success of this action depends on obtaining the necessary funding and staffing resources and cooperation of the many water right holders.

Predicted benefits: Providing additional water will increase the amount of available habitat for all life stages of salmonids, thus increasing the productivity of the creek.

Action 1(b): Maintain a minimum 40 cfs instream flow below Centerville Diversion Dam.

Objective: Provide suitable holding, spawning, and rearing habitat.

Location: Centerville Diversion Dam.

Narrative description: Temperature modeling and IFIM studies have been completed by PG&E to define flow requirements for summer holding and spawning for spring-run salmon in the reach between the Centerville Diversion Dam and the Centerville Powerhouse. These studies indicated a need for a minimum of 40 cfs for summer temperature control and a minimum of 40 and 30 cfs for spawning and egg incubation, respectively (Steitz pers. comm.). As a result of these studies and additional negotiations with the resource agencies, FERC adopted in January 1992 a 40-cfs minimum flow between December 15 and October 31 and a 30-cfs minimum flow between November 1 and December 14 during normal water years.

During dry years, however, the FERC license adequately addresses only summer flows (40 cfs minimum between June 1 and September 15) with a low 10-cfs minimum required the rest of the year. This 10-cfs minimum is considered inadequate for adult spawning and juvenile rearing. Therefore, a flow regime similar to that required for normal water years should also be required for dry years.

Related actions that may impede or augment the action: In several recent dry years, PG&E has accommodated resource agency requests to provide additional flows (up to 30 cfs) for salmon spawning and egg incubation. These actions suggest that PG&E recognizes the need for additional minimum flows during dry years and may be open to further negotiations on this issue.

Agency and organization roles and responsibilities: DFG and USFWS should open negotiations with PG&E and FERC to obtain the necessary minimum flows needed to sustain adult spawning and juvenile rearing below the Centerville Diversion Dam during dry years.

Potential obstacles to implementation: PG&E is already providing nonmandated flows (30 cfs during dry years after September 15) and may be reluctant to provide these flows on a permanent legally binding basis.

Predicted benefits: Providing suggested water releases will ensure better holding and spawning conditions for spring-run chinook salmon. Additional benefits will also be afforded to rearing juvenile salmon and steelhead.

Action 1(c): Purchase existing water rights from diverters.

Objective: Ensure adequate instream flows.

Location: Any or all points of diversion.

Narrative description: Additional instream flow could come from purchasing water rights from willing sellers. Several water rights holders have expressed interest in selling. Additional water might be available through the Western Canal system and could potentially be acquired as a trade for other waters delivered through the SWP and Oroville Reservoir. When purchasing water, consideration should be given to site-specific requirements within the overall system and changing conditions during the year.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG and USFWS should initiate negotiations with water rights holders to purchase their water.

Potential obstacles to implementation: Success of this action depends on necessary funding and the cooperation of water rights holders.

Predicted benefits: Any additional water obtained will benefit the system by increasing the available salmon and steelhead habitat. Obtaining water higher up in the system will have greater benefits to the entire system.

Action 2(a): Build a new high-volume fish ladder at Durham Mutual Dam.

Objective: Provide adequate passage for adult salmonids.

Location: Durham Mutual Dam.

Narrative description: Durham Mutual Dam is a concrete-base, seasonally installed flashboard structure. Erosion below the dam now makes passage a problem under other than the highest flows. There are presently two existing fish ladders, only one of which is capable of passing fish under all flows. Diversions at this site occur throughout the entire year.

Related actions that may impede or augment the action: Potential for Western Canal siphon project to increase diversion amount at this site.

Agency and organization roles and responsibilities: DFG should assist the Durham Mutual Dam operators in developing means for better fish passage.

Potential obstacles to implementation: Improving fish passage could be too costly.

Predicted benefits: Recovery of salmon and steelhead on a sustainable basis requires adequate spawning and rearing habitat. Expedited passage at this site will reduce delays and injury and provide a significant benefit.

Action 2(b): Install fish screens on both diversions at Durham Mutual Dam.

Objective: Prevent entrainment of juvenile salmonids.

Location: Durham Mutual Dam.

Narrative description: Durham Mutual Dam is a concrete-base, seasonally installed flashboard structure. Diversions at this site occur throughout the entire year. Neither of the diversions at this site is screened.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG should coordinate design and placement of necessary screens at this diversion.

Potential obstacles to implementation: Cooperation of dam owners is necessary for this action to be successful.

Predicted benefits: Screening this diversion will prevent loss of juvenile salmon and steelhead from entrainment and will likely increase production from the creek.

Action 3(a)(1): Develop and construct Western Canal siphon.

Objective: Eliminate adult passage and juvenile entrainment problems associated with five dams and obtain additional instream flows.

Location: Western Canal Dam.

Narrative description: WCWD diverts Feather River water into and across Butte Creek from January through December in some years. Flows range as high as 1,200 cfs during the peak of the irrigation season of April-August. Fall flows of greater than 200 cfs are routed down Butte Creek to supply the Butte Sink duck clubs during October through January. Adult salmonids are known to stray into the Western Canal, as well as into the many channels of Little Butte Creek, probably as the result of flows through the Western Canal. WCWD has proposed to remove its dam and install a siphon under Butte Creek. The WCWD completed a conceptual design study in 1992 and is currently proceeding with an additional feasibility level investigation of the potential to include removal of Adams, Gorrill, McGowan, and McPherrin dams as part of the project.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG, the USBR, and DWR should be involved with this activity and provide any assistance the WCWD needs to complete its feasibility study and project approval. Interaction by the agencies at this stage may be critical to the proposal's successful implementation.

Potential obstacles to implementation: Without agency support, it is possible that the proposal would not be feasible based on costs or future water needs.

Predicted benefits: Construction of this siphon and removal of the four additional dams will eliminate several passage and entrainment problems.

Action 3(a)(2): Investigate the possibility of consolidation or replacement of additional diversions below the Western Canal siphon project.

Objective: Eliminate adult passage and juvenile entrainment problems and potentially obtain additional instream flows.

Location: Entire stream.

Narrative description: There are numerous diversions below the proposed Western Canal siphon project that could potentially be consolidated or removed.

Related actions that may impede or augment the action: The approval of WCWD's feasibility study (previously described for Action 3[a][1]) to remove its Western Canal Dam may provide the opportunity and impetus to develop alternative water sources or to remove additional downstream diversion dams.

Agency and organization roles and responsibilities: DFG, DWR, and USFWS, together with dam owners, should initiate an investigation to identify the possibility of developing alternate water sources or conveyance methods. Potential alternatives might include consolidation of diversions, transfers from other watersheds, utilization of groundwater or installation of screened pumps.

Potential obstacles to implementation: The success of this action depends on cooperative efforts with the dam owners.

Predicted benefits: Elimination of diversions will immediately benefit adult and juvenile passage and may potentially provide additional instream flows.

Action 3(a)(3): Acquire water rights as a part of the Western Canal siphon project.

Objective: Obtain adequate instream flows.

Location: Western Canal Dam.

Narrative description: There should be an investigation of the possibility of acquiring additional water rights as a part of the Western Canal siphon project supplement to Actions 1(a) and 1(c). Previously, DFG acquired right to 60 cfs of excess Butte Creek flows below the Western Canal Dam. The 60-cfs DFG fish flows are available only after 462 cfs are supplied to priority right holders. Generally, during most critical periods for salmon passage of both adults and juveniles, far less than 462 cfs of the natural flow of Butte Creek remains, thus making DFG's water right of little practical value.

Related actions that may impede or augment the action: This action is supplementary to Action 1(b).

Agency and organization roles and responsibilities: DFG, the USBR, DWR, and USFWS should initiate this study in cooperation with water right holders. This activity should be closely integrated with ongoing feasibility studies looking at removal of Western Canal Dam.

Potential obstacles to implementation: Lack of dedicated staff and funding could limit the success of this action.

Predicted benefits: Additional instream flows will provide immediate benefits by increasing available habitat for all life stages of salmonids.

Action 3(b)(1): Adjudicate water rights and provide watermaster service or equivalent for entire creek.

Objective: Ensure adequate instream flows.

Location: Entire creek.

Narrative description: Adjudication of the creek below the Western Canal would be beneficial in maintaining adequate instream flow.

Related actions that may impede or augment the action: Butte Creek is currently adjudicated in the reach above the Western Canal (Butte Creek Judgment and Decree No. 18917). Watermaster service is currently provided from April through September from the headwaters to the Western Canal under the original adjudication.

Agency and organization roles and responsibilities: DFG, DWR, and USFWS should initiate actions to provide watermaster service or the equivalent, such as a water supervisor, in the entirety of Butte Creek to cover the entire year.

Potential obstacles to implementation: This action would probably involve much negotiation among water users and possible litigation and would be very costly.

Predicted benefits: Watermaster service resulting from adjudication, or its equivalent, such as a water supervisor, would serve to protect instream flows for the rest of the creek and for the rest of the year. Maintenance of defined instream flows throughout the entire creek will significantly benefit migratory salmonids.

Action 3(b)(2): Remove Western Canal Dam and replace with siphon.

Objective: Expedite adult passage, eliminate straying of adults, and prevent entrainment of juveniles.

Location: Western Canal Dam.

Narrative description: The Western Canal Dam is a concrete-base, seasonally installed flashboard structure. Passage over the foundation with the dam not installed is somewhat restrictive, although large rocks have been used to stabilize downstream erosion. A single fish ladder is operational, although it is thought to be marginally effective as the result of size and volume of flow. The diversion is also unscreened. WCWD diverts Feather River water into and across Butte Creek from January through December in some years. Flows range as high as 1,200 cfs during the peak of the irrigation season from April through August. Fall flows of greater than 200 cfs are routed down Butte Creek to supply the Butte Sink duck clubs during October through January. Adult salmonids are known to stray into the Western Canal, as well as into the many channels of Little Butte Creek, probably as the result of flows through the Western Canal.

Related actions that may impede or augment the action: This action is related to the success of Action 3(a)(1), which is a higher priority action. If Action 3(a)(1) does not evolve, then this action takes precedence.

Agency and organization roles and responsibilities: The success of this action depends on cooperative efforts with WCWD.

Potential obstacles to implementation: Costs and staff resources could be the major limiting factors.

Predicted benefits: Recovery of salmonids on a sustainable basis requires access to adequate spawning and rearing habitat. Expedited adult salmon passage at this site will reduce delays and injury and provide a significant benefit salmonid production. Additionally, prevention of juvenile entrainment will also benefit production.

Action 3(b)(3): Establish operational criteria for Sanborn Slough Bifurcation.

Objective: Provide better passage for adult salmonids and prevent entrainment of juveniles.

Location: Sanborn Slough dam.

Narrative description: Flow splits at the Sanborn Slough Bifurcation Structure may cause delay and or stranding of juvenile and adult salmonids. The existing Sanborn Slough structure is an earthen cobble dam with two large gated culverts installed across the main channel of Butte Creek. Operational responsibility for the structure is unclear, although there is a loose arrangement between the duck clubs and agricultural users to provide diversions to meet the respective needs by time of year. In addition, Reclamation District 1004 has an open application to appropriate additional Butte Creek waters that specifies operational criteria at this site. Depending on time and flows, this site may be a major barrier to adult migration and could divert significant numbers of juveniles into the Butte Sink.

Related actions that may impede or augment the action: If Actions 3(a)(1-3) are successful, the flow issues would be resolved. However, fish passage issues must still be addressed.

Agency and organization roles and responsibilities: DFG, with USFWS support, should lead an effort to bring together involved parties and develop operational criteria for flow splits, either through legally binding agreements, or as a part of an overall Butte Creek water right adjudication (Action 3[b][1]).

Potential obstacles to implementation: Cost and complexity of water right issues can slow this action.

Predicted benefits: Developing operational objectives will reduce or prevent entrainment and expedite passage of juvenile and adult salmon and steelhead.

Action 3(c): Develop operational criteria for, and potential modification to, Butte Slough outfall.

Objective: Provide sufficient attraction and passage flows for adults and outmigration flows for juveniles.

Location: Butte Slough outfall and Sutter Bypass.

Narrative description: The Butte Slough Outfall gates and the effects of the flow split into the Sutter Bypass may be causing passage problems due to insufficient attraction flows and due to the gates acting as a physical barrier. Potentially, a regulated flow split will be required to provide passage through both systems during the period when anadromous fish might be present.

Butte Slough outfall gates are controlled by DWR and Reclamation District 70 based on flood and agricultural needs. Flood needs are generally met by balancing flows between the Sacramento River and Butte Creek utilizing the gated culverts at the end of Butte Slough. Agricultural needs generally are met by completely closing these gates and routing all Butte Creek flows through the Sutter Bypass. The change in operation frequently occurs in the early spring at a time when adult spring chinook salmon would be migrating past the mouth of the Feather River, with the net result that attractant flows into Butte Creek would be changing in volume and point of entry between Butte Slough outfall and Sacramento Slough. Fish that would be attracted up the Sacramento River to attempt to enter Butte Creek via the Butte Slough outfall gates have an obstacle of unknown magnitude in the form of the flap gates on the Sacramento River side of Butte Slough culverts. In addition, changing flow regimens through the Sutter Bypass could serve to delay or prevent migration into upper Butte Creek. Operational objectives should be developed that provide continuous passage at the outfall gates from January to June and October through December.

Related actions that may impede or augment the action: Upstream adult fish passage issues must still be addressed.

Agency and organization roles and responsibilities: DFG should take the lead in supporting Action 3(c) and incorporating appropriate flow passage needs either at the Butte Slough outfall gates or the Sacramento Slough. If flows are designed for fish upstream entry at the Butte Slough outfall, DFG, with USFWS support, should design and construct adult upstream passage facilities in conjunction with the gates that would be operational at high- and low-flow levels.

Potential obstacles to implementation: Necessary flows for fish passage at the Sacramento Slough entry and costs for a fish passage facility at this location can be high.

Predicted benefits: Developing and implementing operational criteria and potential modifications to the flap gates will facilitate movement of adult and juvenile salmon and steelhead and potentially significantly improve production.

Action 4(a)(1): Build new high-volume fish ladder at Adams Dam.

Objective: Improve adult fish passage.

Location: Adams Dam.

Narrative description: Adams Dam is a concrete-base, seasonally installed flashboard type structure. Severe erosion below the dam has resulted in significant passage problems for adults at low flows with the dam removed. The existing fish ladder is operational only with the dam installed and is extremely inefficient due to the size of the ladder, volume of water, and ineffective ladder entrance. If the Western Canal siphon project is not completed or Adams Dam is not included, Adams Dam should be modified.

Related actions that may impede or augment the action: Adams Dam has been identified for possible removal if the Western Canal siphon project is completed and an alternate conveyance system for a source of water can be identified.

Agency and organization roles and responsibilities: If the dam is not removed, DFG should design and install a high-volume fish ladder.

Potential obstacles to implementation: None.

Predicted benefits: Improving the fish ladder will expedite fish passage and reduce injury and stress to adult salmon and steelhead.

Action 4(a)(2): Install fish screens on both diversions at Adams Dam.

Objective: Prevent entrainment of juvenile salmonids.

Location: Adams Dam.

Narrative description: Adams Dam is a concrete-base, seasonally installed flashboard type structure. Neither of the diversions at Adams Dam is screened, which would be a necessity only if dam was not removed as part of the Western Canal siphon project (Action 3[a][1]).

Related actions that may impede or augment the action: Adams Dam has been identified for possible removal if the Western Canal siphon project is completed and an alternate source of water and conveyance system can be identified.

Agency and organization roles and responsibilities: If the Adams Dam remains, DFG should develop contingency plans to design screens and upstream passage facilities in conjunction with the dam operators.

Potential obstacles to implementation: None are anticipated at this time.

Predicted benefits: Installing fish screens will prevent entrainment at this site and increase production.

Action 4(a)(3): Build new high-volume fish ladder at Gorrill Dam.

Objective: Improve adult fish passage.

Location: Gorrill Dam.

Narrative description: Flows below Gorrill Dam are a significant passage issue during late spring and early fall. Late-arriving spring-run and early arriving fall-run chinook salmon are affected by ineffective passage at this site. Gorrill Dam is a concrete-base, seasonally installed flashboard structure. As with all the other diversion dams, erosion below the structure has caused significant passage problems for adult salmon. The existing structure has a low-flow center ladder that is marginally passable with the dam out. When the dam is installed, a second ladder is operational, although it is probably marginally effective as the result of size, volume of flow, and ineffective entrance characteristics.

Related actions that may impede or augment the action: Gorrill Dam has been identified for possible removal as part of the Western Canal siphon project if an adequate conveyance system and source of water can be identified.

Agency and organization roles and responsibilities: If the dam is not removed, DFG should design and install a high-volume fish ladder.

Potential obstacles to implementation: The decision to design and build a fish ladder would probably be delayed until a decision has been made regarding the removal of Gorrill Dam.

Predicted benefits: Improving the fish ladder will expedite fish passage and reduce injury and stress to adult salmon and steelhead.

Action 4(a)(4): Install fish screens on diversions at McGowan Dam.

Objective: Prevent entrainment of juvenile salmonids.

Location: McGowan Dam.

Narrative description: McGowan Dam, partially or entirely owned by DFG, diverts water to the DFG Upper Butte Basin Wildlife Area. Past operation of the diversion was generally restricted to March-September. With the change of usage to wildlife, the diversion will potentially be operated on a year-round basis depending on flow conditions in Butte Creek. McGowan Dam is a concrete-base, seasonally installed flashboard type structure. Diversions from this site are unscreened and include one large gravity diversion and two or more small pumped diversions.

Related actions that may impede or augment the action: McGowan Dam has been identified for possible removal as part of the Western Canal siphon project if an adequate conveyance system and source of water can be identified.

Agency and organization roles and responsibilities: If the dam is not removed, DFG should design and install screens on all of the diversions.

Potential obstacles to implementation: The decision to design and build fish screens would probably be delayed until a decision has been made about the removal of McGowan Dam.

Predicted benefits: Installing fish screens will prevent entrainment at this site and increase production.

Action 4(a)(5): Install fish screens on three diversions at McPherrin Dam.

Objective: Prevent entrainment of juvenile salmonids.

Location: McPherrin Dam.

Narrative description: McPherrin Dam, partially or entirely owned by DFG, diverts water to the DFG Upper Butte Sink Wildlife Area and others. As with the McGowan Dam, past operation was generally restricted to March-September. Acquisition of the wildlife area has resulted in a year-round operation dependent on flow conditions in Butte Creek. The dam is a concrete-base, seasonally installed flashboard structure. Three major gravity diversions and several pumped diversions are unscreened.

Related actions that may impede or augment the action: McPherrin Dam has been identified for possible removal as part of the Western Canal Siphon project if an adequate conveyance system and source of water can be identified.

Agency and organization roles and responsibilities: If the dam is not removed, DFG should design and install screens on all of the gravity and pumped diversions.

Potential obstacles to implementation: The decision to design and build fish screens would probably be delayed until a decision has been made regarding the removal of McPherrin Dam.

Predicted benefits: Installing fish screens will prevent entrainment at this site and increase production.

Action 4(b)(1): Install fish screens on both diversions at Western Canal Dam.

Objective: Prevent entrainment of juvenile salmonids.

Location: Western Canal Dam.

Narrative description: The Western Canal Dam is a concrete-base, seasonally installed flashboard structure. The diversion is also unscreened. WCWD diverts Feather River water into and across Butte Creek from January through December in some years. Flows range as high as 1,200 cfs during the peak of the irrigation season from April through August. Fall flows of greater than 200 cfs are routed down Butte Creek to supply the Butte Sink duck clubs during October through January.

Related actions that may impede or augment the action: Western Canal Dam has been identified for possible removal as part of the Western Canal Siphon project if an adequate conveyance system and source of water can be identified.

Agency and organization roles and responsibilities: If the dam is not removed, DFG should design and install screens.

Potential obstacles to implementation: The decision to design and build fish screens would probably be delayed until a decision has been made about the removal of Western Canal Dam.

Predicted benefits: Prevention of juvenile entrainment will benefit production.

Action 4(b)(2): Build new high-volume fish ladder at Western Canal Dam.

Objective: Provide better adult fish passage.

Location: Western Canal Dam.

Narrative description: The Western Canal Dam is a concrete-base, seasonally installed flashboard structure. Passage over the foundation with the dam not installed is somewhat restrictive, although large rocks have been used to stabilize downstream erosion. A single fish ladder is operational, although it is thought to be marginally effective as the result of size and volume of flow. WCWD diverts Feather River water into and across Butte Creek from January through December in some years. Flows range as high as 1,200 cfs during the peak of the irrigation season from April through August. Fall flows of greater than 200 cfs are routed down Butte Creek to supply the Butte Sink duck clubs during October-January. Adult salmonids are known to stray into the Western Canal, as well as into the many channels of Little Butte Creek, probably as the result of flows through the Western Canal.

Related actions that may impede or augment the action: Western Canal Dam has been identified for possible removal as part of the Western Canal Siphon project if an adequate conveyance system and source of water can be identified.

Agency and organization roles and responsibilities: If the dam is not removed, DFG should design and install a high-volume fish ladder.

Potential obstacles to implementation: The decision to design and build a high-volume fish ladder would probably be delayed until a decision has been made about the removal of Western Canal Dam.

Predicted benefits: Recovery of salmonids on a sustainable basis requires access to adequate spawning and rearing habitat. Expedited adult salmon passage at this site will reduce delays and injury and provide a significant benefit salmonid production.

Action 4(b)(3): Install fish screens on both diversions at Gorrill Dam.

Objective: Prevent entrainment of juvenile salmonids.

Location: Gorrill Dam.

Narrative description: Gorrill Dam is a concrete-base, seasonally installed flashboard structure with two unscreened diversions.

Related actions that may impede or augment the action: Gorrill Dam has been identified for possible removal as part of the Western Canal Siphon project if an adequate conveyance system and source of water can be identified.

Agency and organization roles and responsibilities: If the dam is not removed, DFG should design and install screens on all of the gravity and pumped diversions.

Potential obstacles to implementation: The decision to design and build fish screens would probably be delayed until a decision has been made about the removal of Gorrill Dam.

Predicted benefits: Installing fish screens will prevent entrainment at this site and increase production.

Action 4(b)(4): Build new high-volume fish ladder at McPherrin Dam.

Objective: Improve adult fish passage.

Location: McPherrin Dam.

Narrative description: The dam is a concrete-base, seasonally installed flashboard structure. Adult passage with the dam removed is not a problem. The existing structure has an operational fish ladder that is believed to provide marginal passage resulting from fish not rapidly finding and traversing the ladder. McPherrin Dam, partially or entirely owned by DFG, diverts water to the DFG Upper Butte Sink Wildlife Area. As with the McGowan Dam, past operation was generally restricted to March-September. Acquisition of the Wildlife Area has resulted in a year-round operation dependent on flow conditions in Butte Creek.

Related actions that may impede or augment the action: McPherrin Dam has been identified for possible removal as part of the Western Canal Siphon project if an adequate conveyance system and source of water can be identified.

Agency and organization roles and responsibilities: If the dam is not removed, DFG should design and install a high-volume fish ladder.

Potential obstacles to implementation: The decision to design and build a high-volume fish ladder would probably be delayed until a decision has been made regarding the removal of McPherrin Dam.

Predicted benefits: Improving the fish ladder will expedite fish passage and reduce injury and stress to adult salmonids.

Action 4(c)(1): Build a new high-volume fish ladder at McGowan Dam.

Objective: Improve adult fish passage.

Location: McGowan Dam.

Narrative description: McGowan Dam, partially or entirely owned by DFG, diverts water to the DFG Upper Butte Basin Wildlife Area. Past operation of the diversion was generally restricted to March-September. With the change of usage to wildlife, the diversion will potentially be operated on a year-round basis, depending on flow conditions in Butte Creek. McGowan Dam is a concrete-base, seasonally installed flashboard type structure. There are no known adult passage problems with the dam removed. Adult passage with the dam installed is generally a problem as the result of fish not rapidly finding and traversing the existing ladder. A high-volume fish ladder should be installed at the dam if it is not removed.

Related actions that may impede or augment the action: McGowan Dam has been identified for possible removal as part of the Western Canal Siphon project if an adequate conveyance system and source of water can be identified.

Agency and organization roles and responsibilities: If the dam is not removed, DFG should design and install a high-volume fish ladder.

Potential obstacles to implementation: The decision to design and build a high-volume fish ladder would probably be delayed until a decision has been made about the removal of McGowan Dam.

Predicted benefits: Improving the fish ladder will expedite fish passage and reduce injury and stress to adult salmon and steelhead.

Action 5(a)(1): Build new high-volume fish ladder at East-West Diversion Weir.

Objective: Provide passage for adult salmonids.

Location: East-West Diversion Weir.

Narrative description: Flows entering the East and West Barrows of the Sutter Bypass are regulated by a concrete flashboard structure referred to as the East-West Diversion Weir. This weir is operated by Meridian Farms Water Company. Flows are routed to the East and West Barrows to meet the needs of agriculture during spring. With the changing requirements for the elimination of rice straw in conjunction with waterfowl habitat, flows may also be regulated in fall and early winter. Flow manipulations at this site may therefore be significantly affecting passage of adults and juveniles of both races of chinook salmon. This weir does not contain a fish ladder and under some flows is a barrier. Construction of a high-volume fish ladder will alleviate most passage problems associated with this dam.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG should design and install a high-volume fish ladder.

Potential obstacles to implementation: Cooperation by the dam owner, Meridian Farms Water Company, and funding are unknown factors at this time.

Predicted benefits: Installing a fish ladder will expedite fish passage and reduce injury and stress to adult salmon and steelhead.

Action 5(a)(2): Establish operational criteria for the East and West Barrows.

Objective: Improve adult fish passage.

Location: East-West Diversion Weir.

Narrative description: Diversions and their impacts in this reach are unknown; however, flows entering the East and West Barrows of the Sutter Bypass are regulated by a concrete flashboard structure operated by Meridian Farms Water Company. Flows are routed to the East and West Barrows to meet the needs of agriculture during spring. With the changing requirements for the elimination of rice straw in conjunction with waterfowl habitat, flows may also be regulated in fall and early winter. Flow manipulations at this site are affecting outmigration of juvenile salmonids.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG and DWR, in cooperation with the Meridian Farms Water Company operators, need to develop operational criteria for timing and volume of flow splits between the East and West Barrows.

Potential obstacles to implementation: Cooperation by dam owner, Meridian Farms Water Company, and funding are unknown factors at this time.

Predicted benefits: Developing operational criteria will provide better passage flows for adult salmon and steelhead.

Action 5(a)(3): Establish operational criteria for Sutter Bypass Weir #2.

Objective: Improve adult fish passage.

Location: Sutter Bypass Weir #2.

Narrative description: Flow splits between the East and West Barrows and the impacts on anadromous fish are not well understood, particularly with the recent changes in water usage resulting from rice straw decomposition and waterfowl needs in fall and winter. In general, the East Barrow has been identified as the most desirable migration route. Drainage flows enter the East Barrow at the Wadsworth Canal and are a mixture of various diversions from the Feather River. Adult salmon are periodically reported to have migrated up the Wadsworth Canal, presumably to have died without spawning. Weir #2, a concrete, seasonally installed flashboard structure, is located approximately 1 mile south of the Wadsworth Canal. A fish ladder installed on the west side of the weir is generally passable. Weir #2 is operated and maintained by DWR and is generally in place from March through early November. There is, however, a concern for delay and also for regulation of flows within the fish ladder, which are often found to be impassable. With the recent advent of waterfowl needs for the Sutter National Wildlife Refuge, and potential rice straw decomposition needs, Weir #2 is operated over a longer period and, as demonstrated in 1993-1994, was never removed. Thus, Weir #2 can be a major obstacle to anadromous fish migration.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG and DWR, in cooperation with dam operators, need to develop operational criteria relative to installation date and removal of the weir.

Potential obstacles to implementation: None.

Predicted benefits: Developing operational criteria will serve to identify and facilitate passage flows for adult and juvenile salmon and steelhead, while maintaining agricultural and wildlife needs.

Action 5(a)(4): Establish operational criteria for Nelson Slough.

Objective: Improve adult fish passage.

Location: Nelson Slough.

Narrative description: Flows from the East Barrow, other than floodflows, historically have rejoined the West Barrow at several locations, including Gilsizer, Willow, and Nelson Sloughs. Problems in regulating flows through the three sloughs often resulted in stranded adult salmon. The result was a decision to route all flows during most of the year through Willow Slough, which was modified with a concrete denile fish ladder. Currently, Nelson Slough is the lowermost interconnection with the West Barrow and Sacramento Slough and generally flows only during flood events. During 1994, DWR installed a control structure that will allow regulation of flows into Nelson Slough during nonflood periods to facilitate better regulation of flows and elevations at the lower end of the East Barrow.

Related actions that may impede or augment the action: Even with the single route through Willow Slough and an improved fish ladder, delay and injury are probably still a factor at this site. Also, the newly installed control structure that will allow regulation of flows into Nelson Slough during nonflood periods has the potential to cause stranding of salmon and steelhead.

Agency and organization roles and responsibilities: DFG and DWR need to develop operational criteria relative to installation date and removal of the weir.

Potential obstacles to implementation: Funding is unknown at this time.

Predicted benefits: Developing operational criteria will serve to enhance passage and reduce stranding of salmon and steelhead.

Action 5(a)(5): Establish operational criteria for Sutter Bypass Weir #1.

Objective: Improve adult fish passage.

Location: Sutter Bypass Weir #1.

Narrative description: Weir #1, the lowermost of the West Barrow dams, is located immediately upstream of the Tisdale Bypass and is owned and operated by the USFWS for the Sutter National Wildlife Refuge. This weir is primarily utilized for the management needs of the refuge; however, it also provides for agricultural users. As with the other dams in the Sutter Bypass, changing conditions are resulting in year-round operations in some years, creating potentially significant impacts on migrating salmon and steelhead.

Weir #1 is a seasonally installed concrete flashboard structure, with an existing operational fish ladder. As with all of the other weirs and dams, Weir #1 creates a major blockage that, even with its operational fish ladder, contributes to delay and injury of migrating salmon.

Related actions that may impede or augment the action: Alternative sources of water for the Sutter Refuge are currently being developed. If an alternative is developed, the weir could potentially be eliminated or the time of use reduced.

Agency and organization roles and responsibilities: DFG, DWR, and USFWS need to develop operational criteria relative to installation date and removal of the weir and to explore alternative water sources to allow dam removal.

Potential obstacles to implementation: None.

Predicted benefits: The development of sound operational criteria or weir removal will benefit salmon and steelhead as well as wildlife.

Action 5(a)(6): Install fish screens at Sanborn Slough Bifurcation Structure.

Objective: Prevent entrainment of juvenile salmonids.

Location: Sanborn Slough Bifurcation Structure.

Narrative description: Flow splits at the Sanborn Slough Bifurcation Structure may cause delay and or stranding for juvenile salmon and steelhead. The existing structure is an earthen cobble dam with two large gated culverts installed across the main channel of Butte Creek. The potential for installation of a fish screen at this site needs to be investigated. Operational responsibility for the structure is unclear, although there is a loose arrangement between the duck clubs and agricultural users to provide diversions to meet the respective needs by time of year. In addition, Reclamation District 1004 has an open application to appropriate additional Butte Creek waters that specifies operational criteria at this site. Depending on time and flows, this site may be a major migrational barrier and could divert significant numbers of juveniles into the Butte Sink.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG should coordinate screen design and installation.

Potential obstacles to implementation: None.

Predicted benefits: A fish screen at this site could prevent the loss of significant numbers of salmon and steelhead resulting from straying into the Butte Sink.

Action 5(a)(7): Install fish screens at White Mallard Dam.

Objective: Prevent entrainment of juvenile salmonids.

Location: White Mallard Dam.

Narrative description: Reclamation District 1004 diverts Butte Creek flows at the White Mallard Dam during the agricultural season, and White Mallard Duck Club diverts water at this site during the fall waterfowl season. The dam is an earthfilled, seasonally installed flashboard structure. There is an existing fish ladder that, in conjunction with the dam, is of questionable durability.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG, in conjunction with the USBR and USFWS, should design and install a new fish screen.

Potential obstacles to implementation: None.

Predicted benefits: Installation of a fish screen will prevent the loss of juvenile salmon and steelhead at this dam.

Action 5(a)(8): Screen diversions within Sutter Bypass where necessary.

Objective: Prevent entrainment of juvenile salmonids.

Location: Sutter Bypass, Butte Slough to Sacramento River.

Narrative description: Diversions and their impacts in this reach are largely unknown; however, flows entering the East and West Barrows of the Sutter Bypass are regulated by a concrete flashboard structure operated by Meridian Farms Water Company. Flows are routed to the East and West Barrows to meet the needs of agriculture during spring. With the changing requirements for the elimination of rice straw in conjunction with waterfowl habitat, flows may also be regulated in fall and early winter. None of the diversions within the Sutter Bypass are screened, and thus they potentially entrain significant numbers of juvenile salmon and steelhead.

Related actions that may impede or augment the action: Development of alternative water source for Sutter Refuge could eliminate need for one or more screens.

Agency and organization roles and responsibilities: DFG, with support from the USFWS, should investigate the need for fish screens and facilitate installation where necessary.

Potential obstacles to implementation: None.

Predicted benefits: Fish screen installation has the potential to prevent the loss of juvenile salmon and steelhead.

Action 5(b)(1): Install culvert and riser at White Mallard Duck Club outfall.

Objective: Prevent straying of adult salmonids.

Location: White Mallard Duck Club outfall.

Narrative description: Reclamation District 1004 diverts Butte Creek flows at the White Mallard Dam during the agricultural season, and White Mallard Duck Club diverts water at this site during the fall waterfowl season. Tailwater from the diversion at the White Mallard Dam often results in stranding of adult salmon at the base of the White Mallard Duck Club bottom weir. Adult salmon, primarily fall-run salmon, are attracted out of Butte Creek approximately 0.5 mile to the base of the bottom weir.

Related actions that may impede or augment the action: None

Agency and organization roles and responsibilities: DFG, USFWS, and White Mallard Duck Club need to provide corrections to the system to avoid attracting and stranding salmon below the White Mallard Duck Club's bottom weir.

Potential obstacles to implementation: None.

Predicted benefits: Elimination of stranding at this site will increase production in the creek.

Action 5(b)(2): Rebuild and maintain existing culvert and riser at Drumheller Slough outfall.

Objective: Prevent straying of adult salmonids.

Location: Drumheller Slough outfall.

Narrative description: Tailwater from Drumheller Slough at the point it enters Butte Creek, under current operating conditions, is known to attract adult fall-run chinook salmon, stranding them in the upper portion of the slough. Changing water needs for wildlife and rice straw decomposition may eventually cause impacts on late fall-run and spring-run chinook salmon and steelhead. The existing structure needs to be rebuilt and maintained.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: Reclamation District 1004, with support from DFG and USFWS, needs to design, build, and maintain the existing culvert and riser at Drumheller Slough outfall to avoid attracting and stranding salmon and steelhead.

Potential obstacles to implementation: None.

Predicted benefits: Rehabilitation of the existing culvert and riser at the outfall will prevent the loss of adult salmon due to straying and increase production in the creek.

Action 5(b)(3): Establish operational criteria for Sutter Bypass Weir #5.

Objective: Improve adult fish passage.

Location: Sutter Bypass Weir #5.

Narrative description: Anadromous fish migration is generally encouraged through the East Barrow; however, flows in the West Barrow are generally present and sufficient to attract anadromous fish. Three weirs (dams) are located within the West Barrow below the East West Diversion Structure. The uppermost dam, Weir #5, is a seasonally operated concrete flashboard structure located approximately 1 mile south of the Highway 20 bridge crossing. It is operated primarily for agricultural needs in spring, although it may have some use in fall flooding for waterfowl and rice straw decomposition. Fish passage at the site is not well understood and has the potential, under some flow conditions, to present a significant blockage to migrating adults.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG, DWR, and USFWS, in cooperation with dam operators, need to develop operational criteria for this weir.

Potential obstacles to implementation: None.

Predicted benefits: Developing operational criteria will facilitate passage for adult salmon and steelhead.

Action 5(b)(4): Establish operational criteria for Sutter Bypass Weir #3.

Objective: Improve adult fish passage.

Location: Sutter Bypass Weir #3.

Narrative description: Weir #3, the second of the West Barrow dams, is located across from the mouth of the Wadsworth Canal. It is operated primarily for agricultural needs and, as with the other weirs, will potentially have increasing usage in fall and winter for waterfowl and rice straw decomposition. Fish passage at this site is not well understood; however, it is thought to be a problem under some flow conditions. Operational criteria need to be developed.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG, DWR, and USFWS, in cooperation with dam operators, need to develop operational criteria for this weir.

Potential obstacles to implementation: None.

Predicted benefits: Developing operational criteria will provide better passage flows for adult salmonids.

Action 6(a)(1): Initiate legal actions on diverters who are violating water right allocations.

Objective: Ensure sufficient instream flows.

Location: Entire creek.

Narrative description: In general, during most periods when impacts on anadromous fish would be of concern, adequate flows exist below the Western Canal. Cursory review has revealed however, that some users in this reach appear to be diverting water outside of their right or entitlement.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG, with USFWS support, needs to investigate this problem and consider legal action only after other actions have failed (see Action 3[a][1]).

Potential obstacles to implementation: Cost and cooperation are important to the success of this action.

Predicted benefits: Legally defined instream flows will provide significant benefit to migrating salmon and steelhead.

Action 6(a)(2): Install high-volume fish ladder on Sutter Bypass Weir #2.

Objective: Improve adult fish passage.

Location: Sutter Bypass Weir #2.

Narrative description: Flow splits between the East and West Barrows and the impacts on anadromous fish are not well understood, particularly with the recent changes in water usage resulting from rice straw decomposition and waterfowl needs in fall and winter. In general, the East Barrow has been identified as the most desirable migration route. Drainage flows enter the East Barrow at the Wadsworth Canal and are a mixture of various diversions from the Feather River. Adult salmon are periodically reported to migrate up the Wadsworth Canal and, presumably, to die without spawning. Weir #2, a concrete, seasonally installed flashboard structure, is located approximately 1 mile south of the Wadsworth Canal. A fish ladder is installed on the west side of the weir and is generally passable. There is a concern for delay and regulation of flows within the fish ladder, which is often impassable. Weir #2 is operated and maintained by DWR and is generally in place from March through early November. With the recent advent of waterfowl needs for the Sutter National Wildlife Refuge, and potential rice straw decomposition needs, Weir #2 is operated over a longer period and, as demonstrated in 1993-94, was never removed. Thus, Weir #2 can be a major obstacle to anadromous fish migration.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG, in cooperation with DWR, needs to design and install a high-volume fish ladder.

Potential obstacles to implementation: None.

Predicted benefits: Installation of a high-volume fish ladder will improve fish passage at this site.

Action 6(a)(3): Install high-volume fish ladder on Sutter Bypass Weir #1.

Objective: Improve adult fish passage.

Location: Sutter Bypass Weir #1.

Narrative description: Weir #1, the lowermost of the West Barrow dams, is located immediately upstream of the Tisdale Bypass and is owned and operated by the USFWS for the Sutter National Wildlife Refuge.

This weir is primarily utilized for the management needs of the refuge; however, it also provides for agricultural users. As with the other dams in the Sutter Bypass, changing conditions are resulting in year-round operations in some years, thus potentially having significant impacts on salmon and steelhead. Weir #1 is a seasonally installed concrete flashboard structure, with an existing operational fish ladder. As with all of the other weirs and dams, Weir #1 creates a major blockage, even with its operational fish ladder, that contributes to delay and injury of migrating salmon.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG and USFWS need to install a high-volume fish ladder at this weir.

Potential obstacles to implementation: If an alternative source of water for Sutter Refuge is developed, the weir might be removed or the time of operation reduced.

Predicted benefits: Installation of a high-volume fish ladder will improve fish passage at this site.

Action 6(a)(4): Install fish screens on Little Dry Creek pumps.

Objective: Prevent entrainment or impingement of juvenile salmonids.

Location: Little Dry Creek pumps, approximately 1 mile below Afton Road.

Narrative description: The reach between McPherrin Dam and Sanborn Slough borders the Little Dry Creek Unit of the Upper Butte Basin Wildlife Area. Two unscreened pumps supply water to the Little Dry Creek Unit, while an unknown number of additional pumps exist in this reach. None of the pumps are screened.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG and USFWS need to coordinate screening of all pumps on Butte Creek.

Potential obstacles to implementation: None.

Predicted benefits: Screening will prevent loss of juvenile salmon and steelhead.

Action 6(a)(5): Increase law enforcement of fishing regulations.

Objective: Eliminate or reduce poaching.

Location: Entire creek.

Narrative description: Poaching is considered to be a significant problem along the entire length of Butte Creek. One additional warden position was added by DFG during 1994 to patrol spring-run salmon streams. However, the one additional position is responsible for providing patrol on five or six tributaries. Additional intensive enforcement might be achieved by providing funding overtime to existing wardens in the key areas.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG and USFWS need to provide the resources to accomplish this action.

Potential obstacles to implementation: None.

Predicted benefits: Increased enforcement of fishing regulations will prevent loss of adult salmon and steelhead due to poaching.

Action 6(b)(1): Install high-volume fish ladder on Sutter Bypass Weir #5.

Objective: Improve adult fish passage.

Location: Sutter Bypass Weir #5.

Narrative description: See the narrative description for Action 5(b)(3).

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG and USFWS need to install a high-volume fish ladder at this weir.

Potential obstacles to implementation: None.

Predicted benefits: Installation of an improved ladder will aid in fish passage problems associated with this dam.

Action 6(b)(2): Install high-volume fish ladder on Sutter Bypass Weir #3.

Objective: Improve adult fish passage.

Location: Sutter Bypass Weir #3.

Narrative description: See the narrative description for Action 5(b)(4).

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG, DWR, and USFWS need to install a high-volume fish ladder at this weir.

Potential obstacles to implementation: None.

Predicted benefits: Installation of an improved ladder will aid in fish passage problems associated with this dam.

Action 7(a)(1): Install high-volume fish ladder at White Mallard Dam.

Objective: Improve adult fish passage.

Location: White Mallard Dam.

Narrative description: Reclamation District 1004 diverts Butte Creek flows at the White Mallard Dam during the agricultural season and White Mallard Duck Club diverts water at this site during the fall waterfowl season. The dam is an earthfilled, seasonally installed flashboard structure. There is an existing fish ladder that, in conjunction with the dam, is of questionable durability.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG and USFWS need to install a high-volume fish ladder at this dam.

Potential obstacles to implementation: None.

Predicted benefits: Installation of an improved ladder will aid in fish passage problems associated with this dam.

Action 7(a)(2): Develop and enforce land use plans that create buffer zones between the creek and development.

Objective: Protect existing salmonid habitat from further human development.

Location: Entire stream.

Narrative description: Local land use plans and regulations need to be implemented or modified to create buffer zones between the creek and any new development. An ecosystem approach needs to be developed to integrate any anadromous fishery management plans into an overall watershed management plan that will require participation of all federal, state, and local entities, including land owners and private groups. Formation of local advocacy groups should be encouraged to ensure that the legitimate needs of all stakeholders are considered and addressed. One such group, the Butte Creek Spring Run Restoration Committee, is currently addressing and reviewing spring-run restoration activities. DFG is in the process of developing a plan that would protect riparian habitats. Local groups should be encouraged to participate in such an effort.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: All agencies need to continue their interactions with local conservation groups to facilitate development and outside support of anadromous fish restoration plans.

Potential obstacles to implementation: None.

Predicted benefits: A healthy riparian corridor is important to the maintenance of the watershed.

Action 7(a)(3): Develop a watershed management program.

Objective: Protect existing salmonid habitat while providing for human use of the resources.

Location: Entire stream.

Narrative description: See the narrative description for Action 7(a)(2).

Related actions that may impede or augment the action: None.

<u>Agency and organization roles and responsibilities</u>: All agencies need to continue interagency and local conservation group interactions to facilitate collaborative development and outside support of anadromous fish restoration plans.

<u>Potential obstacles to implementation</u>: None.

<u>Predicted benefits</u>: Preserving and protecting the existing watershed is very important to the restoration and continued existence of salmon and steelhead in Butte Creek.

Action 7(b): Enhance fish passage at natural barrier below Centerville Diversion Dam.

<u>Objective</u>: Increase the amount of available salmonid habitat.

<u>Location</u>: 0.5 mile downstream of the Centerville Diversion Dam.

<u>Narrative description</u>: A natural barrier exists approximately 0.5 mile below the Centerville Diversion Dam which, under most flow conditions, would preclude spring-run chinook salmon and steelhead from ascending. Some additional spawning and rearing habitat is available above this barrier. Potential solutions include construction of a fish ladder or physical modification of the barrier.

<u>Related actions that may impede or augment the action</u>: None.

<u>Agency and organization roles and responsibilities</u>: DFG should investigate the feasibility of removing or modifying this barrier for upstream movement of spring-run chinook salmon and steelhead.

<u>Potential obstacles to implementation</u>: None.

<u>Predicted benefits</u>: Some additional spring-run and steelhead habitat would be provided.

Action 8: Enhance fish passage at PG&E diversion dams.

<u>Objective</u>: Increase the amount of available salmonid habitat.

<u>Location</u>: Centerville Diversion Dam and above.

<u>Narrative description</u>: Within the upper watershed area above the Centerville Diversion Dam, flows are regulated by PG&E. Flows from Butte Creek are commingled with diversions from the West Branch of the North Fork of the Feather River for power generation at the PG&E Desabla and Centerville Powerhouses. West Branch flows are augmented by storage in Round Valley and Philbrook Reservoirs. Currently,

releases from the two reservoirs are based primarily on power generation needs, with some consideration given to recreation in Philbrook Reservoir and flow and temperature considerations below the Centerville Diversion Dam, a prime spring-run chinook salmon holding area. Salmon are currently blocked under almost all flow conditions from further upstream movement by the Centerville Diversion Dam.

If PG&E diversion dams in the Butte Creek system are to be considered permanent structures, the potential to enhance anadromous fish habitat above the dams can be achieved only by installation of fish ladders. This consideration would, of necessity, be incremental in nature due to the three-dam sequence blocking the original natural route to the extreme upper watershed area. The second of these, the Forks of Butte diversion, is a recent installation owned and operated by Energy Growth Partnership. In addition, natural barriers that existed prior to the dams or that formed after dam installation, would need to be evaluated for passage.

Related actions that may impede or augment the action: PG&E is currently reevaluating the efficacy of maintaining and operating the DeSabla-Centerville Project. The FERC license (FERC 803), which expires in 2009, may significantly alter considerations relative to the continued existence of the dams and their operation.

Agency and organization roles and responsibilities: DFG, in conjunction with USFWS, should begin negotiating with PG&E and Energy Growth Partnership to facilitate fish passage. The success of this action is also depends on the completion of Action 7(b).

Potential obstacles to implementation: None.

Predicted benefits: Unimpeded passage, either through installation of fish ladders or removal of dams, would provide additional habitat that is thought to have been historically utilized by salmon and steelhead.

Colusa Basin drain -

Limiting factors and potential solutions -

Migration barriers - Access to westside tributaries is currently blocked by the levee system along the Sacramento River. In addition, migration from the Colusa Basin Drain into the individual tributaries is often blocked by various dams and checks installed by irrigation and reclamation districts. To facilitate movement of salmon and steelhead, defined migrational corridors would have to be identified, constructed, and maintained.

Migrational flows - Most of the flow of the major westside tributaries is captured by the various irrigation and reclamation districts. Thus, it is virtually impossible for adults to consistently enter the system and for juveniles to consistently exit the system. To facilitate adult entrance and juvenile exit, defined instream flows have to be provided for each of the specified tributaries.

Water temperatures - Temperature is probably limiting for juveniles and adults entering or exiting the system during April through October. Drain flows often exceed 2,000 cfs and water temperatures exceed 80°F. Drainage flows entering the Sacramento River at Knights Landing during April through June probably significantly affect Sacramento River temperatures below Knights Landing.

Restoration actions -

Action 1: Develop defined migrational routes.

Objective: Provide direct access to Westside Tributaries.

Location: Westside Tributaries entering Colusa Basin.

Narrative description: Before water development, westside tributaries that currently enter the Colusa Basin Drain probably entered the Sacramento River through various sloughs between the towns of Glenn and Knights Landing. Reclamation efforts have since blocked this access other than through the outfall gates at Knights Landing. In addition, within the basin, most tributaries are blocked or diverted by various irrigation and reclamation districts.

Related actions that may impede or augment the action: Migrational corridors have to be identified that would either provide river access similar to that existing historically or, alternatively, provide a defined route through the Colusa Basin Drain outfall into the tributaries. Either alternative would require significant structural work such as levees, fish screens, fish ladders, siphons, and bridges.

Agency and organization roles and responsibilities: It is necessary for DFG, USFWS, and DWR to reach consensus as to the feasibility of developing anadromous fish production potential in the Colusa Basin Drain, given the low potential for developing migration corridors and the necessary infrastructure to ensure successful passage and reproduction (small reservoirs, levees, fish screens, fish ladders, siphons, and bridges).

Potential obstacles to implementation: The cost to make necessary structural fixes to a complex irrigation drainage system to gain a potentially small anadromous fish production contribution and the high temperature input during May to June suggest that greater salmon production benefits could accrue from investing similar costs into major diversion screens located on the mainstem of the Sacramento River or enhancing higher production potential streams.

Predicted benefits: Potential benefits are unknown although defined access routes might allow sporadic opportunistic runs of fall-run salmon based on historical knowledge of the drainage. Alternatively, some unknown benefit to upper Sacramento River salmon stocks might result from excluding entry to the Colusa Basin Drain at the Knights Landing outfall gates. A greater benefit to salmon stocks, particularly fall-run, may be preventing entrance into the Colusa Basin Drain. Currently, it is believed that any fish entering the drain and respective tributaries are straying from the Sacramento River as the result of high return flows at the Knights Landing outfall gates.

Action 2: Develop defined migrational flows.

Objective: Provide direct access to Westside Tributaries.

Location: Westside Tributaries entering Colusa Basin.

Narrative description: Before water development, westside tributaries that currently enter the Colusa Basin Drain probably entered the Sacramento River through various sloughs between the towns of Glenn and Knights Landing. Most likely, historical flows were sporadic and confined to October through March.

Related actions that may impede or augment the action: Currently, during most of the year, flows are diverted by various irrigation and reclamation districts. Some potential might exist to enhance flows through implementation of a foothill reservoir project identified by DWR (1964) as a possible flood control alternative. In addition, significant structural work such as levees, fish screens, fish ladders, siphons, and bridges would be required.

Agency and organization roles and responsibilities: See roles and responsibilities discussed for Action 1.

Potential obstacles to implementation: As stated for Action 1, general benefits to salmon stocks, particularly fall-run stocks, might be improved by preventing entrance into the Colusa Drain. Again, it is believed that any fish entering the drain and respective tributaries are straying from the Sacramento River as the result of high return flows at the Knights Landing outfall gates. See potential obstacles discussed for Action 1.

Predicted benefits: Benefits are the same as stated for Action 1.

Action 3: Reduce water temperatures.

Objective: Enhance survival in Colusa Drain and westside tributaries.

Location: Westside tributaries entering Colusa Basin.

Narrative description: Historically, water temperatures were probably a limiting factor that, in conjunction with inconsistent flows, served to limit salmon populations in the Colusa Basin Drain tributaries. Isolating flows through defined channels, in conjunction with enhanced flows from a foothill reservoir project, might provide some marginally lower water temperatures.

Related actions that may impede or augment the action: Temperature impacts on the Sacramento River from drain return flows are believed to be significant during the late spring and early fall periods. Enlargement of the Knights Landing Ridge Cut might facilitate allowing such flows to be routed into the Yolo Bypass, thereby eliminating impacts on the river at Knights Landing and below.

Agency and organization roles and responsibilities: See roles and responsibilities discussed for Action 1.

Potential obstacles to implementation: See potential obstacles discussed for Action 1.

Predicted benefits: Potential benefits are unknown although reduced temperatures facilitate sporadic opportunistic runs of fall-run salmon. Alternatively, some unknown benefit to upper Sacramento River salmon stocks might result by routing excess bypass flows during spring and fall into the Yolo Bypass. As stated for Action 1, general benefits to salmon stocks, particularly fall-run, might be improved by preventing entrance into the Colusa Drain. See predicted benefits discussed for Action 1.

Miscellaneous small tributaries -

Limiting factors and potential solutions - Table 3-Xb-15 lists key limiting factors for chinook salmon and steelhead in small tributaries and potential solutions. Small tributaries have been degraded in many ways. Some have been diverted into irrigation canals such as the Glenn-Colusa Canal and are no longer direct tributaries to the river. Others have been channeled for drainage or flood control and burned or sprayed with herbicides to keep channels free of plant obstructions. Irrigation diversions, usually in upstream areas where the stream is perennial, contribute to early dewatering of downstream reaches used for rearing by juvenile chinook salmon. Sometimes tributaries are damaged simply because local people fail to recognize their value and place burn piles where they destroy riparian vegetation or carelessly overspray the streams with herbicide or pesticide. Most small tributaries have been used as dumps for all sorts of waste, including car batteries, engine blocks, oil filters, animal carcasses, refrigerators, TVs, and household garbage, all of which may leach toxic substances into the water. In some cases, fish are lost to irrigation diversions that pull river water upstream near the mouth of the tributary. While chinook salmon rearing in most small tributaries is limited by one or more of the above problems, the smaller streams have not been studied enough to detail which reach of which stream needs particular restoration.

Table 3-Xb-15. Key limiting factors for chinook salmon and steelhead in small tributaries and potential solutions to those problems.

Limiting factors	Potential solutions
Degraded rearing habitat	Revegetate denuded stream reaches; restore a protected riparian strip
Loss to agricultural diversion	Move pumps to the river where sufficient bypass flow exists to avoid entrainment of juvenile salmonids and avoid screen intakes
Presence of toxic materials in streams	Remove existing hazardous materials; educate public about importance of small streams; enforce ordinances prohibiting dumping in streams
Early dewatering of streams	Find alternative sources of water for upstream diversions
Blocked upstream passage for rearing juvenile chinook salmon	Replace bridge/ford combinations with bridges or enlarged culverts
Loss of rearing habitat due to interception of tributaries by canals	Provide siphons to get "beheaded" tributary streams past irrigation canals

Restoration actions -

Action 1: Revegetate denuded stream reaches and restore and maintain a protected riparian strip in all tributaries.

Objective: Expand the usable rearing habitat and provide habitat diversity, cover from predators, and shade to retain lower water temperatures in late spring.

Location: All Central Valley reaches of rearing tributaries.

Narrative description: Restore and maintain a natural riparian corridor that is not sprayed, mowed, burned, channeled, or used as a garbage dump. Educational campaigns to dispense knowledge about the value of small tributaries as salmon habitat should help significantly to preserve and restore tributary habitat. Recruitment of school groups and local conservation groups for cleanup, riparian planting, fencing, and other restoration projects would contribute both to education and direct restoration. Critical stream reaches might be preserved by purchase of conservation easements.

Related actions that may impede or augment the action: All of the actions in this report augment one another because they all improve rearing habitat for juvenile chinook salmon.

Agency and organization roles and responsibilities: Cooperation between DFG, DWR, and local conservation groups is essential.

Potential obstacles to implementation: Enforcing conservation laws may be difficult if there is a shortage of enforcement personnel.

Predicted benefits: Trees, roots, and stumps at the stream edge create eddy currents during flood. The eddies scour out the deep holes that young salmon need for survival in dry years. The trees also shade the stream, keeping temperatures safe for juvenile salmon, while the roots and fallen branches provide cover for escape from predators. Resultant habitat diversity supports many forms of aquatic foods, while terrestrial insects, falling into the water from overhanging vegetation, also contribute to the food base. Improved habitat from riparian revegetation would result in greater survival of juvenile chinook salmon rearing in tributaries. Recruitment of school groups and local conservation groups for cleanup, riparian planting, fencing, and other restoration projects would contribute both to education and direct restoration.

Action 2: Move pumps to the river where sufficient bypass flow exists to avoid entrainment of juvenile salmonids. (Screen pumps.)

Objective: Reduce loss of juveniles to agricultural diversion.

Location: All Central Valley reaches of rearing tributaries where diversion pumps are located but designed to take water from both tributary and river.

Narrative description: Pumps are frequently located on a tributary just off the river to reduce damage and displacement from the meandering river. When functioning, they reverse the natural flow between them and the river. While convenient and cheaper for the water user, pumps are disastrous to anadromous fish. During winter or early spring, juvenile chinook salmon move up the tributaries for rearing (Maslin and McKinney 1994). If the pumps located in the tributaries are turned on before the salmon leave, most salmon will be lost. Such diversions should be relocated, moved to the river, and re-installed with screening and bypass flows. Federal and state funds should be made available to avoid excess hardship to small operators.

Related actions that may impede or augment the action: See related actions discussed for Action 1.

Agency and organization roles and responsibilities: This action should be accomplished by a collaboration between DWR, DFG, the USBR, USFWS, and local water users.

Potential obstacles to implementation: The cost of moving and screening pumps could be an obstacle.

Predicted benefits: Thousands of juvenile chinook salmon would be saved annually (Maslin and McKinney 1994).

Action 3: Find alternative sources of water for upstream diversions.

Objective: Prevent early dewatering of stream reaches used for rearing.

Location: All rearing tributaries with upstream diversion.

Narrative description: Small irrigation diversions exist in almost all of these streams, usually in the foothill region where streams are perennial. They cause reduced flow in downstream reaches, often resulting in early dewatering and associated loss of juvenile salmonids that would have successfully emigrated in a few weeks. Timing and quantity of agricultural diversion need to be changed to prevent early dry down in downstream reaches. Substitution of groundwater sources from mid-April to mid-May would improve survival, particularly of fall-run juveniles.

Related actions that may impede or augment the action: See related actions discussed for Action 1.

Agency and organization roles and responsibilities: This action should be accomplished by collaboration between DWR, the USBR, and local water districts.

Potential obstacles to implementation: Lack of understanding of the importance of small tributaries may affect the cooperation of water users.

Predicted benefits: Fall-run juvenile chinook salmon that are almost to the smolt stage are often trapped as intermittent streams dry down in late April and early May. Leaving additional water in small tributaries at these critical times could permit survival of thousands of juvenile salmon (Maslin and McKinney 1994).

Action 4: Survey tributaries for toxic materials, follow with cleanup projects as needed; expand enforcement of dumping ordinances.

Objective: Remove hazards and potential hazards such as car batteries, oil filters, and animal carcasses from streams. Prevent further use of streams for dumps.

Location: All Central Valley reaches of rearing tributaries.

Narrative description: The value of intermittent streams is often unrecognized, and, consequently, the streams are used as convenient waste receptacles. All sorts of waste, including car batteries, engine blocks, oil filters, animal carcasses, refrigerators, TVs, and household garbage, can be observed in these tributary streams. This problem can be addressed by a combination of cleanup, education, and enforcement of existing prohibitions on dumping.

Related actions that may impede or augment the action: See related actions discussed for Action 1.

Agency and organization roles and responsibilities: Cooperation between DFG, DWR, and local conservation groups is essential.

Potential obstacles to implementation: Lack of understanding of the importance of small tributaries may limit public cooperation. Enforcing conservation laws may be difficult if there is a shortage of enforcement personnel.

Predicted benefits: While it is impossible to estimate loss of juvenile salmonids due to toxic and oxygen-demanding materials in streams, rampant illegal dumping is substantially degrading habitat.

Action 5: Replace bridge/ford combinations with bridges or larger culverts.

Objective: Expand the usable habitat in some tributaries.

Location: Central Valley reaches of rearing tributaries that have bridge/ford crossings.

Narrative description: Some rearing tributaries have low road crossings, usually constructed of concrete with small culverts so that low flows pass through the culverts at high velocity and higher flows spill over the road bed (e.g., Elder Creek by TCC, Dye Creek at Shasta Boulevard.) The high velocity and turbulence of water passing through these culverts prevent juvenile chinook salmon from migrating further upstream, sometimes blocking access to miles of channel suitable for rearing.

Related actions that may impede or augment the action: See related actions discussed for Action 1 above.

Agency and organization roles and responsibilities: Resolution of this problem should be accomplished by a collaboration between the California Department of Transportation, DFG, and private land owners.

Potential obstacles to implementation: Costs of improving road crossings could be an obstacle.

Projected benefits: Additional rearing habitat would become accessible to juvenile salmon. The absolute benefit would vary with the proximity to the river of the crossing and the amount of potential rearing habitat upstream. Within a few miles of the river, a reasonable projection would be about 1,500 juveniles per stream mile.

Action 6: Provide siphons to get "beheaded" tributary streams past irrigation canals.

Objective: Expand the usable habitat.

Location: Central Valley streams that formerly were tributary to the Sacramento River but now emptying into an irrigation canal, especially on the west side of the Sacramento River in Glenn and Colusa counties.

Narrative description: Many tributaries now flow directly into canals. (e.g., Willow, Hunter's, Corral, Lurline, Freshwater, Sand, Oat Creeks.) Because water in these streams no longer reaches the river, their habitat is no longer available to anadromous fish. Some of these "beheaded" streams formerly supported minor spawning populations of fall-run chinook salmon; most provided rearing habitat.

Related actions that may impede or augment the action: See related actions discussed for Action 1 above.

Agency and organization roles and responsibilities: Local water districts, DWR, DFG, and the USBR should cooperate to solve this problem.

Potential obstacles to implementation: The cost of providing siphons could be an obstacle.

Predicted benefits: Each tributary could provide rearing habitat for between 5,000 and 20,000 juvenile chinook salmon annually. Small spawning populations (50 to 100 adults) could be supported by some (Paul Maslin, professional opinion pers. comm.).

C. LOWER SACRAMENTO RIVER AND DELTA TRIBUTARIES

Approach -

The Lower Sacramento River and Delta Tributaries Salmon and Steelhead Technical Team's approach to developing recommendations for the anadromous fisheries restoration program was to assign drainages to individual team members (Table 3-Xc-1). Team members were each responsible for taking a lead role in developing recommendations for their assigned drainages. Individual team members enlisted the help of additional authors to help them write their sections, or additional authors were enlisted by the team leader.

Table 3-Xc-1. List of team members and additional authors assigned to writing sections for each of the lower Sacramento River and Delta tributaries.

Drainage	Assigned member	Additional authors[a]
Feather	Ted Sommer, DWR	Dan Castleberry, USFWS
Yuba	Paul Bratovich, Beak Consultants	Mike Bryan, Beak Consultants
Bear	Nick Villa, DFG	John Nelson, DFG Steve Croci, USFWS
American	Paul Bratovich, Beak Consultants	Mike Bryan, Beak Consultants
Cosumnes	Nick Villa, DFG	Dawne Becker, DFG Steve Croci, USFWS
Mokelumne	Joe Miyamoto, EBMUD	Gary Rensink, USFWS
Calaveras	Kate Puckett, USBR	

[a] In addition to the listed authors, formatting and editorial changes were made by the USFWS, primarily at the request of the Core Group.

To develop this report, the team first developed a comprehensive list of potential limiting factors. This list is not included in the report. Each team member selected only those factors that were potentially limiting in their drainage and included those factors under the header "Limiting factors and potential solutions". Team members then selected only those factors that they considered to be of primary importance and described restoration actions for these factors under the header "Restoration actions".

Throughout this process, team members agreed to confine their lists of limiting factors and restoration actions to those factors and actions that take place within the drainage to which they were assigned.

Two factors that affect production outside the assigned drainages and that all team members agreed must be addressed are that (1) substantial progress toward restoration must be achieved within the Sacramento-San Joaquin Delta if natural production of salmonids that spawn in the lower Sacramento River and Delta tributaries was expected to double and (2) ocean harvest of naturally produced chinook salmon must not be allowed to occur at higher levels than natural production on small rivers can support. Because the authors believed these factors would be discussed elsewhere in the report, the sections on individual drainages that follow rarely mention these factors.

Feather River -

Limiting factors and potential solutions - - Following is a list of factors that may limit chinook salmon and steelhead production within the Feather River basin (ranked in approximate order of importance).

Instream flows - Low flows during the baseline period may have limited spawning habitat, rearing habitat, and juvenile outmigration.

Spawning gravel - The quantity and quality of spawning gravels are reduced by armoring, gravel mining, lack of gravel recruitment, and encroachment of vegetation.

Water temperature - Warm temperatures below Thermalito outlet possibly could negatively affect the reproductive success of adult spring-run chinook salmon. However, temperatures in the low-flow channel remain relatively cool because of dam releases. Field observations during 1992 indicated that temperatures below Thermalito outlet in the springtime reach levels considered unsuitable for young salmon.

Angling - Recent studies indicate that Feather River fishery in-river and Bay/Delta anglers may harvest 20-21% of the spawning escapement (Brown and Green in press). In addition to reducing the numbers of spawners, anglers also trample redds, potentially reducing the survival of pre-emergent salmonids in the redd.

Hatcheries - The viability of spring-run salmon in this system is questionable because of possible interbreeding with fall-run salmon, resulting in genetic dilution. Studies are needed to determine if pure stocks of spring-run salmon remain. In addition, Cramer (1990) estimated that a large percentage of hatchery-produced salmon stray to other rivers in the Sacramento Basin. While these fish contribute to the overall escapement in the Central Valley, production in the Feather River could be increased by reducing straying rates.

Bank and streambed modification - Channelization is aggravated by levees and embankments that restrict lateral channel movement, increasing flow velocities and deepening the channel. Channelization and riprapping may also reduce habitat diversity, instream cover, and food availability for fry and juveniles.

Diversions - Several unscreened agricultural diversions and pumps exist along the lower Feather River. The degree to which these diversions affect salmonids is unknown; however, it is possible that some entrainment occurs.

Water quality - The effects of wastewater discharge into the river are unknown; however, Dick Painter (DFG retired pers. comm.) expressed concern that water quality problems were possible. This issue should be investigated.

Predation - Large schools of striped bass congregate near the mouth of the Yuba River during the months of peak outmigration of smolts. Predation rates have not been measured, but are expected to be significant.

Table 3-Xc-2. Key limiting factors for chinook salmon production in the Feather River and potential solutions.

Limiting factor	Potential solutions
Instream flows	1. Compete instream flow study 2. If initial instream flow results are accurate, increase discharge into the low-flow channel 3. Increase flows in reach below Thermalito Dam to 2,500 cfs 4. Gravel restoration to increase spawning habitat, particularly near the hatchery 5. Experimental pulse flow events in spring to promote outmigration 6. Test the effectiveness of increasing turbidity in the river as an alternative to pulse flows

Limiting factor	Potential solutions
Spawning gravel	1. Gravel restoration to reduce armoring in spawning habitat, particularly near the hatchery 2. Gravel replacement at the head of one or more low-flow channel riffles 3. Increase instream flows to reduce encroachment 4. Consider occasional flushing flows to clean channel margins 5. Gravel restoration at the margins of problem riffles, including removal of encroaching riparian vegetation
Water temperature	1. Complete temperature model for the river as a tool to examine this issue 2. Develop alternatives to reduce temperatures during critical periods. Increasing flow through the low-flow channel in summer is one possible alternative
Angling	1. The extent of this problem requires further study 2. Restrict sport fishing in the Feather River 3. Educate sport fishers on risks of redd trampling 4. Promote catch-and-release fishing
Hatcheries	1. Conduct studies to determine if pure stocks of spring-run chinook salmon remain 2. If spring-run salmon are shown to be genetically distinct, modify hatchery practices to maintain their viability 3. Continue tagging studies to determine the extent of the straying problem

Limiting factor	Potential solutions
Bank and streambed modification	Actions related to channelization remain to be determined. Further studies are needed to assess possible impacts.

Restoration actions -

Action 1: Increase flows in low-flow channel.

Objective: Enhance and maintain spawning and rearing habitat.

Location: Low-flow channel.

Narrative description: Under this action, instream flows in the low-flow channel would be increased for at least part of the year. Under the present configuration of the system, most flow in the lower Feather River is generally diverted through Thermalito Diversion Dam, leaving a constant flow level of 600 cfs in the "natural" watercourse, the low-flow channel. Extra flow through the low-flow channel during at least September through May may enhance spawning habitat without an adverse effect on rearing. Two alternate flow schedules are discussed below. Schedule A flows would be as follows:

Schedule A. Adopt for 1 year and evaluate.

Months	Flow (cfs) for three year types	
	Wet and normal	Dry
September-May	2,500	1,700
June-August	1,100	800

Adoption of Schedule B would depend on the results of evaluation of Schedule A. Under Schedule B, flows would be set at 800 cfs year round in all year types.

The rationale for this action is that initial results from a DWR/DFG instream flow study suggest that spawning habitat in the low-flow channel would be maximized at higher flows than the present level of 600 cfs (Sommer 1994). DWR (1982) studies also indicate that excessive spawning densities in the low-flow channel result in superimposition of redds, reducing egg survival by as much as 40%. Recent field observations confirm the presence of extensive superimposition.

The two schedules are based on two different modeling scenarios presented in a draft IFIM report (Sommer 1994). The modeling scenarios differed in assumptions about depths preferred by spawning chinook salmon. Recommendations may be modified after completion and final release of the IFIM report.

Schedule A is based on the assumption that chinook salmon prefer to spawn at depths greater than or equal to 1.5 feet, provided that velocity and substrate requirements are met. Evidence for this assumption comes from observations of chinook salmon spawning in the American and Sacramento rivers. Although most salmon have been observed to spawn at a depth of 1.5 feet in the Feather River, it is possible that flows have not been sufficiently high during the period of observation to create the right habitat conditions.

Schedule B is based on the assumption that chinook salmon in the Feather River prefer to spawn at a depth of 1.5 feet. Evidence for this assumption comes from observations of chinook salmon spawning in the low-flow channel of the Feather River (Sommer 1994).

Whether Schedule A or B provides optimal spawning habitat depends on which assumption is most realistic. Flows similar to those recommended in Schedule A did not occur during the period of observation, but flows similar to those in Schedule B did occur. Without observations at flows similar to Schedule A flows, it is difficult to compare the validity of the two assumptions.

Based on this uncertainty, the effects of Schedule A flows on spawning habitat (especially depth preferences) should be tested. The test should consist of at least 1 year of Schedule A flows in the low-flow channel and should include observations of spawning habitat and preferences. Because the potential exists for Schedule A flows to result in substantially less spawning habitat than is present at existing flows (as is predicted by the modeling scenario on which Schedule B flows are based), the effects of Schedule A flows should be evaluated yearly. If Schedule A flows result in a reduction in spawning habitat, Schedule B flows (or flows derived from subsequent analyses) should be adopted.

Potential obstacles to implementation: Instream flows in the low-flow channel have been set through an agreement between DWR and DFG. FERC also has regulatory authority over Oroville Dam operations. Any changes in flow would require approval from these parties. In addition, the action would have costs to the SWP as a result of the water that would no longer be diverted through Thermalito Power Plant.

Predicted benefits: This action is probably one of the best ways to improve salmonid production in the lower Feather River. Benefits include increased spawning habitat, egg survival, and outmigration flows. However, the projected benefits of this action are difficult to specify because of the preliminary nature of the instream flow model questions about whether "deep spawning" is realistic. Given the severity of the superimposition problem in this reach, an increase in salmon production by 10-50% may be expected, depending on which alternative is most realistic.

Action 2: Consider providing experimental pulse flows

Objective: To stimulate outmigration of juvenile chinook salmon.

Location: Low-flow channel and reach below Thermalito outlet.

Narrative description: Experimental pulse flows could be considered as an approach to promote outmigration. Outmigration is a particular concern in the low-flow channel, where flows are constant unless surface runoff or floodflows enter the river. Moreover, temperatures are cooler in the low-flow channel; fish who delay their migration because of insufficient migration cues may face dangerously high temperatures in the lower reach (Sommer 1993). Pulse flows might provide important cues to enhance the migration. Possible experimental release schedules remain to be developed.

Potential obstacles to implementation: Changes to instream flow will require approval from DFG, DWR, and FERC. Flood control is also a potential concern.

Predicted benefits: A possible benefit of this action is enhanced survival of smolts. However, the potential effects on salmonid production in the system cannot be identified until field trials are conducted.

Action 3: Consider providing experimental high-turbidity pulses.

Objective: To stimulate outmigration of juvenile chinook salmon.

Location: Low-flow channel and reach below Thermalito outlet.

Narrative description: Turbidity pulses could be considered as an approach to promote outmigration. Outmigration is a particular concern in the low-flow channel, where flows are constant unless surface runoff or floodflows enter the river. Moreover, temperatures are cooler in the low-flow channel; fish that delay their migration because of insufficient migration cues may face dangerously high temperatures in the lower reach. However, initial observations from the Feather River suggest that turbidity or flow pulses might provide important cues for outmigration (Sommer 1993). Moreover, studies by Ligon et al. (in prep.) suggest that increased turbidity reduces predation losses during outmigration.

Potential obstacles to implementation: This option is *highly* experimental; techniques have not yet been developed. Moreover, clearance would be needed from the CVRWQCB and perhaps other agencies.

Predicted benefits: A possible benefit of this action is enhanced survival of smolts. However, the potential effects on salmonid production in the system cannot be identified until new studies are completed.

Action 4: Restore gravel and create spawning habitat in the low-flow channel.

Objective: Reduce armoring; increase spawning habitat.

Location: Low-flow channel and reach below Thermalito outlet.

Narrative description: Problems with limited spawning habitat were described previously under the instream flow option. Additional problems are that: 1) the existing spawning habitat is undergoing significant armoring, particularly near the high density spawning area near the Feather River Fish Hatchery (DWR 1982); and 2) low, stable flows appear to have promoted vegetation encroachment at the edge of spawning riffles. Maintenance of relatively stable flows in the low-flow channel through much of the past decade may have promoted vegetation encroachment at the margins of spawning riffles. Flood events in 1986 and 1993 are the major exception to this comment. Although flows have been much more variable below Thermalito outlet, reduced flow during many months of the recent 6-year drought may have promoted vegetation encroachment in this reach of the river.

Restoration activities should be undertaken to reduce armoring and increase spawning habitat. A total of approximately 2-3 river miles are considered high priority for restoration.

Potential obstacles to implementation: Extensive engineering studies are needed before this option can be implemented. Permits would probably be required from the Corps, DFG, CVRWQCB, and perhaps other agencies.

Predicted benefits: Redd superimposition could be reduced if the quality of spawning habitat was improved and if new riffles were created. Possible benefits cannot yet be identified until engineering studies identify the potential areas and design constraints for restoration and riffle creation.

Action 5: Replenish gravel.

Objective: Reduce the degradation of spawning gravel.

Location: Low-flow channel and reach below Thermalito outlet.

Narrative description: Clear water releases from Lake Oroville are eroding streambanks and the channel bottom without replenishment. Gravel studies indicate that channel degradation is expected to continue throughout the river below Oroville Dam (DWR 1982). Placement of gravel in upstream areas and allowing it to migrate downstream may help to alleviate this problem.

Potential obstacles to implementation: Extensive engineering studies are needed before this option can be implemented. Permits would probably be required from the Corps, DFG, CVRWQCB, and perhaps other agencies.

Predicted benefits: This option would help arrest channel degradation caused by the construction of Oroville Dam. However, it is unclear if this option would significantly increase the quality and quantity of spawning habitat. At the very least, it would help to reduce long-term reduction in fish production.

Action 6: Complete temperature model.

Objective: Develop a temperature model as a tool for river management.

Location: Low-flow channel and reach below Thermalito outlet.

Narrative description: A temperature model is needed to help address issues for adult holding, egg incubation, and rearing of young, summarized below. The University of California, Davis, is presently completing this model under contract with DWR.

Adult holding: Warm temperatures below Thermalito outlet may negatively affect spring-run salmon. The extent of this problem has not yet been documented. However, temperatures in the low-flow channel remain relatively cool because of dam releases. Temperatures are considered less of a problem for fall-run salmon because they appear to remain in downstream areas until suitable temperatures are present in the river for spawning.

Incubation: It is unknown if water temperatures result in egg mortality in this system. Impacts are most likely to occur in October on spring-run salmon and early spawning fall-run salmon.

Rearing: Field observations during 1992 indicated that spring temperatures below Thermalito outlet reach levels considered unsuitable for young salmon in relation to the available information on temperature tolerance (Sommer 1993). If high temperatures are a problem for any of these life stages, a likely action would be to increase flows through the low-flow channel.

Predicted benefits: The possible benefits of a temperature model remain to be determined, but the model is expected to be a key tool for the management of salmonids in the system.

Action 7: Conduct studies on the hatchery program.

Objective: 1) Determine distribution of Feather River Fish Hatchery chinook salmon in Central Valley stocks, and 2) determine genetic integrity of Feather River spring-run chinook salmon.

Location: Feather River Fish Hatchery.

Narrative description: The viability of spring-run salmon in this system is questionable because of possible interbreeding with fall-run salmon. Studies are needed to determine if pure stocks of spring-run salmon remain. Also unclear is the degree to which Feather River salmon stray to other basins in the system. Cramer (1990) estimated that a large percentage of hatchery-produced salmon stray to other Sacramento Basin tributaries. A better understanding of the effect of hatchery practices on salmon survival and distribution may help to improve salmon production and maintain genetic integrity in the system.

Based on these observations, two studies are proposed:

1) **Genetic testing on Feather River spring-run chinook salmon.** The initial part of this study would focus on electrophoretic or DNA studies to determine if viable pure stocks of spring-run salmon exist. If viable stocks can be demonstrated, the second phase of the study would develop hatchery practices to maintain genetic integrity.

2) **Tagging of hatchery fish.** During the past year, DWR initiated an extensive program of tagging hatchery fish. The goal is to mark approximately 1 million salmon each year for at least 5 years. The fate of these tagged salmon would be determined through creel census, spawning, and hatchery surveys. Survival rates would ultimately be compared to the hatchery practices and environmental conditions during the release of smolts.

Predicted benefits: Preservation of a viable spring-run salmon stock would be a major benefit to the gene pool of Central Valley salmon stocks. Moreover, hatcheries have a major, but poorly understood, effect on salmon production. Tagging studies would allow better management of salmon in the system. However, projected improvements in production cannot be specified at this time.

Action 8: Increase flows below Thermalito outlet.

Objective: Enhancement of rearing habitat, maintenance of spawning habitat.

Location: Reach below Thermalito outlet.

Narrative description: Under the proposed action, flows would be increased according to the schedule shown below for salmon and steelhead.

Months	Flow (cfs) for year types		
	Wet	Normal	Dry
October-March	2,500	2,500	1,700
April-May	3,000	3,000	2,100
June-August	1,000	1,000	1,000
September	2,500	2,500	1,400

A draft instream flow report (Sommer 1994) forms the basis of this recommended action for salmon and steelhead. However, implementation of these flows should include completion of the IFIM study to confirm the initial recommendations. The March-June flows apply to salmon and steelhead only.

Preliminary IFIM results indicate that spawning habitat during October through December would be maximized in the 750- to 2,750-cfs range (Sommer 1994). There is no evidence that the recommended normal and wet year flows of 2,500 cfs for October through December would increase spawning habitat, but this higher level may be a safer level for maintenance of habitat. For example, vegetation encroachment at the margins of some riffles may be reduced.

The main purpose of the January-May flows is to increase rearing habitat for fry and juveniles and to promote outmigration. IFIM results show that increasing January-May flows would create additional rearing habitat, although it remains to be demonstrated that rearing habitat is a limiting factor in the system (Sommer 1994). Nonetheless, increased flows would probably have temperature and outmigration benefits for rearing, particularly in late winter and early spring.

The June-August flows remain unchanged from the present instream flow requirement (DWR/DFG 1983). However, recommended flows for these months are contingent on the completion of a temperature model for the system. Additional changes are possible to benefit spring-run salmon adults, which migrate upstream in spring and hold throughout summer in the low-flow channel.

Potential obstacles to implementation: Instream flows are presently set through an agreement between DWR and DFG. FERC also has regulatory authority over Oroville Dam operations. Any changes in flow would require approval from these parties.

Predicted benefits: The benefits of this proposal cannot be quantified at this time.

Yuba River -

Limiting factors and potential solutions - - Upstream migration of spawning adult salmonids is physically blocked by the Englebright Reservoir; hence, all spawning occurs below this point. The following list of limiting factors (Table 3-Xc-3) is limited to the lower Yuba River as defined by Englebright Reservoir on the upstream end and the Feather River on the downstream end.

Table 3-Xc-3. Factors limiting chinook salmon and steelhead production in the lower Yuba River and potential solutions.

Limiting factor	Potential solutions
Inadequate instream flows	Reoperate New Bullards Bar and Englebright Reservoirs to: 1. Maintain mimimum flows of 600-700 cfs from October 1 to March 31 in all water years 2. Maintain flows ≥1,000 cfs from April 1 to June 30 in all water years 3. Maintain minimum flows of 450 cfs from July 1 to September 30 in all water years 4. Evaluate pulse flows for facilitating juvenile outmigration in dry years 5. Reduce and control flow ramping rates
Unsuitable water temperature	1. Evaluate the efficacy of modifying the physical water release outlet structure at Englebright Dam.
Losses of juveniles at diversions	1. Re-screen the Hallwood-Cordua, Brophy-South Yuba, and Browns Valley diversions 2. Consolidate and screen smaller diversions 3. Modify timing and rate of water diverted 4. Improve efficiency of fish bypasses at diversions 5. Exclude piscivores from areas around diversions

Limiting factor	Potential solutions
Barriers to migration	1. Maintain ≥175 cfs through the critical Simpson Lane reach during spawning seasons of all years 2. Improve fish ladders at Daguerre Point Dam and maintain appropriate flows through ladders 3. Remove Daguerre Point Dam
Bank and streambank modifications	1. Purchase streambank conservation easements 2. Place large woody debris into rearing habitats 3. Terminate current programs that remove woody cover from the stream channel
Overharvest of adults	1. Further limit ocean harvest of naturally produced fish 2. Increase DFG enforcement efforts to stop poaching during the spawning seasons
Losses due to predation and competition	1. Modify Daguerre Dam face to keep outmigrants within the main channel 2. Remove Daguerre Point Dam

Two factors, water quality and gravel extraction, are not included in Table 3-Xc-3 or in the section on restoration actions and are addressed below.

Water quality - The only water quality parameter known to limit salmonid production on the lower Yuba River is water temperature (see "Water Temperature" subsection above). However, a water treatment plant does exist on, and discharge effluent into, Deer Creek, a tributary entering the lower Yuba River just below Englebright Dam (John Nelson, DFG, pers. comm., 1994). No data are currently available concerning the impact (if any) of this point-source discharge on salmonid production in the lower Yuba River and its tributary Deer Creek. However, because the potential for adverse water quality impacts exists at such sites, monitoring of water quality at the confluence of Deer Creek with the Yuba River would be in order.

Gravel extraction - Spawning gravel is not viewed as a limiting factor in the lower Yuba River today. However, wise management must guard against it from becoming one in the future because natural gravel recruitment has been severely limited by the construction and operation of New Bullards Bar and Englebright dams. Along such lines, DFG has made it a priority to regulate gravel extraction to protect salmon and steelhead spawning areas in the lower Yuba River (Reynolds et al. 1993). One option to ensure maintenance of salmonid spawning gravel would be to require mining operators, as a condition of their permits, to occasionally place gravel in the stream to enhance existing salmonid spawning beds.

Restoration actions -

Action 1: Maintain minimum flows of 700 cfs from October 1 through March 31 in all water years.

Objective: Optimize migration, spawning, and incubation conditions in the lower Yuba River.

Location: Entire lower Yuba River (flows measured at the Marysville gage).

Narrative description: Reallocation of water from New Bullards Bar and Englebright Reservoirs will be required to meet the instream flows recommended above for improving lower Yuba River spawning conditions. The Garcia Gravel Pit reach (from just north of Smartville downstream to Daguerre Point Dam) and the Daguerre Point Dam reach (from the dam downstream to the north side of Marysville) provide nearly all of the spawning habitat in the lower Yuba River. A flow of 700 cfs at Marysville maximizes spawning habitat in these reaches, particularly the more heavily utilized Garcia Gravel pit reach.

Current instream flows during the spawning/incubation seasons are often inadequate for optimal production.

Adult spawning migrations: Instream flows may limit adult salmonid migration (via straying) if there is an inadequate quantity of natal stream flows to provide sufficient environmental cues for homing. Furthermore, inadequate instream flows have been known to block upstream spawning migrations of salmon in dry years. For additional information on this factor, see the "Migration Barriers" subsection below.

Spawning habitat: Fall-run chinook salmon spawn during October through January; steelhead begin spawning in January and continue through April. In most years, minimum flow requirements appear adequate for providing suitable spawning habitat. The Garcia Gravel Pit and Daguerre Point Dam reaches provide nearly all of the spawning habitat in the lower Yuba River (DFG 1991). Approximately 60% of fall-run chinook salmon spawn between Daguerre Point Dam and the Highway 20 bridge.

The results of an instream flow study performed by Beak Consultants for DFG on the lower Yuba River indicated that weighted usable area (WUA) is highest for spawning chinook salmon at 600-700 cfs. Thus, when fall flows in the lower Yuba River drop substantially below 600 cfs, spawning habitat becomes limiting. DFG believes that salmonid spawning and rearing habitats are currently limiting in the Yuba River and has therefore assigned an A-1 priority to their improvement (Reynolds et al. 1993).

Rearing habitat: Rearing habitat is of special concern for fall-run chinook salmon from December through March. However, steelhead fry rearing occurs throughout the year and flows must be maintained at a level that permits successful rearing of both species.

Juvenile chinook salmon and steelhead-rearing habitat availability, as determined by IFIM studies (Beak 1989), is maximal at flows of 150-200 and 200-350 cfs, respectively.

Juvenile outmigrations: Juvenile outmigration of both chinook salmon and steelhead occur from April through June. Maintenance of at least 700-cfs flows during this outmigration period would facilitate juvenile downstream movement. Flows of 1,000, 2,000, and 1,500 cfs at the Marysville gage in April, May, and June, respectively, have been recommended for salmon and steelhead emigration (DFG 1991).

Actions for improving instream flows: Maintaining 700-cfs flows at Marysville from October 1 through March 31 would provide good conditions for salmon and steelhead migration and spawning. Furthermore, maintaining 700-cfs flows at Marysville during these months would prevent dewatering of redds and/or stranding of young chinook salmon and steelhead throughout the lower Yuba River. However, because steelhead spawn from January through April, a period when fall-run chinook salmon are in a rearing life stage, a distinct conflict arises regarding target instream flows during these months. Optimal flows for spawning steelhead would be 700 cfs, whereas IFIM studies suggest that rearing salmon would benefit most from flows of about 200 cfs. Because spawning requirements tend to be less elastic than those for rearing of juveniles, and because decreasing flows in January to accommodate those fry that have emerged may result in dewatering of late redds, flow rates should be maintained at 700 cfs from October through March. A compromise flow rate of 600 cfs at Marysville from January through March may be reasonable. Outmigrations of both species occur primarily during April through June, at which time target flows at Marysville should range between 1,000 and 2,000 cfs. However, it should be noted that such flows would reduce the availability of preferred rearing habitat young chinook salmon and steelhead remaining in the river. If flows of 1,000 cfs or greater can not be maintained from April through June during dry and critically dry years, lower base flows punctuated by pulsed flows of approximately 2,000 cfs should be considered. Flow rates at Marysville from July through September should be maintained at 450 cfs for steelhead rearing because, by July, nearly all juvenile salmon have left the river. The upper end of the flow range indicated to be optimal for steelhead rearing was selected because greater thermal protection is afforded by higher flow rates during these warm weather months. For effective management of lower Yuba River salmonids, emphasis should be placed on *consistently* meeting biologically appropriate instream flows throughout the year.

Since the impoundment of the New Bullards Bar Reservoir in 1969, fall chinook salmon and steelhead spawning runs have not increased as anticipated, largely because of consistent failure to meet required instream flows and temperatures during critical periods of the year. Hence, achieving target flows and temperatures in the lower Yuba River will likely involve reoperation of both New Bullards Bar and Englebright Reservoirs. Because instream flows and temperatures are believed to be the two most limiting factors to salmonid production in the lower Yuba River, reservoir reoperation to meet target flows and temperatures must be pursued within the constraints of all other uses of reservoir and river waters. In addition to meeting minimum flow requirements, reoperations should include physical modification of the water release outlets at Englebright Dam, if shown to be effective, in order to control the depth (and thus temperature) at which water is released from the reservoir.

Predicted benefits: Lack of suitable spawning flows is currently a key factor limiting salmonid production on the lower Yuba River, particularly in October. Significant improvements to spawning habitat quantity and quality, made by increased and maintained flow rates, has perhaps the greatest potential for increasing annual salmonid production in the river. Although quantitative estimates of increased production resulting from incremental increases in flows are not presently available, appropriate spawning flows will significantly contribute to the goal of doubling salmon and steelhead production in the lower Yuba River.

Action 2: Maintain minimal flows of 1,000 cfs during April, 2,000 cfs during May, and 1,500 cfs in June in all years.

Objective: Optimize juvenile rearing and outmigration conditions in the lower Yuba River.

Location: Entire lower Yuba River (flows measured at the Marysville gage).

Narrative description: Current instream flows during the rearing and outmigration periods are often inadequate, resulting in increased juvenile salmonid mortality from predation, thermal stress, and stranding. Reallocation of water from New Bullards Bar and Englebright Reservoirs will be required to meet the instream flows recommended above for improving lower Yuba River rearing and outmigration conditions.

Predicted benefits: Lack of suitable juvenile rearing and outmigration conditions are factors that currently limit salmonid production on the lower Yuba River. The recommended flows would provide suitable conditions for continued spring-run salmon and fall-run/steelhead smolt emigration. Furthermore, such flows would guard against juvenile fish isolation and stranding and would provide for spring-run chinook salmon attraction and immigration flows. Although IFIM studies indicated that these flows would actually reduce WUA for juvenile rearing, they are necessary to produce the greatest benefit to the greatest number of fish species and stocks.

Maintaining appropriate rearing and outmigration flows will increase annual salmonid production in the river by decreasing juvenile mortality from predation, thermal stress, and stranding. Although quantitative estimates of increased production resulting from incremental increases in flows are not presently available, appropriate rearing and outmigration flows will significantly contribute to the goal of doubling salmon and steelhead production in the lower Yuba River.

Action 3: Maintain minimum flows of 450 cfs from July 1 to September 30 in all years.

Objective: Improve juvenile steelhead rearing conditions.

Location: Entire lower Yuba River (flows measured at the Marysville gage).

Narrative description: Current instream flows during the late summer rearing period are often unsuitable for steelhead, resulting in limited physical habitat and stressfully high water temperatures. Such conditions cause increased juvenile mortality from predation and thermal stress. Reallocation of water from New Bullards Bar and Englebright Reservoirs will be required to meet the instream flows recommended above for improving late summer steelhead rearing conditions.

Predicted benefits: Lack of suitable rearing conditions and area currently limit juvenile steelhead survival in the lower Yuba River. Maintaining appropriate rearing flows will increase annual production in the river by decreasing juvenile mortality from predation and thermal stress. However, it should be noted that flows as low as 450 cfs at this time of year could adversely affect spring-run chinook salmon upstream immigration. Although quantitative estimates of increased production resulting from incremental increases in flows are not presently available, appropriate late summer rearing flows will significantly contribute to the goal of increasing steelhead production in the lower Yuba River.

Action 4: Evaluate the effectiveness of pulse flows for facilitating successful juvenile salmonid outmigration.

Objective: Optimize outmigration success when water is in short supply (e.g., dry and critically dry years).

Location: Lower Yuba River.

Narrative description: The faster juveniles can emigrate (within physiological constraints associated with smoltification), the greater their probability of survival. Reduced time in the Lower Yuba, Feather, and Sacramento rivers during outmigration reduces the length of time juveniles are exposed to instream predators and physiologically stressful water temperatures.

Pulse flows should be evaluated as an approach to promote successful salmonid outmigration. Studies are needed for determining how to maximize juvenile outmigration success when water supplies are limited in drier years, and thus instream flows could be reduced during the outmigration period (April-June).

Predicted benefits: Such studies will provide a basis for facilitating juvenile outmigration when water within the system is limited. Rapid outmigration associated with a pulse flow will likely increase juvenile survival rates and thus overall production.

Action 5: Reduce and control instream flow ramping rates.

Objective: Reduce hazards posed to young salmonids when flow rates change quickly.

Location: New Bullards Bar and Englebright dams (points of water discharge).

Narrative description: Fluctuating flows during the base period limited salmonid production by dewatering redds. Redd dewatering continues to be a problem in the lower Yuba River (DFG 1991).

Operations at New Bullards Bar and Englebright dams relating to the release of water downstream should be modified so that adjustments made to instream rates are more gradual than they are currently. Gradual ramping rates will decrease salmonid losses due to redd dewatering and fry and juvenile displacement and stranding, all of which occur when flow rates are changed substantially and quickly. Ramping rates should not exceed 30% of an existing initial flow during any 24-hour period.

Maintaining flows of 700 cfs in the river throughout the spawning and incubation periods of October through April would prevent dewatering of redds and/or stranding of young chinook salmon and steelhead. To further minimize flow reduction impacts on spawning salmonids and fry survival if flows become elevated above target levels between October and February, the following additional flow recommendations are made: 1) If the average flow for a 7-day period is >800 to <1,000 cfs, the minimum flow rate should default to 800 cfs from the date of occurrence through February; 2) if flows for a 7-day period average >1,000 to <1,500 cfs, minimum flows should default to 1,000 cfs; 3) finally, if flows for a 7-day period average ≥1,500 cfs, flows should be maintained at 1,500 cfs through February (DFG 1991). Doing so will help prevent redd dewatering and fry stranding during the October to February period.

Predicted benefits: Establishment of more gradual ramping rates, particularly during spring and midsummer, will reduce losses of young salmonids and contribute to increased production. The exact contribution of this action to increased salmonid production can not be calculated at this time.

Action 6: Maintain adequate instream flows for temperature control.

Objective: Reduce thermal stress to salmonids during the spawning, incubation, rearing, and outmigration periods.

Location: Entire lower Yuba River.

<u>Narrative description</u>: Effects of water temperature on fishery resources in the lower Yuba River have been a concern for many years (DFG 1991). River water temperatures are primarily a function of 1) ambient air temperature and 2) flows and temperatures released from Englebright and New Bullards Bar Reservoirs. Because of its great depth and storage capacity, there is always access to the cold water pool of New Bullards Bar Reservoir, even in late summer of dry years. However, waters released from New Bullards Bar warm substantially within Englebright Reservoir. Furthermore, Englebright Dam currently has no physical mechanism by which the depth (and hence temperature) of water released into the lower Yuba River can be controlled. Thus, a physical modification of the water release outlets of Englebright Dam should be evaluated for improving the control over the temperatures of downstream water releases.

<u>Adult migration, spawning, and incubation</u>: These life stages occur from September to February and October to April for fall-run chinook salmon and steelhead, respectively. Stressful water temperatures that impede spawning can occur during adult upstream migration in October, particularly if low flows combine with high air temperatures. Water temperatures are rarely too high for adults migrating during November. Optimum temperatures for chinook salmon and steelhead migration, spawning, and incubation range from 44°F to 56°F and from 46°F to 52°F, respectively (Beak 1989). Constant exposure of salmonid eggs to temperatures above 56°F result in some egg mortality, while water temperatures above 62°F result in complete egg mortality. Future reservoir releases should target the optimal range of temperatures during the fall spawning period, particularly during October through December. For these life history events, chronic low stress will affect chinook salmon if temperatures are above 56°F and equal to or less than 61°F. Chronic low stress for steelhead during these life stages will occur if water temperatures are above 52°F and equal to or less than 59°F. Thus, water temperature approaching 61°F and 59°F will have significant adverse impacts on the spawning and incubation success of chinook salmon and steelhead, respectively.

DFG (1991) compared thermal preferences of various chinook salmon life stages to Yuba River seasonal water temperatures during the six water years from 1973 to 1978. DFG found in-river temperatures at Marysville to be near or above 57°F until after mid-October and regularly into November as well.

<u>Fry and juvenile rearing</u>: Fry and juvenile rearing of chinook salmon occurs in the Yuba River from December through April, while fry and juvenile rearing of steelhead occurs throughout the year. Optimum instream temperature ranges for rearing young chinook salmon and steelhead are 53°F-56°F and 55°F-60°F, respectively (Beak 1989). Chronic low stress is believed to occur in juvenile chinook salmon if temperatures are above 56°F and equal to or less than 63.5°F. For steelhead, chronic low stress will occur if water temperatures are above 60°F and equal to or less than 68°F. Thus, water temperature approaching 63.5°F and 68°F during critical rearing months will have significant adverse impacts on the rearing success of chinook salmon and steelhead, respectively.

Water temperatures near Marysville may often exceed preferred juvenile chinook salmon rearing temperatures by early April, and, by June, even water that is released from Englebright Dam may exceed the preferred range (DFG 1991).

Juvenile outmigration: Peak juvenile outmigrations occur for both species in April-June. Stressfully high water temperatures frequently occur in June and can also occur in April and May, depending on flow levels and ambient air temperatures. Optimum instream temperature ranges for chinook salmon and steelhead juvenile outmigrations are 46°F-56°F and 44°F-52°F, respectively (Beak 1989). Chronic low stress will occur in chinook salmon outmigrants if temperatures are above 56°F and equal to or less than 63.5°F and in steelhead if temperatures are above 52°F and equal to or less than 60°F. Thus, water temperature approaching 63.5°F and 60°F during these months will have a significant adverse impact on the success of juvenile chinook salmon and steelhead outmigrations, respectively. Elevated water temperatures during this period of the year are particularly a problem below Daguerre Point Dam. Instream flows are substantially reduced below this point, thus allowing high ambient air temperatures to quickly warm instream waters.

Actions for improving water temperature: To facilitate successful salmon and steelhead immigration, spawning, and incubation, river water temperature at Marysville should not exceed 57°F for the months of October through March. Because both species experience peak juvenile outmigration from April through June, river water temperatures at Marysville should not exceed 60°F during April and May and 65°F during June. For the thermal protection of juvenile steelhead, river water temperatures throughout the remainder of the year (July through September) should be maintained at or below 65°F as well.

For effective management of lower Yuba River salmonids, emphasis should be placed on consistently meeting biologically appropriate instream flows and temperatures throughout the year. Adequate uncommitted water currently exists in the Yuba River system (i.e., Englebright and New Bullards Reservoirs) to restore the river's anadromous fishery. Reoperation of New Bullards Bar and Englebright Reservoirs to provide appropriate seasonal instream flows and temperatures for salmonid production in the lower Yuba River should be pursued. Because of the large storage capacity of New Bullards Bar Reservoir (relative to Englebright Dam), reoperation of New Bullards Bar Reservoir should take priority for achieving target instream flows and temperatures. Reoperation of Englebright Reservoir will therefore be heavily influenced by operational changes made upstream at New Bullards Bar. Colder temperatures for chinook salmon spawning in October, for example, could possibly be achieved by: 1) drawing Englebright Reservoir down in August and refilling it with cold water from New Bullards Bar Reservoir, and/or 2) installing a "curtain" into the water release outlets of Englebright Dam so that water can be released from the lower depths of the cold water pool only.

Appropriate outmigration flows and temperatures must be maintained to the Marysville gage to prevent heavy losses of juvenile salmonids below Daguerre Point Dam due to predation and thermal stress.

Related actions that may impede or augment the action: Higher instream flows (Actions 1-3) provide the means for achieving target water temperatures in the lower Yuba River. Better access to the coldwater pool in Englebright Reservoir in fall (see Action 7) could be heavily relied on to meet target spawning temperatures in October and November for fall-run chinook salmon. Drawing Englebright Reservoir down in August or September and refilling with cold water from New Bullards

Bar is likely impractical due to adverse impacts on recreation that would occur at Englebright Reservoir as a result of this action.

Predicted benefits: Lack of suitable in-river rearing and spawning temperatures currently limits both steelhead and salmon production in the lower Yuba River. Maintaining appropriate river temperatures will increase annual salmonid production by decreasing juvenile mortality from predation and thermal stress and increasing early fall reproductive and incubation success. Although quantitative estimates of increased production resulting from incremental changes in river temperatures are not presently available, much is known about how water temperatures affect salmonid survival rates during each life stage (e.g., USFWS 1990). This information clearly shows that lower Yuba River water temperatures are generally higher than that which is optimal for steelhead and chinook salmon and thus every effort should be made to maintain lower river temperatures throughout the early spawning and entire rearing and outmigration periods of the year.

Of all limiting factors and potential solutions, maintaining suitable river temperatures and instream flows will probably do more for increasing salmonid production within the lower Yuba River than all other actions combined.

Action 7: Evaluate and modify (if shown to be effective and appropriate) the water release outlets at Englebright Dam.

Objective: Physically modify (if found to be effective) the water release outlets of Englebright Dam to improve control over the depth at which water is discharged.

Location: Englebright Dam.

Narrative description: Reallocation of water from New Bullards Bar and Englebright Reservoirs will be required to meet the instream flows needed to achieve target river temperatures. To effectively utilize the cold water pool of Englebright Reservoir, appropriate and effective modifications to the exsting water release outlets may be needed at the dam. The greater the control over the depth at which reservoir waters are released, the better one can control downriver temperatures and manage the reservoirs' coldwater pools throughout summer.

Predicted benefits: See predicted benefits discussed for Action 6.

Actions 8, 9, and 10: Improve efficiency of fish screening devices and fish bypasses at the Hallwood-Cordua, Brophy-South Yuba, and Browns Valley water diversion facilities. Modify the timing and rate of water diverted from the river annually.

Objective: Reduce losses of juvenile salmonids.

Location: Hallwood-Cordua, Brophy-South Yuba, and Browns Valley water diversion facilities.

Narrative description: The current fish screening devices at the Hallwood-Cordua, Brophy-South Yuba, and Browns Valley water diversion facilities do not meet existing DFG fish screening criteria. Thus, fish screens at these facilities should be rebuilt to meet the DFG criteria. All water diversions on the lower Yuba River, big or small, should be evaluated for fish losses and screened according to current DFG criteria. Additionally, the efficiency of fish bypasses at these sites should be evaluated and changes made as warranted.

In addition to improving the fish screens and bypasses at these diversions, consideration should be given to the timing and magnitude of water diverted with regard to the timing of juvenile salmonid outmigration, and hence exposure to diversion screens and bypasses. Decreasing diversion flow rates at times of peak salmonid outmigration (e.g., April-June) would decrease fish losses at diversion facilities.

The three most significant diversions along the Yuba River occur at or near Daguerre Point Dam. Water diversions typically occur at this site from late March through October. The Hallwood Irrigation Company, the Cordua Irrigation District, and the Ramirez Water District share one diversion, Brophy and South Yuba Water Districts another, and Browns Valley Irrigation District a third. The combined diversions add up to a maximum of 1,085 cfs.

Juvenile salmonids are lost at all three diversion intake structures due to impingement, entrainment, or predation. While losses at individual diversions may not be great, the cumulative loss from all diversions is an important factor limiting annual salmonid production (Reynolds et al. 1993).

Unscreened diversions: Although a partial gabion structure exists, the Browns Valley Irrigation District's diversion is, for all practical purposes, unscreened, and losses of juvenile salmonids are known to occur there. The Hallwood-Cordua diversion is screened only during peak fall-run chinook salmon outmigrations (i.e., April through June) and remains unscreened during the remainder of the year. In addition, this diversion is not screened for the entire April through June outmigration period in every year and the screen does not meet DFG screen criteria for salmonids smaller than smolt size.

Juvenile salmonid survival is likely limited by pump entrainment at unscreened irrigation diversions. The exact number of unscreened agricultural diversions that exist on the lower Yuba River is not known at this time. However, an estimated six such diversions exist below Daguerre Point Dam (John Nelson, DFG pers. comm. 1994). The degree to which such diversions add to annual juvenile mortality is unknown.

Insufficiently screened diversions: Among the three primary water diversions, the Hallwood-Cordua diversion provides the best fish protection. It uses a V-shape, punched-plate screen that directs fish to a collection tank for removal and transport to a release location downstream. This screen is efficient in preventing the entrainment and impingement of smolt-sized juvenile salmonids (DFG 1991). However, losses do occur near the screen face and in the intake channel due to predation by squawfish. Losses range from 19.0% to 50.2% for test groups examined during 1977 and 1978.

The Brophy-South Yuba gravity diversion is screened by a permeable rock dike that still allows passage of juvenile-fish, even when the diversion is not in operation. This levee separates the diversion pool from a diversion and bypass channel. Studies have shown that fish losses through the levee were proportional to the amount of water diverted. DFG concluded from a survey that the levee is permeable to small fish, even when the diversion is not operational. Approximately 50% of the fish lost were attributed to predation by Sacramento squawfish in the diversion and bypass canal on the upstream side of the rock levee. Additionally, this gabion structure is topped during high flows (e.g., greater than 20,000 cfs), allowing juvenile salmonids to become entrained in the pool behind the structure (John Nelson, DFG, pers. comm. 1994).

The Browns Valley diversion is partially screened by a gabion that stretches across the mouth of the slough where the pump is located. However, a breech was cut through the gabion near the upstream bank to enhance diversion flow after it became clogged. The breech has reduced the effectiveness of the gabion to screen out fry and juvenile fish. Entrainment losses of smolts were calculated for diversion flows ranging from 10 to 75 cfs with 60-day losses estimated to range from 87 to 1,200 fish. At the maximum legal diversion rate of 42 cfs, total loss over a 60-day period was estimated to be 525 fish (DFG 1991).

These losses appear small; however, the overall cumulative effects of losses at all diversion sites make total losses significant. Juvenile salmonids are clearly lost to entrainment and impingement at all of these facilities. Thus, DFG has assigned an A-1 priority to improving these screening devices (Reynolds et al. 1993). In accordance with Fish and Game Code 6100, existing gravel and weir type fish screens have proven unreliable and ineffective and should therefore be replaced and screened with state-of-the-art perforated plate or wedge wire type screens located on the river (DFG 1991).

Inefficient bypass: At the Hallwood-Cordua screen, turbulence in front of the screens prevents juvenile salmonids from being quickly transported into the bypass. As recommended for fish screening devices, all bypasses should be evaluated for their efficiency and actions taken to improve effectiveness where warranted.

Flow reduction: The combined diversions from Hallwood-Cordua, South Yuba-Brophy, and Browns Valley diversions add up to a maximum of 1,085 cfs. When considered with New Bullards Bar Reservoir, the diversions result in increased flows above Daguerre Point Dam and decreased flows below Daguerre Point Dam. Specific effects of the diversions depend on flow levels and months when the diversions are made. Flow reductions from all diversions on the lower Yuba River have undoubtedly limited salmonid production during dry and critically dry water years. The effect of water diversion at Daguerre Point Dam (on in-river water temperatures) is most pronounced when diversions exceed 500 cfs and flows of only 200-300 cfs pass downstream. Low flows allow a more rapid warming of river waters with increasing distance downriver.

Actions for reducing fish losses at diversions: Juvenile salmonids continue to be lost at all diversion intake structures due to impingement, entrainment, and predation. Even if spawning success is high, net annual production of salmonids will remain low if in-river juvenile mortality rates continue to be high. Losses are believed to be highest at the South Yuba-Brophy and Browns Valley diversions. The inefficient rock-gabion structure at the Brophy-South Yuba diversion should be replaced and screened according to current DFG criteria (DFG 1991). Likewise, an effective fish screening devise must be installed at the Browns Valley diversion where no screen currently exists. In addition, all water diversions on the lower Yuba River should be accurately inventoried and effective screens and/or by-passes installed at all diversions identified to protect outmigrating juvenile salmonids. DFG has assigned an A-1 priority to inventorying all water diversions between Englebright Dam and the Feather River and to installing effective screening devises at the Hallwood-Cordua, South Yuba-Brophy, and Browns Valley diversions (Reynolds et al. 1993). Finally, modifications to the timing and duration of water diversions should be considered to reduce the impact of water diversions during critical periods of the year (e.g., juvenile outmigration from April through June).

A routine maintenance program must be established to prevent debris from blocking the entrance to fish bypasses. Similarly, bypass flows must be adequate and pathways from the channel into bypasses direct enough to ensure that fish can find bypass entrances. Finally, structures should be designed and installed near screens and bypass outlets to exclude and thus prevent squawfish and striped bass from selectively preying on juvenile salmonids that become disoriented and hence particularly vulnerable at such sites.

Predicted benefits: Modifications to fish screening devices, bypasses, and the timing of water diverted would reduce annual juvenile salmonid loses at the above-mentioned water diversion facilities. Increased juvenile salmonid survival and thus increased lower Yuba River salmonid production would result.

Action 11: Exclude piscivores from areas around diversions where disoriented juvenile salmonids become easy prey.

Objective: Reduce predation losses of juvenile salmonids.

Location: Hallwood-Cordua, Brophy-South Yuba, and Browns Valley water diversion facilities.

Narrative description: Predation on juvenile salmonids by squawfish and, to a lesser degree, by striped bass is significant at the screening facilities and bypasses of diversions. At the Hallwood-Cordua screens, squawfish and, to a lesser degree, striped bass prey on juvenile salmonids that are concentrated at the screen face. Squawfish and striped bass predation is also potentially significant at the discharge site of the fish bypass system for the Hallwood-Cordua screening facility. Any alterations to existing screens and/or bypass structures that would reduce predatory fish access to disoriented juvenile salmonids would reduce such predation losses. Measures that reduced squawfish access to juvenile salmonids at screening and bypass sites would also reduce predation from adults of other fish species.

Observations by Vogel Environmental suggest that predation losses could be the single greatest source of juvenile salmonid mortality within the Mokelumne River. Although each river within the Central Valley is unique, such findings suggest that juvenile salmonid losses from predation are likely to be significant in other rivers, such as the Yuba River.

Actions for reducing juvenile salmonid losses from predation/competition: Consideration should be given to a squawfish control program in the lower Yuba River. Structures could be designed and installed near screens and bypass outlets to exclude and thus prevent squawfish and striped bass from selectively preying on juvenile salmonids that become disoriented and hence particularly vulnerable at such sites.

The effectiveness of physical and/or electrical devises should be investigated for installation at the Hallwood-Cordua, Brophy-South Yuba, and Browns Valley water diversion facilities and associated bypasses to prevent piscivores from gaining access to disoriented juvenile salmonids. Doing so would reduce predation losses at these facilities.

Predicted benefits: Exclusion of piscivores from areas where outmigrating juvenile salmonids become particularly vulnerable to predation would increase outmigration survival. Increased juvenile salmonid survival will likely increase overall lower Yuba River salmonid production.

Action 12: Maintain a minimum flow of 175 cfs through the critical Simpson Lane reach during the spawning period in dry and critically dry years.

Objective: Facilitate passage of spawning adults through the critically shallow portions of the Simpson Lane reach.

Location: Simpson Lane reach (from the north side of Marysville downriver to the confluence with the Feather River).

Narrative description: The most severe obstruction to upstream migration is likely to occur at a critical riffle in the Simpson Lane reach. During dry and critically dry years, if instream flow rates are allowed to drop below 150 cfs in the Simpson Lane reach, physical blockage of upstream spawning migrations can occur, preventing adults from reaching preferred spawning habitat upstream (i.e., Garcia Gravel Pit and Daguerre Point Dam reaches). (See Action 1 for boundary definitions of these reaches.)

The recommended minimum clearance depth for upstream migration of adult chinook salmon varies in the literature. DFG (1991) indicated that a minimum of approximately 175 cfs is required to meet fish passage criteria for this reach. This was determined using a minimum depth criteria of 0.8 foot to continuously cover a minimum of 10% of the stream cross-section.

Actions 1 through 6 specify additional flows needed to provide spawning, incubation, rearing, and outmigration habitat for chinook salmon and steelhead. Flows for passage through the Simpson Lane reach should not be construed to suggest that flows below those specified in Action 1 through 6 are adequate to achieve the goals of the AFRP.

Predicted benefits: If spawning migrations become physically blocked by inadequate flows through the Simpson Lane reach of the lower Yuba River, spawning success will likely be significantly reduced. Thus, by maintaining appropriate flows here, spawning will be allowed to occur in the best habitat available even in dry and critically dry years. The result will be greater egg production and survival to the fry stage than would occur if fish were not allowed to pass beyond this point in the river.

Actions 13 and 14: Modify fish ladders at Daguerre Point Dam and maintain appropriate flows through these ladders to improve adult passage efficiency during the spawning seasons.

Objective: Maximize the number of spawning adults that reach preferred spawning habitat upstream of Daguerre Point Dam.

Location: Daguerre Point Dam.

Narrative description: There are two pool and weir type fish ladders (one on either side of the river channel) at Daguerre Point Dam. The ladders are effective as long as flows exceed 70 cfs over the ladders and are not in excess of approximately 4,000 cfs. Several problems can be stated for the existing set of ladders. First, ladder outlets are arranged at a 90° angle to the main channel's flow pattern. Secondly, attraction flows at the entrance to the ladders are not constant and often inadequate to effectively attract migrating adults. This is particularly a problem at higher flows (John Nelson pers. comm.).

Modifications of Daguerre Point Dam and its fish ladders are recommended to improve the upstream passage of spawning adults and the downstream passage of juvenile outmigrants. Structural modifications to existing fish ladders are needed to: 1) increase and continuously maintain attraction flows at the entrance to the fish ladders, 2) realign the entrance of ladders so they are not at a 90° angle to the main channel flow, and 3) eliminate sharp turns in the ladders to reduce the difficulty of fish passage. In addition, the 70-cfs flow that is currently recommended as the minimum flow through the ladders at Daguerre Point Dam should be reevaluated after ladder reconfiguration and maintained at the optimal flow for successful adult passage during peak spawning periods. Finally, construction of a third fish ladder up the middle of the dam, in line with the main flow pattern, should also be considered, because such a ladder may be most effective in routing fish over the dam.

Removal of Daguerre Point Dam would solve passage problems for both adults and juveniles and should therefore also be considered.

Predicted benefits: Allowing greater numbers of adult salmonids to reach preferred spawning habitat above Daguerre Point Dam while they are in sound physiological condition will improve their spawning success. A greater number of viable eggs and fry produced annually is likely to be the net result of this necessary action.

Action 15: Purchase of streambank conservation easements.

Objective: Improve riparian habitat and instream cover.

Location: Lower Yuba River.

Narrative description: Historically, riparian forests were likely extensive along the lower Yuba River. Riparian vegetation is important to the maintenance of anadromous salmonid populations by virtue of: 1) stabilization of streambanks, thereby reducing sediment load in the river; 2) provision of shade; 3) enhancement of stream nutrients due to decay of plant debris; 4) provision of streamside habitat for terrestrial and aquatic insects that are preyed on by fish; and 5) provision of instream cover. Mine tailings left from previous hydraulic mining activities, however, do not support the rich loam soil required by most native riparian species for reproduction and growth. The lack of native riparian habitat on the lower Yuba River is limiting to its salmonid populations (DFG 1991, Reynolds et al. 1993).

Water temperature: The riparian vegetation along the lower Yuba River is somewhat sparsely distributed and provides limited cover and shading of the stream channel. Lack of riparian cover to provide shading causes river temperatures to be higher than they would be if such cover were present.

Insect availability: Reduction in riparian communities along the lower Yuba River has likely reduced the abundance of aquatic and terrestrial insects. Re-establishment of native riparian cover would increase invertebrate food available to fish by providing additional invertebrate habitat and by increasing river nutrient levels and, hence, productivity.

Habitat diversity and instream cover: Riparian communities remain depauperate with poor habitat diversity. Instream cover and diversity is likely restricted by the riparian vegetation. Riparian vegetation along the river has yet to develop to the point that it significantly contributes to the improvement of rearing habitat that is believed to limit juvenile salmonid survival in the river. The river levees restrict the range of suitable water depths and velocities for salmonid spawning and rearing, particularly at high flows. Additionally, suction gold dredging in areas where salmon reside during summer is a concern of DFG.

Actions for improving streambank and channel habitat: Efforts should be made to protect and enhance existing riparian vegetation along the lower Yuba River. As needed, purchase of stream bank conservation easements would facilitate widening and improving the existing riparian corridor. A management plan would then be needed to determine best possible approaches to improve and maintain the riparian habitat. Local conservation organizations should be contacted to determine their interest in developing and implementing such a riparian enhancement and management plan. Private land owners should be given incentives to enhance riparian vegetation on their lands.

In addition to maintaining appropriate instream flows, improvements in juvenile salmonid rearing habitat can be made by: 1) increasing food availability and 2) increasing instream cover, both of which are results of enhancing riparian habitat. Additional streamside shading provided by enhanced riparian vegetation will also aid in keeping instream temperatures appropriately cool during spring, summer, and fall.

Periodic high flows are necessary for natural channel maintenance and thus should be allowed to occur annually in spring. In addition, no additional riverbanks should be riprapped; rather, natural riparian vegetation should be established and managed to stabilize banks.

Predicted benefits: Enhancement of riparian habitats will increase the abundance of both terrestrial and aquatic insects and therefore their availability to juvenile salmonids. This increased prey base will likely facilitate more rapid growth and earlier outmigration. Riparian cover will also shade river waters, thereby helping to keep water temperatures low enough to prevent thermally stressing outmigrating juveniles and immigrating adults.

Actions 16 and 17: Placement of large woody debris into the stream channel. Terminate current programs that remove woody debris from the stream channel.

Objective: Provide instream cover for juvenile salmonids.

Location: Lower Yuba River.

Narrative description: Trees and logs could be added to selected rearing habitats on the river, particularly upstream of Daguerre Point Dam, to enhance instream cover for juvenile salmonids. In addition, the current practice of clearing trees and other objects from the river to eliminate hazards to recreationists should be terminated. This practice has clearly reduced the availability of instream cover needed by juvenile salmon and steelhead.

Predicted benefits: Establishment and maintenance of instream woody cover will provide needed cover for juvenile salmonids, resulting in increased survival from reduced predation losses. Such instream cover will also provide a substrate for aquatic invertebrates to colonize, ultimately increasing food availability for juvenile salmonids.

Action 18: Impose stricter harvest regulations on commercial fishers.

Objective: Increase spawning escapement.

Location: Pacific Ocean.

Narrative description: Commercial harvest regulations could be modified to reduce current exploitation rates. Oceanic harvests significantly influence escapement and are not stock selective. Thus, reductions in oceanic harvests will likely increase spawning escapement in most Central Valley streams, including the lower Yuba River.

At higher flows (as recommended by Actions 1-3), the lower Yuba River can accommodate a larger number of spawning adults because of increased acreage of suitable spawning habitat.

Predicted benefits: Reducing commercial harvest will likely translate effectively into increased lower Yuba River escapement. Increasing spawning escapement will provide the potential to increase salmonid production within the river through increased fry production. Assuming fry and juvenile mortality rates can be reduced via other actions proposed above, the increase in fry production due to increased escapement will likely translate into an increase in overall salmonid production in the lower Yuba River.

Action 19: Conduct weekly on-river patrols in areas where poaching is a concern.

Objective: Increase spawning escapement.

Location: Lower Yuba River.

Narrative description: No accurate estimates of illegal harvest of adult salmonids at the Daguerre Point fish ladders and elsewhere on the lower Yuba River are currently available. Thus, it is difficult to say if this is a significant limiting factor. Because such losses can be largely prevented, necessary actions in the form of patrolling and increasing fines would be appropriate.

DFG could establish a greater enforcement presence at areas along the lower Yuba River where poaching is a concern (e.g., fish ladders at Daguerre Point Dam). Information regarding the status of the salmon migratory season could be used by the wardens to optimize the time and manpower allocated to patrolling the locations selected for particular days or weeks.

Predicted benefits: At higher flows, the lower Yuba River can accommodate a large number of spawning adults. Increasing spawning escapement will provide the potential to increase salmonid production within the river through increased fry production. Assuming fry and juvenile mortality rates can be reduced via other actions proposed above, the increase in fry production due to increased escapement will likely translate into an increase in overall salmonid production in the lower Yuba River.

Action 20: Modify the dam face of the Daguerre Point Dam.

Objective: Reduce juvenile mortality from predation as outmigrants pass over the dam.

Location: Daguerre Point Dam.

Narrative description: Outmigrating juvenile salmonids pass over the face of the Daguerre Point Dam and become disoriented in waters below, where waiting piscivores (e.g., squawfish and striped bass) prey heavily on them. This is a particular problem because juveniles can pass over the dam face at any point and thus often fall into calmer waters adjacent to the main channel flows where piscivores are particularly successful in capturing them. Losses at the base of Daguerre Point Dam are of greatest concern during dry years.

Notches or other structures directing flow through particular points on the dam face should be considered in order to route outmigrating smolts into the main channel of the river below the dam. Doing so would allow higher velocity main-channel flows to more quickly carry disoriented smolts beyond waiting predators.

Removal of Daguerre Point Dam would solve passage problems for both adults and juveniles and should therefore also be considered.

As a related action, physical/electrical barriers could be designed and installed below the dam, which would deny piscivores access to disoriented smolts immediately below the dam. This would reduce predation losses from squawfish and other piscivores at Daguerre Point Dam.

Predicted benefits: By reducing the opportunity for squawfish and other piscivores to feed on disoriented smolts following their passage over Daguerre Point Dam, juvenile survival through the outmigration stage will be increased. Increased juvenile survival during outmigration may result in an increase in future escapement of that year-class.

Bear River -

Limiting factors and potential solutions - - Following is a list of factors that may limit chinook salmon and steelhead production within the Bear River basin (Table 3-Xc-4).

Table 3-Xc-4. Limiting factors for chinook salmon and steelhead in the Bear River and potential solutions.

Limiting factors	Potential solutions
Instream flow	1. Increase instream flows 2. Determine instream flow requirements for chinook salmon and steelhead
Water temperature	Increase instream flows
Water diversions	Screen diversions
Water quality	Monitor water quality particularly at agricultural return outfalls
Migration barriers	Negotiate for removal or modification of the culvert crossing at Patterson Sand and Gravel

Restoration actions -

Action 1: Establish and protect adequate instream flows.

Objective: Provide a sufficient amount water at the appropriate temperatures for salmonid migration, holding, spawning, incubation, rearing, and outmigration.

Location: South Sutter Water District's (SSWD's) diversion dam.

Narrative description: Lack of flows limit anadromous fish production in the lower Bear River. Presently, flows in the Bear River below SSWD's diversion dam are not adequate for salmonid production. In past years, high escapement estimates corresponded to high fall flows (Table 3-Xc-5).

Table 3-Xc-5. Estimates of numbers of chinook salmon that spawned in the lower Bear River for selected years.[a]

Year	Number of adult spawners	Flow range (cfs) in October [b]	Flow range (cfs) in November [c]
1978	0	1.6 - 8.7	0.45 - 14
1980	0	2.1 - 9.2	4.9 - 29
1982	<100	6.8 - 37	28 - 7,170
1983	>200	37 - 55	484 - 4,360
1984	300	19 - 47	24 - 1,430
1985	0	4.4 - 33	10 - 28
1986	1	9.5 - 20	15 - 34

[a] Source: DFG Region 2, Rancho Cordova, file data for Bear River-Placer, Sutter, and Yuba counties.

[b] Source: USGS Water Resources Data, California, Volume 4, various years, gage 11424000, Bear River near Wheatland.

[c] Estimate of angler catch from Dry Creek.

Table 3-Xc-6 lists the minimum stream flow and maximum temperature regimes that should be maintained in the lower Bear River during wet and normal water years for the protection and maintenance of chinook salmon. These recommendations are based on information provided by the SSWD for its proposed Garden Bar Project (Nelson pers. comm.). According to SSWD (1988), the microhabitat variables describing depth, velocity, and substrate for the juvenile and spawning life stages of fall-run chinook salmon were taken from Bovee (1978) for use in the simulation model. However, comparison of the criteria used with that presented by Bovee (1978) indicates that criteria for juvenile substrate and spawning substrate and depth were not taken from Bovee (1978).

Table 3-Xc-6 was developed in the absence of PHABSIM analyses of the physical habitat WUA/river discharge relationships for steelhead. Information for fall-run chinook salmon indicate that the preferred physical living space requirements are optimized by the flow regime presented in Table 3-Xc-6.

Table 3-Xc-6. Minimum instream flow and maximum temperature regimes for wet and normal water-year types to facilitate doubling production of chinook salmon and steelhead in the Bear River.

Month	Flows (cfs)	Temperature (°F)[a] at:	
		Wheatland[d]	Highway 70
October 1-14	100[b]	60	60
October 15-December 15	250[b]	58	57
January-March	250[b,c]	56	57
April-June	250[c]	60	60
July-September	10[d]	65	65

[a] Recommended mean daily temperatures to be maintained during normal and wet water years for protection of chinook salmon.

[b] Flows needed for spawning and incubation of chinook salmon and steelhead.

[c] Flows needed for rearing and outmigration of chinook salmon and steelhead. Physical habitat needs alone (depth, velocity, and substrate in PHABSIM analyses) suggest that chinook salmon require flows of at least 190 cfs from January to March and 100 cfs from April to June.

[d] Flows for July to September will need to be higher to address temperature requirements of steelhead.

Evaluating existing river temperatures and flows indicates that it may be possible to achieve favorable water temperatures for chinook salmon under these flows. The flow regime during the July through September period, however, will not achieve the temperature requirements necessary for steelhead because temperatures at existing flows since 1963 have been consistently recorded above 75°F at Wheatland during July and August. Once additional studies of the temperature and flow relationship downstream of Camp Far West Reservoir and of the physical habitat WUA/river discharge relationship for steelhead are completed, changes in this flow regime will be necessary to meet the above temperature requirements for steelhead during the July through September period and possibly during other times of the year for chinook salmon as well.

Analysis of the annual flow at Wheatland indicates that the recommended flow regime at Wheatland (95,249 af) represents only 29.5% of the unimpaired flow (Table 3-Xc-7). Comparing the lower Bear River's proposed flows at Wheatland with the river's annual unimpaired flow for the 63-year period indicates that the total annual flow recommended for fishery purposes is exceeded about 94% of the years (Table 3-Xc-6). Hence, on the average, there is insufficient water in the Bear River to meet fishery needs in only 6 out of every 100 years.

Comparing the monthly unimpaired flow with the recommended monthly flow indicates that recommended October flow exceeds the unimpaired requiring a flow augmentation of 6,207 af (Table 3-Xc-7).

Table 3-Xc-7. Estimated Bear River mean monthly unimpaired flow at Wheatland for the 63-year period 1921-1983, actual flow at Wheatland gage for the 1964-1990 period, and proposed minimum flow regime at Wheatland.

Month	Unimpaired flow, 1921-1983[a]	Actual flow, 1964-1990[b]	Proposed minimum flow
October 1-14	2,250 (81)	461 (17)	2,777 (100)
October 15-31	2,750 (81)	561 (17)	8,430 (250)
November	16,000 (269)	9,458 (159)	14,876 (250)
December	43,000 (699)	30,757 (500)	15,372 (250)
January	61,000 (992)	58,579 (953)	15,372 (250)
February	68,000 (1,224)	64,772 (1,158)	13,884 (250)
March	61,000 (992)	67,176 (1,092)	15,372 (250)
April	42,000 (706)	43,537 (732)	14,876 (250)
May	17,000 (276)	11,726 (191)	15,372 (250)
June	6,000 (101)	2,690 (45)	14,876 (250)
July	2,000 (33)	1,061 (17)	615 (10)
August	1,000 (16)	934 (15)	615 (10)
September	1,000 (16)	823 (14)	595 (10)
Total	323,000	292,535	133,032

Note: Flows are in af with cfs in parenthesis.

[a] Source: DWR (1987).

[b] Source: USGS, Water resource data - California, water years 1964 through 1990.

Because flow in the lower Bear River is impaired by water project operations and diversions, comparison of the actual and recommended flows at Wheatland provides a more representative evaluation than one using unimpaired flows. Compared to the total annual impaired flow, the recommended flow regime represents only 32.6% of the impaired flow at the Wheatland gage. However, comparing the monthly recommended flow with the monthly impaired indicates that on the average to achieve the recommended minimum flow, the recommended flow exceeds the average monthly impaired during June, October, and November requiring flow augmentation of 18,864 af.

Potentially, water can be acquired by: (1) evaluating the existing water rights throughout the watershed and petitioning SWRCB for a change to obtain increased streamflow and (2) purchasing water from willing sellers (potentially SSWD and PG&E).

Water temperatures in the lower Bear River are affected by the operations of Camp Far West Reservoir, other reservoirs upstream, and diversions downstream of Camp Far West Reservoir. Operations of the Camp Far West project and diversions have resulted in low flows and elevated temperatures downstream during critical life stages of chinook salmon and steelhead. Evaluation of existing temperatures indicated that river temperatures are often at or above preferred ranges for salmon and steelhead life stages. Maintenance of ideal temperatures can be achieved by developing operational criteria for Camp Far West Reservoir and other reservoirs upstream and incorporating them into the prescribed flow schedule.

Predicted benefits: Providing adequate instream flows will encourage spawning in Bear River. Based on past records, this action should, independently, double escapement.

Action 2: Conduct an IFIM to determine instream flow and temperature requirements for all life stages of salmon and steelhead.

Objective: Ensure that the available water is utilized to its fullest potential to benefit all life stages of salmon and steelhead.

Location: Entire stream below SSID's diversion dam.

Narrative description: Previous IFIM studies proved inconclusive due to the methodology employed (see Action 1) and did not consider steelhead (temperature) or biological criteria. DFG, with aid from the SSID, should conduct an IFIM on the entire river. The study should evaluate the needed flows for all life stages of salmon and steelhead using biological and physical parameters.

Predicted benefits: An IFIM study will ensure the available water is used wisely for all life stages of salmon and steelhead. Ensuring ideal or adequate flows will directly benefit salmonid restoration.

Action 3: Effectively screen all diversions.

Objective: Reduce loss of production to entrainment.

Location: Entire stream below SSID's diversion dam.

Narrative description: Loss of juvenile salmon due to unscreened water diversions is a generic problem in the Central Valley. DFG should identify what diversions need screening on Bear River. Under the authority of standing Fish and Game Codes (6100), all diversions should then be screened.

Predicted benefits: Screening will directly prevent the loss of juveniles and likely increase production.

Action 4: Monitor water quality particularly at agricultural return outfalls.

Objective: Ensure that suitable water quality exists for all life stages of salmon.

Location: Entire stream, particularly below agricultural drains.

Narrative description: Excess water from agricultural diversions return to the river. This water may be contaminated with herbicides, pesticides, and agricultural wastes that may affect water quality. The EPA or CVRWQCB should conduct water quality testing, particularly at the outfalls of agricultural drains. Additionally, water quality may be affected by past heavy metal mining.

Predicted benefits: Monitoring the water quality will help identify potential sources of pollution. Eliminating these sources will improve the overall quality of the river and potentially increase production.

Action 5: Negotiate for removal or modification of the culvert crossing at Patterson Sand and Gravel.

Objective: Provide uninhibited passage for all life stages of salmonids.

Location: Patterson Sand and Gravel culvert.

Narrative description: DFG or USFWS should contact Patterson Sand and Gravel and assist it in modifying the culvert to ensure adequate passage of all life stages of salmonids. The culvert is likely a migration barrier under most flow conditions.

Predicted benefits: This action will enable better passage at this point and increase the available habitat.

American River -

Limiting factors and potential solutions - The following information (Table 3-Xc-8) was compiled to identify potentially limiting factors to fall-run chinook salmon and steelhead production in the lower American River. Although some factors are clearly more limiting, fish production is ultimately limited by the cumulative effects of all limiting factors. Thus, actions that reduce or eliminate any of these limiting factors will increase salmonid production. Nevertheless, efforts should center on those factors that are generally most limiting from year to year.

This list concentrates on factors pertaining to the lower American River as defined by Nimbus Dam on the upstream end and the confluence of the American River with the Sacramento River on the downstream end. Obviously, a major factor limiting production of salmon and steelhead in the American River is the presence of Nimbus and Folsom dams, which have eliminated access for salmonids to their historical spawning and rearing areas above Nimbus Dam. Because removal of these dams or facilitation of movement of salmonids past Nimbus Dam and especially Folsom Dam seems impractical, this list is limited to those factors potentially limiting populations of salmon and steelhead in the American River below Nimbus Dam.

The limiting factors addressed in this section of the report are organized under major section headings taken from the original matrix of limiting factors developed by the Lower Sacramento River and Delta Tributaries Chinook Salmon and Steelhead Technical Team.

Table 3-Xc-8. Limiting factors for chinook salmon and steelhead production in the lower American River and potential solutions.

Limiting factors	Potential solutions
Inadequate instream flows	1. Modify existing instream flow requirements 2. Develop water allocation guidelines 3. Evaluate pulse flows for facilitating juvenile outmigration in dry years 4. Reduce and control flow ramping rates
Unsuitable water temperatures	Reconfigure water release shutters at Folsom Dam

Limiting factors	Potential solutions
Inadequate spawning substrate	Implement a spawning gravel management program
Water diversion operations	1. Evaluate the effectiveness of the fish screen at the Fairbairn Water Treatment Plant and improve if necessary 2. Evaluate the efficacy and modify the timing and rate of water diverted annually, if appropriate
Bank and streambank modifications	1. Implement a riparian corridor management plan 2. Terminate current programs that remove woody cover from the stream channel
Overharvest of adult brood stock	1. Further limit sport and commercial harvests of naturally produced fish 2. Increase DFG enforcement efforts to stop poaching during the spawning seasons
Hatchery practices	1. Reduce reliance on stocking programs for meeting angler demands 2. Use all available spawning stock, not just those fish over a minimum length or arriving at a given time (to increase genetic diversity) 3. Discontinue stocking fish produced from adults taken from other rivers if those fish are genetically distinct from the native stock

The degree to which these and other factors may have limited production in the lower American River is unclear and is therefore subject to further study. Information is currently being complied to more completely assess this issue and to estimate current and past salmon and steelhead run sizes annually entering the lower American River.

Because of the interrelatedness among the various limiting factors, assigning a rank of relative importance to each factor is difficult. Furthermore, relative importance among limiting factors varies across years. Nevertheless, with adequate historical data, conditions in the lower American River, Sacramento River, and Delta could be related to annual spawning run sizes and numbers of juvenile outmigrants using multiple regression procedures. Such a statistical approach would allow limiting factors to be ranked in terms of their relative impacts on spawning run size and numbers of juvenile outmigrations passing defined points in the lower American River. This approach would also shed light on the relative importance of in-river versus down-river conditions as they pertain to salmonid production in the lower American River.

Several potential limiting factors were not addressed by restoration actions. These factors were not considered to be key factors currently limiting the production of salmonids in the lower American River. Nevertheless, they are briefly discussed below.

Migration barriers - Nimbus Dam, located about 23 miles upstream of the confluence, is the upstream terminus of anadromous fish migration in the lower American River. Approximately 73% of salmon and 100% of steelhead in the American River historically spawned upstream of Nimbus Dam (Hallock 1987). No significant migration barriers exist in the lower American River between Nimbus Dam and the confluence. Nimbus Hatchery weir prevents upstream migration and diverts spawners to the hatchery egg-take facility.

As no significant migration barriers exist on the lower American River, no action options are needed. Relative to the Nimbus Hatchery, however, one might suggest that time periods that the weir is in place be managed to balance benefits to the hatchery and natural production.

Water quality - The major water quality parameter known to be adversely affecting salmonid production in the lower American River is water temperature (see Actions 1 and 5).

Urban runoff - Urban development within the lower American River watershed contributes substantial urban runoff. Inadequate treatment of runoff results in contaminants reaching the American River. The extent to which urban runoff affects salmonid production is not currently known and therefore warrants additional study and monitoring.

Other point sources - Various industries along the American River, such as Aerojet and others, may be introducing contaminants into the river. Aerojet does not appear to be an issue at this time; however, it has the potential to contaminate groundwater, and thus both groundwater and surface water quality monitoring programs for the lower American River basin are needed.

Options to improve water quality - Improvements in the capture and treatment of urban runoff would undoubtedly improve water quality in the river. Public education to reduce the amount of contaminants introduced into urban drainage system would also benefit water quality. Water quality monitoring programs are necessary for identifying water quality problems when they arise, determining their source(s), and identifying corrective actions.

Predation/competition - Important predators of juvenile salmonids, including squawfish and striped bass, are common in the lower American River. Predation by these species is generally considered to be serious near instream obstructions and diversions where unusual flow patterns disorient or concentrate smolts. Because of the general absence of these conditions in the river, it is believed that although predation losses of juvenile salmonids from piscivores are probably lower in the American River than in many other rivers, it should still be considered a limiting factor.

Squawfish and other piscivores - Squawfish and various centrarchids are believed to be responsible for most piscivorous predation on outmigrating salmonids in the lower American River. Squawfish are present in the river year-round and are known to prey heavily on salmon and steelhead here and elsewhere in Central Valley streams. Juvenile salmonids isolated by reduced flows in side channels and backwater areas that support higher densities of squawfish and centrarchids often experience high predation losses.

Striped bass - Striped bass are known to prey on juvenile salmon and steelhead in the lower American River. A year-round sport fishery exists for striped bass, suggesting adult-sized striped bass are in the river year-round. Juvenile striped bass are also common in the lower sections of the river and may compete with juvenile salmon and steelhead. Lack of vegetative and woody cover, especially in the lower sections of the river, limits salmon and steelhead refuge from predators.

Hatchery fish - Hatchery fish, when released into the river, may prey on or compete with naturally produced fish.

Avian predators - Mergansers, egrets, herons, kingfishers, terns, and other fish-eating birds are common on the lower American River. Mergansers are particularly common during the early spring when salmon fry are most abundant. Fluctuating flows during spring may contribute to increased predation on juvenile salmonids. Fish temporarily stranded by reduced flows in pools and ponds along the river channel (a circumstance not necessarily lethal) have been observed to be the focus of heron and other avian predators.

Options for reducing juvenile salmonid losses from predation/competition - Restoration of instream vegetative and woody cover may partially alleviate fish and avian predation problems. Higher flows and cooler water would also favor salmon and steelhead over striped bass and other warmwater species that often prey on juvenile salmonids (e.g., various centrarchids). Continuing the policy of not releasing hatchery-produced fish to river (but rather downstream) would be effective in reducing predation on naturally produced salmonids by hatchery fish. However, this practice exacerbates the straying problem. Hence, simply decreasing reliance on hatchery-produced fish is the best policy for restoring native stocks. To effectively do so, we must act on the other limiting factors discussed in this paper.

Restoration actions -

Action 1: Maintain flows recommended in Table 3-Xc-9.

Objective: Optimize conditions in the lower American River for all salmonid life stages.

Location: Throughout the lower American River.

Narrative description: In 1972, the Environmental Defense Fund (EDF) filed suit against the East Bay Municipal Utility District (EBMUD) challenging the proposed diversion of water from Nimbus Dam through the Folsom South Canal, bypassing the lower American River. A 1990 court decision resulting from this case (known as the Hodge decision) ordered the following flows for the protection of salmonid resources in the lower American River: 2,000 cfs between October 15 and February 28; 3,000 cfs between March 1 and June 30; and 1,750 cfs between July 1 and October 14. These flows were established after extensive review of available scientific data concerning the relationship between lower American River flows and salmonid production.

It should be noted that Hodge decision flows were selected to protect aquatic public trust resources in the lower American River, not to double production of anadromous fish in the river. Hence, use of Hodge decision flows will not necessarily facilitate doubling production. Additional information addressing optimal instream flows for salmonid spawning and incubation, rearing, outmigration, and temperature control has been developed subsequent to the Hodge decision. Much of this information has been developed as part of the retained jurisdiction associated with the *EDF et al. vs. EBMUD* litigation, and was used to develop the instream flow recommendations for the lower American River that appear below.

Adult migration: Instream flows in the lower American River are typically not limiting to upstream passage. However, in recent years it has been observed that relatively high flow releases during the summer months have attracted adult chinook salmon upstream as far as the basin below Nimbus Dam. The origin of these fish is uncertain, although it is speculated that their origin may be from the Feather River or Coleman National Fish Hatchery. Conversely, the typical pattern of flow reduction to about 1,500 cfs during late September through October or November has occurred concurrently with elevated water temperatures released from Nimbus Dam. These elevated temperatures may cause prespawning mortality, reduce embryo viability, and/or delay timing of spawning. Thus, instream flows may adversely affect adult upstream migration primarily through elevated water temperatures.

Spawning habitat: Chinook salmon spawning is concentrated in several well-documented areas in the river between RMs 14 and 22 (Snider et al. 1993). During low flow conditions, the areal extent of available spawning habitat is further restricted. Recent redd surveys conducted by DFG have shown that the incidence of redd superimposition increases at lower flow levels (e.g., 42% in 1992 vs. 8% in 1991) (Snider et al. 1993).

Redd dewatering: Flow releases from Folsom and Nimbus dams are made to augment Sacramento River flows to: 1) meet Delta water quality standards, 2) generate hydroelectric power, 3) make deliveries to downstream users, and 4) provide fish protection. These demands result in considerable flow fluctuations in the river. DFG aerial redd surveys conducted for 1991-1993 (Snider and McEwan 1992, Snider et al. 1993, Snider and Vyverberg 1995) have provided evidence that chinook salmon redds are dewatered as a result of flow reductions during the fall and winter months. The potential for significant losses is greatest in years when flows are low and redds are concentrated.

Redd or fry stranding: Fluctuating flows are believed to result in considerable stranding and loss of chinook salmon and steelhead fry. Observations of stranded fish have been recorded in the river. For example, on May 31, 1990, a reduction of flow in the 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 death resulting from thermal stress.

Rearing habitat: Low flows reduce the availability of appropriate rearing habitat. In addition, rapid ramping rates may affect diversity, productivity, and availability of insects (an important food source for salmon and steelhead) in the lower American River. The flows (high and low) at which the availability of rearing habitat for juvenile salmonids becomes limiting, from the standpoint of physical space or suitable depth and velocity distributions, is not well documented. At low-flow levels, however, these considerations are probably overridden by water temperature issues.

Juvenile outmigration: Inadequate flows during April through June decrease the success of juvenile salmon and steelhead outmigrations. When flows drop below 1,500 cfs, extensive juvenile isolation and stranding occurs (Bill Snider, DFG, pers. comm. 1994).

Table 3-Xc-9. Instream flow regimes[a] recommended to facilitate doubling of chinook salmon and steelhead production in the lower American River[b] under four year types[c]

Month	Flow (cfs) for each of four year types			
	Wet	Normal	Dry/ critical[d]	Critical relaxation[e]
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

[a] These flow regimes were developed in consideration of water availability (i.e., unimpaired runoff at Fair Oaks) associated with each of the hydrologic conditions (wet, normal, dry/critical, critical relaxation). One objective associated with these flow regimes is that Folsom Reservoir achieves a target storage of about 610 taf by September 30 to provide a sufficient volume of water (and coldwater pool) to maintain spawning and incubation (fall and winter) flows; however, hydrologic modeling was not conducted as part of this review. These flow recommendations likely will be modified based on additional hydrologic evaluations. In addition, these flow regimes likely will be modified based on the results of monitoring programs intended to evaluate the effectiveness of these flows, as well as additional restoration actions.

[b] Lower American River flows (cfs) measured at the H Street Bridge.

[c] These flow regimes should be viewed as "minimum" flows under each hydrologic condition. Therefore, it is important to note that higher flows are likely to occur during a given month depending on precipitation and runoff patterns, particularly during the "wetter" hydrologic conditions.

[d] The dry/critical flow regime can accommodate a relatively wide range of hydrologic conditions, including all but the most severe drought conditions.

[e] The "critical relaxation" flow regime is intended for application to hydrologic conditions characterized by the most severe drought years.

Options for improving instream flows (instream flow recommendations) -

Wet year type: Even in a wet year, the amount of water that can be released from Folsom Reservoir during the chinook salmon spawning and incubation period (October through February) is limited by the storage in the reservoir on October 1. The 2,500-cfs flow recommendation for October through February in a wet year approaches the maximum release rate that can be sustained throughout this and subsequent months. Releases during this fall period are conducted prior to knowledge of the water-year type that is being entered in the following year. Thus, excessive drawdown resulting from fall releases in excess of 2,500 cfs are not recommended, because this may create severe water availability problems. Because the reservoir will be filling throughout the late fall and winter months, flows may be increased to 4,500 cfs from March through June to provide: 1) appropriate juvenile rearing habitat availability and outmigration flows and 2) temperature control during May and June (i.e., maintain mean monthly river temperatures below 65°F at H Street). Flows are reduced to 2,500 cfs during July through September to provide some thermal protection (i.e., maintain mean monthly river temperatures at or below 70°F) for resident steelhead juveniles, while remaining within a realistic water budget for the year.

Normal: A flow rate of 2,000 cfs is recommended for October through February in a normal water-year type (Table 3-Xc-9). This flow is believed to provide appropriate spawning conditions for fall-run chinook salmon and steelhead in the lower American River during a normal water year.

Flow rates are increased to 3,000 cfs for March through June to provide 1) appropriate juvenile rearing habitat availability and outmigration flows and 2) temperature control during May and June (i.e., below 65°F). Flow recommendations of 2,500, 2,000, and 1,500 cfs for July, August, and September, respectively, are to provide some thermal protection (i.e., maintain mean monthly river temperatures at or below 70°F) for resident juvenile steelhead while not exceeding projected water availability for this water year type. Lesser flows during July and August (e.g., 1,000 cfs) produce mean monthly temperatures near or exceeding 72°F. Chronic exposure of juvenile steelhead to such temperatures would likely result in high mortality during these months. These summer flow recommendations are intended to reduce such losses.

Dry/critical: During a dry/critical year type, prioritization should be given to producing a good spawn, and facilitating successful juvenile outmigration. The recommended flow rate of 1,750 cfs for October through February is believed to provide reasonable spawning/incubation flows under the dry/critical regime. Flows are recommended to be increased to 2,000 cfs for March through June to provide adequate rearing habitat and outmigration flows. Temperatures will often exceed 65°F, particularly during June, at this flow rate. Because July is the month of greatest concern for river water temperatures, 1,500 cfs is recommended for July to provide minimal temperature protection for resident juvenile steelhead. The mean monthly temperature achieved in July at 1,500 cfs (about 71-71.5°F) can be achieved in August at the lower flow rate of 1,000 cfs. Finally, temperature control is of much lesser concern during September, so flows may be dropped to 500 cfs. Doing so aids in achieving adequate carryover for the upcoming fall spawning season.

Critical relaxation: In such water year types, insufficient water exists within the system to meet even minimal requirements of fish throughout the year. Thus, substantial trade-off decisions must be made. A flow rate of 800 cfs is recommended for October to save water for subsequent spawning months. A flow rate of 1,200 cfs is recommended for November through February to achieve reduced, but successful spawning. The recommended flow rate is increased to 1,500 cfs for March through May to facilitate successful rearing and outmigration for a substantial portion of the juveniles produced. Because little water remains available by this point in the year, flow rates are dropped to 500 cfs in June, out of necessity, and remain there through September.

To achieve the recommended seasonal instream flows discussed above, operations of Folsom Reservoir will require modification. Clearly, annual management for appropriate instream flows must be flexible, because the amount of water available to meet target flows will vary with water year type. During wet years, instream flows likely will exceed Hodge decision flows and facilitate natural channel maintenance, reduce the likelihood of spawning gravel becoming embedded, and provide optimal flows for fish. Redistributing the timing of flows will also be important to meeting fish flow needs. For example, in 1988 to 1992, the highest measured streamflow occurred during months of the year with the lowest estimated fish flow needs. Finally, additional attention must be given to storage carryover in Folsom Reservoir. Extensive drawdown of the reservoir from various water uses (including Delta water quality flows) can lead to insufficient water supplies for meeting in-river fall-run chinook salmon spawning needs, particularly during October.

Related actions that may impede or augment the action: Water allocation guidelines developed as a result of Action 2 may affect possible flow levels, especially in dry and critical relaxation water years as proposed in Table 3-Xc-9. In fact, regional water planning efforts are underway that build on the regimes presented in Table 3-Xc-9 via a more thorough hydrologic evaluation, because flows presented in Table 3-Xc-9 may not be consistently achievable or sustainable. These ongoing efforts are focusing on alternative assessments of water availability (i.e., storage in Folsom Reservoir) and subsequent allocation of available water to provide maximum instream beneficial use. It is presently assumed that resultant flow regimes will be dynamic and responsive to water availability on an annual basis.

Agency and organization roles and responsibilities: USBR is responsible for managing Folsom Dam and Reservoir.

Potential obstacles to implementation: The various water-user groups will likely have a difficult time agreeing to recommended flows that will alter present or future operations.

Predicted benefits: Although quantitative estimates of increased production resulting from incremental increases in flows are unavailable, the recommended instream flows will significantly contribute to the goal of doubling salmon and steelhead production in the lower American River.

Action 2: Develop water allocation guidelines.

Objective: Provide, through planning, a reasonable way to allocate limited water resources among beneficial uses, including maintenance of aquatic resources (fish and aquatic habitat).

Location: The American River watershed (within the context of inflow to Folsom Reservoir), Folsom Reservoir, and throughout the lower American River.

Narrative description: There is a pressing need to develop a resource management plan that maximizes the public trust resources of the lower American River. Setting minimum flow requirements as shown above (Table 3-Xc-9) is productive in satisfying fish needs. However, history shows that target fish flows are often violated when water within the system becomes insufficient to meet them. The reason this occurs so frequently is that clear guidelines for where water allocation cuts will be made when water becomes limited have not been established to date for the American River system.

The focus of studies on the lower American River must be redirected toward establishing a resource management plan that will provide specific guidance on how best to manage the water supply from the American River from year to year and month to month. Thus, initial operational studies are needed to determine: 1) the frequency that Hodge decision flows can be maintained with existing CVP operational constraints and 2) the optimum flow regimes for those years when insufficient water is available to fully meet Hodge decision or other recommended flows for fisheries. These studies will also be used to evaluate CVP constraints (physical, institutional, or legal) that reduce the CVP's ability to optimize flow and temperature conditions for the fisheries. Each identified institutional or legal constraint could then be evaluated to determine the benefit on flows and temperatures of removing that constraint. The impact, if any, of removing each constraint on other CVP project purposes could also be determined. The goal of this effort would be to identify operations of Folsom Dam and Reservoir and the impacts of the operations that would optimize flow and temperature conditions for the lower American River fisheries, within the context of other environmental operation constraints on the CVP.

Operation studies could also serve to identify biological data needed to validate or refine existing management approaches. Thus, the operations studies could be used to determine which biological data are necessary to make management decisions and to monitor the results of management actions.

Such a study program could develop balances between the many competing public trust resource needs. An initial protocol that manages given water supplies could result from the development of this lower American River operations and fisheries plan. The information obtained from this effort could improve the ability to make rational decisions regarding the best management of water during times when water availability is not sufficient to serve all purposes.

Related actions that may impede or augment the action: See this section for Action 1.

Agency and organization roles and responsibilities: USBR, DFG, USFWS, and other water-user groups will need to develop together any water allocation guidelines.

Potential obstacles to implementation: The various water-user groups will likely have a difficult time agreeing on what constraints, if any, should be eliminated.

Predicted benefits: Although quantitative estimates of increased production resulting from incremental increases in flows are not presently available, the instream flows recommended above (Table 3-Xc-9) and the establishment of fish needs as a priority in an overall resource management plan for the river will significantly contribute to the goal of doubling salmon and steelhead production in the lower American River.

Action 3: Evaluate the effectiveness of pulse flows for facilitating successful juvenile salmonid outmigration.

Objective: Optimize outmigration success when water is in short supply (e.g., dry and critically dry years).

Location: Throughout the lower American River.

Narrative description: The use of pulse flows should be evaluated as an approach to promote outmigration. Studies are needed for determining how to maximize juvenile outmigration success when water supplies are limited in drier years and thus instream flows are reduced during the outmigration period (April-June). The faster juveniles can emigrate (within physiological constraints of the smoltification process), the greater their probability of survival. Reduced time in the Lower American and Sacramento rivers during outmigration reduces the length of time juveniles are exposed to instream predators and physiologically stressful water temperatures. The chances of mortality due to stranding would be reduced when flows are high. However, this may be negated by increased stranding when flows are reduced at the end of each pulse. Anecdotal evidence suggests that increased turbidity may facilitate outmigration of salmonid smolts. Turbidity could be increased artificially, although the injection of clays and other fine materials may adversely affect streambed conditions via sedimentation.

Related actions that may impede or augment the action: Flow reduction/ramping criteria recommended through Action 4 along with flows from Action 1 may make pulses difficult to implement.

Agency and organization roles and responsibilities: USBR would be responsible for controlling flow levels, while DFG and USFWS would take on monitoring and assessment roles.

Potential obstacles to implementation: Various water users may argue as to the benefits of pulse flows to salmonid populations.

Predicted benefits: Such studies will provide a basis for facilitating juvenile outmigration when water within the system is limited. Rapid outmigration associated with a pulse flow will likely increase juvenile survival rates and thus overall production.

Action 4: Reduce and control instream flow ramping rates and flow fluctuations.

Objective: Reduce hazards posed to young salmonids when flow rates change quickly.

Location: Nimbus Dam

Narrative description: Ramping rates of flows across time must be addressed. Stabilization of instream flows to prevent rapid flow rate reductions (i.e., rapid ramping rates) from October through April would reduce the likelihood of stranding redds and fry. Similarly, prevention of rapid flow increases during this period would reduce the frequency of fry displacement. Finally, rapid ramping rates may be associated with gas supersaturation problems that occasionally occur below Folsom Dam. McEwan and Nelson (1991) recommended that USBR adjust overall CVP operations and procedures so that ramping problems can be eliminated, without sacrificing Delta water quality or habitat conditions in the upper Sacramento River for winter-run chinook salmon.

Operations at Folsom Dam relating to the release of water downstream should be modified so that adjustments made to instream rates are more gradual than they are currently. Ramping rates should not exceed 30% of an existing initial flow during any 24-hour period. If flow rates become significantly elevated above target levels for a week or more during the spawning period, flows should be maintained at or near this new level through February to prevent redd dewatering and fry stranding.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: USBR would be responsible for flow release levels, while DFG and/or USFWS would monitor and assess the effects on redd de-watering and juvenile stranding.

Potential obstacles to implementation: USBR may resist implementing ramping restrictions due to their possible effects on flood control and hydroelectric generation operations.

Predicted benefits: Establishment of more gradual ramping rates, particularly in spring and fall, will reduce losses of eggs and young salmonids and contribute to increased production. The exact contribution of this action to increased salmonid production can not be calculated at this time.

Action 5: Reconfigure Folsom Dam (penstock inlet ports) shutters.

Objective: Enhance control over temperature of water released downstream and management of Folsom Reservoir's coldwater pool.

Location: Folsom Dam and Reservoir.

Narrative description: The primary purpose of reconfiguring shutters on Folsom Dam is to provide increased ability to control the temperature of water in the lower American River. Water temperature in the American River is important to multiple life stages of salmonids.

Adult migration: Lower American River water temperatures in late summer and early fall (sometimes extending well into October) are often above 15°C (59°F). Optimum temperatures for adult salmon and steelhead migration are believed to be about 6.5-13°C (44-56°F) and 8-11°C (46-52°F), respectively (Beak 1989). Water temperatures above 15°C (59°F) will likely delay adult spawning migrations and thus may impede reproductive success. Exposure of pre-spawning adult salmonids to water temperatures above 15°C (59°F) can result in reduced gamete production, infertility, and increased embryonic developmental abnormalities.

Spawning: Spawning chinook salmon and steelhead begin to experience chronic stress at water temperatures of 13-16°C (56-61°F) and 11-15°C (52-59°F), respectively (Beak 1989). Salmonids often delay spawning when water temperatures reach the upper end of this range (see "Adult Migration" subsection above). Redds do not appear in the lower American River until water temperatures drop to approximately 15.5°C (60°F) (Snider et al. 1993). However, if spawning does occur at temperatures >15°C, impaired egg maturation and decreased performance and survival of progeny results. In addition, high water temperatures may alter behavior of spawning salmonids, resulting in reduced egg fertilization success and reduced egg survival. It is difficult to separate effects of exposing pre-spawning and spawning adults to high temperatures because the two almost always co-occur. Under such conditions, adult fish may spawn predominately in upper portions of the river to avoid warmer temperatures downstream, possibly increasing superimposition of redds.

Incubation: Constant exposure of salmonid eggs to temperatures above 13°C (56°F) will result in some egg mortality, while incubation at water temperatures above 17°C (62°F) is believed to result in complete egg mortality. Temperatures above 13°C can occur when eggs and larvae are incubating in the lower American River. This problem is most likely to occur for chinook salmon in October and early November.

Rearing: Optimum instream temperatures for rearing of young chinook salmon and steelhead are 11.5-13°C (53-56°F) and 13-15.5°C (55-60°F), respectively (Beak 1989). Juvenile salmon and steelhead in the lower American River can be exposed to temperatures greater than 14°C as early as March and to temperatures greater than 20°C during May. Surveys (seine and snorkel) conducted over the past several years have indicated that juvenile salmon and steelhead congregate in upstream reaches of the river as temperatures in the lower river warm. In addition to direct thermal stress, elevated rearing temperatures result in multiple indirect effects, including increased risk of predation, decreased growth rates, starvation, and susceptibility to disease, all of which contribute to reduced juvenile survival. Thermal stress to juvenile salmonids (primarily steelhead) is a particular problem during July through October, when water temperatures at the Nimbus Hatchery are generally greater than 18.3°C (65°F). In fact, lower American River water temperatures are commonly 65-75°F from July through October and are thus not conducive to high juvenile steelhead survival. Steelhead would not survive such extended warmwater periods in many years and often move prematurely out of the American River in search of cooler water (McEwan and Nelson 1991). High water temperatures during June through October have severely limited natural steelhead production in the lower American River.

Juvenile outmigration: Juvenile outmigration for both species primarily occurs from March through June. Optimal instream temperatures for outmigrating juvenile chinook salmon and steelhead are about 8-13°C (46-56°F) and 7-11°C (44-52°F), respectively (Beak 1989). Stressfully high water temperatures (i.e., >15.5°C [60°F]) frequently occur in June in the lower American River and may also occur in April and May, depending on instream flows and ambient air temperatures. Warm downstream temperatures may cause juveniles to extend their residence in upstream areas (as evidenced by DFG and USFWS surveys). In addition to direct thermal stress, elevated outmigration temperatures result in multiple indirect effects, including increased risk of predation, decreased growth rates, starvation, and susceptibility to disease, all of which contribute to reduced juvenile survival.

Options for improving water temperatures: The most promising near-term option for improving water temperatures in the lower American River is directed toward adult chinook salmon spawning. The pending reoperation of Folsom Reservoir will likely facilitate the preservation of a larger coldwater pool throughout summer so that it may be relied on to meet target chinook salmon adult upstream migration and spawning temperatures of <13°C (56°F) in the river during part of October and all of November.

Folsom Dam currently has nine water release shutters that are arranged in what is referred to as a "1-1-7" configuration. This means that 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. With such a shutter configuration, the coldwater pool can be rapidly depleted when the bottom seven shutters must be opened to release water from the reservoir. This currently occurs whenever the reservoir elevation drops below 402 feet. Hence, in low water years, loss of the coldwater pool has been a concern for chinook salmon spawning during October and November.

Beak Consultants (unpublished) modeled temperatures of reservoir release waters and has predicted daily temperatures to assess the temperature control benefits of three alternative shutter configurations (2-1-6, 2-2-5, 3-2-4, 3-3-3, 2-3-4, 4-2-3, and 3-4-2). Shutter configurations were evaluated using the Corps' lake/reservoir temperature model CE-THERM-R1. Shutter configurations were evaluated by specifying a downstream temperature objective and allowing reservoir withdrawals at levels determined by the model that would best meet the downstream objective. Average daily outflow temperatures for October and November were the primary products of these simulations.

Modeling results indicated that the 3-2-4 configuration would provide the greatest temperature control benefit and therefore the configuration will be physically constructed in 1995. The 3-2-4 configuration under reservoir reoperation will significantly increase control over the temperature of water released throughout the year, thereby providing additional control over the rate of coldwater pool depletion. Water temperature simulations indicated that by reoperating the reservoir with a 3-2-4 shutter configuration, waters released into the lower American River during October would be 1-9°F colder than the temperature attained under current protocol and shutter configuration (1-1-7). Similar but smaller reductions in water temperature would typically occur throughout November as well. Current reservoir operations produce fall water temperatures in the lower American River that exceed the preferred thermal threshold of 56°F for successful chinook salmon spawning and incubation greater than 91% and 41% of the time in October and November, respectively (Beak Consultants unpublished data). Thus, any decrease in river water temperature during these critical spawning months would be significantly beneficial. A decrease in fall river water temperature of 5°F or more (as indicated by simulation model output) could mean the difference between successful and unsuccessful spawning for a large portion of the chinook salmon population in such years.

The multitude of uses of Folsom Reservoir waters must be reevaluated within the context of reservoir operations so that adequate coldwater storage exists to meet these and other target water temperatures throughout the year. Temperatures should be maintained at or below 13°C (56°F) from November through February to provide adequate incubation temperatures for both salmon and steelhead and should not exceed 15.5°C (60°F) for March through June to provide adequate rearing and outmigration temperatures. Increasing flow rates may increase the length of river thermally suitable for rearing, as well as making the early summer months more suitable for rearing.

Related actions that may impede or augment the action: Increased flow rates described in Action 1 will contribute to temperature control. Conversely, flow rates described in Action 1 may be modified to provide the greatest possible benefits to anadromous fish after the shutters are reconfigured (see this section for Action 1).

Agency and organization roles and responsibilities: The Corps and USBR would be responsible for Folsom Dam facility modifications and operations. DFG and/or USFWS would monitor and assess water temperatures and their effects on salmonid survival rates.

Potential obstacles to implementation: Alterations to Folsom Dam shutters may be costly and construction difficult.

Predicted benefits: Lack of suitable spawning temperatures currently limits chinook salmon production in the lower American River. Maintaining appropriate river temperatures will increase annual salmonid production by increasing early fall reproductive and incubation success. Although quantitative estimates of increased production resulting from incremental changes in river temperatures are not presently available, much is known about how water temperatures affect salmonid survival rates during each life stage (e.g., USFWS 1990). Such information clearly shows that lower American River water temperatures are generally higher than optimal for steelhead and chinook salmon, and thus every effort should be made to maintain lower river temperatures throughout the early spawning and entire rearing and outmigration periods of the year.

Enhanced control over the depth of water discharge from Folsom Reservoir would also translate into an increased ability to manage the coldwater pool throughout summer. A larger coldwater pool in fall could then be heavily relied on to meet target spawning temperatures in October and November for fall-run chinook salmon. Of all limiting factors and potential corrective actions, maintaining suitable river temperatures and instream flows will probably do more for increasing salmonid production within the lower American River than all other actions combined.

Action 6: Replenish and/or restore spawning gravel in existing spawning grounds.

Objective: Enhancement of spawning habitat.

Location: Selected areas between RMs 14 and 22.

Narrative description: Several characteristics of spawning gravel may limit production of salmonids spawning in the lower American River. These characteristics are described below.

Gravel size: Observations of lower American River spawning gravel suggest that substrate particle sizes are relatively large by comparison to those typically used by chinook salmon and steelhead in other streams. This condition is related to the lack of recruitment of smaller-sized gravel from areas upstream of Nimbus and Folsom dams. The low availability of suitable-sized spawning gravel may, in part, limit spawning success of salmon and, to a greater degree, steelhead (Snider pers. comm.).

Armoring: Areas of substrate in the upper reaches of the lower American River have become armored. Fine gravel has been washed away during high flow events, leaving mostly large cobble type substrates. Little gravel recruitment occurs to replenish smaller gravels. Armoring may, in part, limit spawning success of salmon and, to a greater degree, steelhead (Snider pers. comm.).

Embeddedness: Some potential spawning grounds within the lower American River have become embedded with fines, thereby removing these areas from the total acreage of suitable spawning habitat. However, this is believed to be of lesser concern than the armoring of spawning beds (Snider pers. comm.).

Gravel recruitment: Folsom and Nimbus dams prevent recruitment of gravel from upstream areas. Even if spawning gravel is not a key limiting factor today, it may become one if production increases and gravel naturally moves downstream without replacement.

Options for improving the quality of spawning gravel: Survey salmonid spawning habitat between RMs 14 and 22 (where nearly all current salmonid spawning occurs) (Snider and McEwan 1992, Snider et al. 1993, Snider and Vyverberg 1995), and identify those areas where gravel of appropriate size is lacking. Physically add gravel measuring approximately 0.6-2.4 inches in diameter to these areas to enhance spawning conditions for salmon and steelhead. Develop and implement a continuing program for restoring and replenishing, as needed, spawning gravel of the appropriate size, and/or develop a program to mechanically loosen and clean existing streambed areas, particularly in areas where subsurface flow is less than optimal. For example, a prototype gravel cleaning machine is being tested on the Tuolumne River by EA Engineering, and a gravel cleaning machine has been used on the single/dual purpose channels at RBDD.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG would identify sites where gravel is to be added or cleaned and implement this action.

Potential obstacles to implementation: Cost and logistics of gravel addition need to be determined.

Predicted benefits: This action is a simple way to increase the reproductive success of lower American River salmonids. Overall production would be increased significantly through: 1) increasing the availability of high-quality spawning substrate, 2) decreasing the frequency and magnitude of redd superimposition, 3) increasing the percent hatchability of eggs, and 4) decreasing mortality rates for yolk-sac fry.

Action 7: Improve fish screen at the Fairbairn Water Treatment Plant.

Objective: Reduce loss of juvenile salmonids at the Fairbairn Water Treatment Plant.

Location: Fairbairn Water Treatment Plant.

Narrative description: The city of Sacramento's Fairbairn Water Treatment Plant, located about 7 miles upstream from the confluence, is the only large diversion (capacity of about 105 million gallons per day) on the lower American River. This pumping facility is screened but does not meet DFG screening criteria. Impingement, entrainment, and predation losses of salmonid fry may occur here but have not been evaluated or documented.

The Fairbairn Water Treatment Plant screen should be modified, as necessary, to meet current DFG salmonid screening criteria.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG would determine what screening is necessary and would install the screen. The city of Sacramento would monitor and maintain the screen.

Potential obstacles to implementation: The city of Sacramento may object to any decrease in the efficiency of operations due to the installation of a screen.

Predicted benefits: Increased juvenile salmonid survival and thus increased lower American River salmonid production.

Action 8: Modify the timing and rate of water diverted from the river annually.

Objective: Reduce loss of juvenile salmonids at American River diversions.

Location: American River watershed.

Narrative description: Water diverted at Folsom-South Canal, at Fairbairn Water Treatment Plant, and by other diverters on the lower American River reduces flow within the river. In addition, water diverted upstream of Folsom Dam reduces water flowing into the reservoir, thereby reducing water available to be released downstream into the lower river. The city of Sacramento's diversion currently withdraws a maximum of about 140 cfs. In all but extremely low-flow years, the reduction in flow downstream of this facility probably does not significantly affect habitat availability or river water temperatures. Nevertheless, the total of all diversions clearly reduces instream flows within the river. Lower flows allow more rapid warming of river waters with increasing distance downstream, reduce habitat availability, and may lead to stranding of young salmonids.

By modifying the timing and duration of water diversions according to critical salmonid life stages, adverse impacts on salmonid production can be minimized. Also, the volume of water diverted should be minimized to maintain the greatest instream flows possible, particularly during dry and critically dry years. Additional limitations on the volume and timing of water diverted may need to be imposed on water users.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: The City of Sacramento would identify any opportunities to change the timing and magnitude of water diversions.

Potential obstacles to implementation: Such alterations to existing water diversion schedules may not be practical.

Predicted benefits: Increased juvenile salmonid survival and thus increased lower American River salmonid production.

Action 9: Develop a riparian corridor management plan.

Objective: Improve riparian habitat and instream cover.

Location: Lower American River, particularly downstream from Howe Avenue.

Narrative description: Riparian habitat along the lower American River is in relatively good condition from Nimbus Dam downstream to Howe Avenue. Downstream from Howe Avenue, however, riveted banks become common and natural riparian cover becomes limited. Riparian vegetation is important to the maintenance of anadromous salmonid populations by virtue of: 1) stabilization of streambanks, thereby reducing sediment load in the river, 2) provision of shade, 3) enhancement of stream nutrients due to decay of plant debris, 4) provision of streamside habitat for terrestrial and aquatic insects that are preyed on by fish and 5) provision of instream cover.

Riprapping: Riprapping exists primarily where development restricts natural channel migration and is particularly common on downstream sections (e.g., below Howe Avenue). For example, streambanks are heavily riprapped from the Fairbairn Water Treatment Plant to Paradise Beach. Because riprapping prohibits vegetation from colonizing river banks, it clearly reduces shading of river waters and decreases insect production and availability to instream fishes.

Gravel recruitment: (See "Gravel recruitment" under the "Spawning Gravel" subsection above).

A management plan would then be needed to determine best possible approaches to improve and maintain the riparian habitat. Local conservation organizations should be contacted to determine their interest in developing and implementing such a riparian enhancement and management plan. Private land owners should be given incentives to enhance riparian vegetation on their lands. Further development and encroachment on the American River floodplain should be prohibited. Efforts should be made to protect and enhance existing riparian vegetation along the lower American River. As needed, purchase of stream bank conservation easements would facilitate widening and improving the existing riparian corridor. No additional riverbanks should be riprapped; rather, natural riparian vegetation should be established and managed to stabilize banks. Periodic high flows are necessary for natural channel maintenance and thus should be allowed to occur annually in spring.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG would likely take a lead role in developing such a riparian corridor management plan for the lower American River.

Potential obstacles to implementation: Current ownership and use of the riparian corridor as well as needs for immediate bank stabilization may be obstacles to this action.

Predicted benefits: Enhancement of riparian habitats will increase both terrestrial and aquatic insect abundance and therefore their availability to juvenile salmonids. This increased prey base will likely facilitate more rapid growth and earlier outmigration. Riparian cover will shade river waters, thereby helping to maintain more suitable localized water temperatures and reducing thermal stress on outmigrating juveniles.

Action 10: Terminate current programs that remove woody debris from the river channel.

Objective: Provide instream cover for juvenile salmonids.

Location: Lower American River, particularly below RM 14.

Narrative description: Habitat diversity in the lower American River is limited in downstream sections (e.g., in the vicinity of the H Street or Fair Oaks Boulevard Bridge) and below. Most large woody debris has been (and continues to be) removed from the river to eliminate hazards to recreationists (especially swimmers and rafters). Lack of vegetative and woody cover reduces habitat diversity, and is limiting to juvenile salmonid survival. Juvenile outmigrants and young steelhead rearing in the river need instream cover to escape fish and avian predators. Lack of instream cover is believed to be particularly limiting to juvenile steelhead survival in the lower American River (Snider pers. comm.). Finally, in addition to protective cover, instream structure provides a substrate for aquatic invertebrates to colonize, thereby increasing prey availability for juvenile salmonids.

Trees and logs could be added to selected rearing habitats on the river to enhance instream cover for juvenile salmonids. In addition, the current practice of clearing trees and other objects from the river to eliminate hazards to recreationists should be terminated. This practice has clearly reduced instream cover for juvenile salmon and steelhead.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: The agency now charged with removing this woody debris would simply terminate this practice.

Potential obstacles to implementation: Instream woody debris providing cover for juvenile salmonids may interfere with rafting activities.

Predicted benefits: Establishment and maintenance of instream woody cover will provide needed cover for juvenile salmonids, resulting in increased survival from reduced predation losses. Such instream cover will also provide a substrate for aquatic invertebrates to colonize, ultimately increasing food availability for juvenile salmonids.

Action 11: Impose stricter harvest regulations on both sport and commercial harvesters.

Objective: Increase spawning escapement of naturally produced fish.

Location: Lower American River and Ocean.

Narrative description: Angling pressure in the lower American River is high. In the past 3 years, estimates of between 28% and 52% of the chinook salmon returning to spawn in the American River were harvested by anglers. In addition, angling pressure is typically heavy near redds, resulting in redd trampling and reduced egg and fry survival.

Options for reducing angler impacts on salmonid production: Because angler harvest of spawning adults is very high in the lower American River, angling/take restrictions may be appropriate if production from this river is to be doubled. It currently remains unclear whether increasing the spawning escapement will result in increased smolt production. As future studies provide additional insight into this issue, decisions regarding further restrictions to in-river angling harvest to increase spawning escapement can better be made. To prevent redd trampling, public education and/or closing areas with high concentrations of redds to the public, for an appropriate period of time, should be considered.

Oceanic harvests are greater than sport harvests and are not stock selective. Thus, reductions in oceanic harvests will likely increase spawning escapement of most Central Valley streams.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG and NMFS will likely be involved in changes made to river and ocean harvest regulations.

Potential obstacles to implementation: It currently remains unclear whether increasing the spawning escapement will result in increased smolt production.

Predicted benefits: Reducing commercial harvest will likely translate effectively into increased lower American River escapement. Increasing spawning escapement will provide the potential to increase salmonid production within the river through increased fry production. Assuming fry and juvenile mortality rates can be reduced via other actions, the increase in fry production due to increased escapement will likely translate into an increase in overall salmonid production in the lower American River.

Action 12: Conduct weekly on-river patrols in areas where poaching is a concern.

Objective: Increase spawning escapement.

Location: Lower American River.

Narrative description: Illegal harvest may be significant in the upper reaches of the river, just below the dams. The take by poachers contributes to overall harvest of spawning adults and should therefore be viewed as significant within this context.

DFG could establish a greater enforcement presence at areas along the lower American River where poaching is a concern. Information on the status of the salmon migratory season could be used by the wardens to optimize the time and manpower allocated to patrolling and the locations selected for particular days or weeks. Preventing losses from poaching will ease the burden on restricting the legal catch. Every effort available should be used to prevent poaching losses.

Related actions that may impede or augment the action: Changes in harvest regulations either in the ocean or the rivers would likely augment this action.

Agency and organization roles and responsibilities: DFG wold take the lead role in this action.

Potential obstacles to implementation: Insufficient warden personnel may limit the feasibility of this action.

Predicted benefits: Increasing spawning escapement will provide the potential to increase salmonid production within the river through increased fry production. Assuming fry and juvenile mortality rates can be reduced via other actions, the increase in fry production due to increased escapement will likely translate into an increase in overall salmonid production.

Action 13: Change hatchery procedures to benefit native stocks.

Objective: Rebuild native stocks.

Location: Lower American River.

Narrative description: Salmon and possibly steelhead runs on the lower American River were probably eliminated and re-established (replaced) by introduction of non-native stocks during and after construction of Folsom Dam. Potential for naturally spawning fish to adapt to local conditions is hampered by continual infusion of hatchery stocks. Loss of genetic integrity and increased angling and straying will all undoubtedly reduce a given fish stock's productivity. The reduced productivity is then augmented by hatchery stocking, and this cycle of events repeats again and again. The more the genetic integrity of native stocks is diluted, the more we will have to rely on hatchery augmentation to meet target population sizes set largely by public angler demands. When large numbers of hatchery fish are stocked and the proportion of the population made up of hatchery fish increases, so too does the fishing pressure on the remaining wild fish. Adverse impacts on salmonid populations due to straying generally increases as the percentage of the population composed of stocked fish increases. The lower American River is believed to receive a large number of hatchery-propagated strays from the Mokelumne and Feather rivers, as well as smaller contributions from other rivers. The practice of releasing hatchery-produced fish downstream of their natal stream increases straying. Straying has far reaching genetic effects and reduces the ability of constant fractional marking approaches to identify hatchery contribution to overall stocks.

Hatchery efforts focus on a subset of the total time that salmon and steelhead spawn in the American River. Hatchery protocols may influence timing of natural runs through genetic and behavioral interactions between naturally and hatchery-produced fish. Also, the tendency is for Folsom Dam operations and structural changes to focus on improving production of hatchery fish. Prior to the construction of Folsom and Nimbus dams, chinook salmon runs occurred in spring, not in fall. The same may be true of steelhead.

Hatcheries create conditions for the proliferation of fish diseases. Examples include fungus (eggs), columnaris, bacterial gill and kidney disease, and whirling disease. The Nimbus Hatchery has also received fish from outside the American River, creating the potential for introduction of new diseases to native stocks. Furthermore, these non-native hatchery-reared stocks are typically more prone to mortality due to disease factors specific to a river; thus, annual mortality rates of stocked fish are generally higher than that of native fish.

Hatchery fish compete directly for food and cover with native stocks. Likewise, hatchery fish prey on young of native stocks produced in the river. Considered together, these two factors add to the already large pool of factors limiting the productivity and survival of native salmonid stocks. Although hatchery stocking may increase the raw numbers of fish in the river, it is counter-productive to the recovery of native stocks.

Options for rebuilding an American River stock: Reliance on Nimbus Hatchery production and stocking can best be reduced by improving conditions (i.e., habitat) for native stocks. In addition, reducing angling pressure and/or implementing a wild stock catch-and-release program will greatly benefit naturally produced stocks that are currently being over harvested. Future regulations should consider selective harvest of hatchery-produced stocks only. This of course would require that hatchery-produced fish be externally identifiable to anglers.

If hatchery programs are to continue, several issues must be addressed. First, hatchery efforts should focus on propagation of the entire run and/or minimize or eliminate potential for interactions between naturally and hatchery-produced fish. To increase genetic diversity, the hatchery should consider using all available broodstock, including grilse. The practice of discarding broodstock under some minimum length simply reduces the genetic diversity of hatchery-propagated fish and thus should be discontinued. However, broodstock from different rivers should not be shared unless shown electrophoretically to be genetically similar enough to warrant such practices. Doing so with genetically distinct stocks will undermine the "edge" each stock has evolved for its respective river. Fish stocked directly into rivers, rather than downstream, will reduce the incidence of straying. However, doing so will greatly increase losses during the outmigration period; thus, a balance between these two conflicting concerns must be attained. Second, hatcheries must strive to reduce disease problems. Consideration should be given to quality, not quantity. This means improving water quality and reducing densities of fish to create conditions less likely to be conducive to development and proliferation of disease. Finally, the hatchery should consider treating its effluent waters to further guard against the introduction of new diseases that may affect native stocks.

In the attempt to rebuild native salmonid stocks in the lower American River, the Nimbus Fish Hatchery may be able to play an alternative role. The hatchery facility could be used to capture immigrating steelhead, and these fish could be transported and released in traditional headwater spawning grounds above Folsom Reservoir. Outmigrating smolts would likewise need to be captured prior to entering Folsom Reservoir, transported, and released below Nimbus Dam (McEwan and Nelson 1991). Such an approach, however, is not consistent with the definition of "natural production".

Fish are stocked because native populations lack the appropriate habitat and/or numbers to produce sufficient annual numbers themselves. Stocking fish does not act on this problem, but rather treats the symptom (i.e., low numbers of fish). In short, the only way to reduce reliance on hatchery stocked fish is to improve in-river habitat for native stocks.

Changes needed at the Nimbus Hatchery to favor the river's native stock include the following:

- Use of all available broodstock, including grilse to increase genetic diversity of propagated fish. The practice of discarding broodstock under some minimum length simply reduces the genetic diversity of hatchery-propagated fish and thus should be discontinued.

- The emphasis must be placed on the quality, not quantity of hatchery production. This means improving water quality and reducing densities of fish to create conditions less likely to be conducive to development and proliferation of disease.

- Nimbus Fish Hatchery should consider treating its effluent waters to further guard against the introduction of new diseases that may affect native stocks.

Related actions that may impede or augment the action: None.

Agency and organization roles and responsibilities: DFG currently operates Nimbus Hatchery.

Potential obstacles to implementation: The measures presented here may conflict with existing goals and objectives of hatchery operation.

Predicted benefits: Changes made to the traditional procedures utilized by Nimbus Fish Hatchery can result in it being a tool to rebuild native stocks rather than one that degrades them. Decreasing the number of hatchery-propagated fish in the lower American River will increase the opportunity for native stock recovery.

Fishery studies needed at this time -

- Salmon redd surveys during different water-year types to describe the response of spawning salmon over a range of flow conditions
- Spawning escapement surveys to provide accurate estimates of escapement
- Juvenile salmon rearing and outmigration studies

An explicit overall conceptual framework must be established to direct these and other studies so that information collected is appropriate for establishing beneficial flow regimes for maximizing salmonid production in the lower American River.

Mokelumne River -

Limiting factors and potential solutions - Following is a list of factors that may limit chinook salmon and steelhead production within the Mokelumne River basin (Table 3-Xc-10).

Table 3-Xc-10. Limiting factors for fall-run chinook salmon on the Mokelumne River and potential solutions.

Limiting factors	Potential solutions
Lack of suitable instream flows	Increase instream flows
Lack of suitable spawning habitat	1. Spawning gravel additions 2. Mechanically loosen and clean the gravel 3. Riparian outfencing 4. Eliminate gravel skimming operations 5. Instream flow increases 6. Provide "cleansing" flows 7. Manage Camanche Reservoir releases to minimize turbidity
Redd de-watering and juvenile stranding	Set flow fluctuation and reduction limits
Predation losses	1. Remove Woodbridge Dam to eliminate predator concentrations at high flows 2. Keep flashboards out at Woodbridge Dam until smolt outmigration ends 3. Pilot predator removal project

Limiting factors	Potential solutions
Loss and delay of juvenile salmonids migrating past Woodbridge Irrigation District (WID) diversion	1. Remove Woodbridge Dam to eliminate barrier 2. Keep flashboards out at Woodbridge Dam until smolt outmigration ends 3. Maintain fish screen and bypass to DFG standards 4. Study WID diversion and Lake Lodi impacts on juvenile survival and migration
Delay of adult salmonids migrating past Woodbridge Dam	1. Remove Woodbridge Dam to eliminate barrier 2. Increase instream flows 3. Convert lower portion of ladder to pool and weir system 4. Replace and modify use of the gate valve at the top of the upper ladder 5. Remove/block Denil fish ladder during high flows 6. Optimize attraction flows to fish ladder
Unscreened diversions	1. Evaluate operation of all riparian diversions 2. Install fish screens at problem diversions 3. Install permanent fish screen at North San Joaquin Conservation District (NSJCD) diversion

Limiting factors	Potential solutions
High water temperatures	1. Maintain a minimum pool in Camanche Reservoir 2. Balance Camanche Reservoir releases with Pardee Reservoir releases 3. Construct multilevel outlet structure at Camanche Dam 4. Increase instream flows 5. Conduct Camanche/Pardee Dam water dynamics study
Loss of riparian habitat	1. Purchase stream bank conservation easements 2. Riparian outfencing projects 3. Convert abandoned dredging and gravel pit mines 4. Provide flooding flows in wet years 5. Implement a riparian management plan 6. Lake Lodi riparian restoration project
Poor water quality	1. Enforce EPA water quality standards 2. Establish a water quality monitoring program 3. Construct multilevel outlet structure at Camanche Dam 4. Maintain a minimum pool in Camanche Reservoir 5. Manage Camanche Dam releases to optimize water quality

Limiting factors	Potential solutions
Poaching and angling of adult salmon	1. Establish DFG enforcement presence at Woodbridge Dam 2. Post "redd trampling" warning signs at Mokelumne Day Use Area 3. Conduct patrols below Woodbridge Dam during the spawning season
Lack of suitable rearing habitat	1. Increase instream flows 2. Utilize abandoned gravel pits as rearing areas

Restoration actions -

Action 1: Provide instream flows beneficial to all salmonid life stages.

Objective: Increase escapement of adults and survival of all salmonid life stages in the lower Mokelumne River.

Location: Mokelumne River from Camanche Dam to confluence with the San Joaquin River.

Narrative description: The flow pattern of the lower Mokelumne River below Camanche Dam has been altered due to projects for storage, diversion, and hydroelectric power generation (DFG 1991). Up to 65% of the unimpaired flow is diverted into the Mokelumne River aqueducts at Pardee Reservoir. Typically, flows at Woodbridge Dam throughout the year are less than those recorded below Camanche Dam due to channel loss and diversions (FERC 1993). Low flows below Woodbridge Dam prevent salmon from reaching the fish ladder as late as the last week in November. Current management of flows released from Camanche Reservoir have resulted in water temperatures detrimental to, and decreased availability of preferred habitat for, all life stages of salmonids at one time or another. Flows adequate for flooding/maintaining the riparian corridor and cleansing spawning gravels are no longer provided except perhaps during extreme storm events.

Chinook salmon spawning habitat is maximized at flows of 300 to 500 cfs (DFG 1991). Comments on the application of IFIM studies to flow recommendations for other than spawning habitat (Chapman 1992, USFWS 1993b) suggest that other criteria be used to determine flows needed to benefit juvenile salmon. Logic suggests that flows that mimic the natural flow regime would be best to ensure optimal survival rates for juvenile/smolt life stages. Tenant (1975) suggests 30% of the average flow, while DFG (1991) recommends 28% of the average annual runoff. The flow schedule to be provided to the San Joaquin River (Table 3-Xc-11) is recommended for implementation:

Table 3-Xc-11. Instream flow regimes[a] recommended to facilitate doubling of chinook salmon and steelhead production in the lower Mokelumne River under three year types.

Month	Flow (cfs) for each of three year types		
	Wet	Normal	Dry
October[b, c]	300	300	200
November-December[b, c]	350	300	200
January[b]	400[d]	300[d]	200[b]
February[b]	450[d]	350[d]	200[b]
March	550[d]	350[d]	250[b]
April	700[d]	600[d]	350[c]
May	1250[d]	900[d]	400[c]
June	950[d]	500[d]	150[c]
July[d]	250	100	60
August-September[e]	60	60	60

[a] Daily flow fluctuations shall not exceed 10% of the average flow within any 24-hour period, and weekly fluctuations shall not exceed 20% of the average flow within any 7-day period. Flows should not be reduced by more than 300 cfs during any 6-day period.

[b] Should flows exceed 400 cfs for any 7-day period during the peak spawning season (October-December), flows shall not be reduced below 400 cfs for the duration of the spawning/incubation period (October-February).

[c] Flows for chinook salmon spawning and incubation.

[d] Flows for spawning, rearing, and migration. Values calculated as approximately 30% of the average monthly unimpaired flows from 1922 to 1991.

[e] Flows for adult passage, based on report of an instream barrier near Thornton that will prevent or impair the upstream migration of adult chinook salmon at flows less than 60 cfs (DFG 1991).

Related actions that may impede or augment the action: The effectiveness of some flows may be impeded by the timing and amount of water diverted to state and federal water projects.

Agency and organization roles and responsibilities: EBMUD directly controls flows in the lower Mokelumne River via releases from Camanche Reservoir.

Potential obstacles to implementation: Water supply availability and extended drought conditions may result in water shortages to implement this action. EBMUD will likely oppose flows substantially greater than those released under current management schemes.

Predicted benefits: Available habitat for some or all salmonid life stages will be increased. Wet year flows may help in the cleansing of spawning gravels and maintenance of the riparian corridor. Barrier and timing problems associated with Woodbridge Dam and diversion may be reduced. The water temperature regime in the lower Mokelumne River will improve. Water quality may improve.

Action 2: Provide flows maximizing suitable chinook salmon spawning habitat.

Objective: To improve the quantity of spawning habitat in the lower Mokelumne River.

Location: Lower Mokelumne River from Camanche Dam to Mackville Road.

Narrative description: Prior to the completion of Camanche Dam in 1964, chinook salmon spawned primarily between Clements (RM 59.2) and the canyon about 3 miles below Pardee Dam (FERC 1993). Most salmon spawning now takes place over the 5-mile reach between Camanche Dam and Mackville Road. The quality and quantity of suitable spawning habitat available in the future will depend to a great degree on the instream flow regime. Although the 1987 IFIM study (Envirosphere 1988) indicates that the maximum potential spawning habitat is available when flow is near 300 cfs, it has been suggested that deep water did not coexist with suitable velocities and substrata at the stream discharges extant in the river when spawning microhabitat was examined, and that DFG recommended flows for spawning in the lower Mokelumne River would be higher if the suitability curves for spawning chinook salmon were to be re-examined at greater river discharges (Chapman 1992).

Flows recommended in Action 1 should be implemented during the spawning season.

Related actions that may impede or augment the action: The effectiveness of these flows may be impeded by the timing and amount of water diverted to state and federal water projects.

Agency and organization roles and responsibilities: EBMUD directly controls flows in the lower Mokelumne River via releases from Camanche Reservoir.

Potential obstacles to implementation: Unimpaired runoff available may not be sufficient to implement the proposed flow releases recommended in Action 1. EBMUD will likely disagree with the recommended flow levels proposed in Action 1.

Predicted benefits: Available spawning habitat may be increased. Wet year flows may help in the cleansing of spawning gravels. Barrier and timing problems associated with Woodbridge Dam and diversion may be reduced for adult salmonids. The water temperature regime in the lower Mokelumne River will improve for salmon spawning. Water quality may improve.

Action 3: Replenish gravels suitable for salmonid spawning habitat.

Objective: To improve the quantity and quality of spawning habitat in the lower Mokelumne River.

Location: Lower Mokelumne River from Camanche Dam to Mackville Road.

Narrative description: Camanche Dam blocks the movement of gravel from upstream, and immediately below the dam there is no source of replacement gravels. Gravel skimming operations may also contribute to a lack of adequate spawning gravels.

Spawning gravel should be added to portions of the river. On June 8, 1994, biologists from EBMUD and DFG identified four potential sites where gravel could be added to the river: 1) at the DFG pasture site (Envirosphere 1988), 2) upstream of the PG&E gas line crossing, 3) directly below Highway 88, and 4) above Mackville near the old "CC Wood" bridge crossing. DFG is in the process of determining land ownership and potential access. Redd surveys (BioSystems 1992) and habitat usage of previous gravel enhancement projects (Hartwell 1994) in the lower Mokelumne River show that berms that are perpendicular to streamflow are preferred spawning habitat. Gravel should be added to the river so that the above-mentioned berms are formed. Funding for salmon spawning habitat restoration through the State Habitat Conservation Fund (Prop. 117) should continue to be pursued by EBMUD.

Related actions that may impede or augment the action: Instream flows will determine how and to what extent added gravels are distributed downstream from the potential sites listed above.

Agency and organization roles and responsibilities: Categorical exemptions can be obtained for most of the permits required under CEQA for gravel placement work through DFG coordinating with the CVRWQCB and the Corps. EBMUD will need to meet its mitigation responsibilities to replenish and maintain gravels according to agreements signed with DFG. DFG should require gravel permit operators to periodically place gravel in the stream to improve the salmon spawning habitat should they continue to be allowed to operate.

Potential obstacles to implementation: Access to the river for gravel restoration projects will require land owner cooperation.

Predicted benefits: Additional spawning habitat may be created, and spawning habitat quality will improve. Redd superimposition may decrease.

Action 4: Cleanse spawning gravels of fine sediments.

Objective: To improve the quality of spawning habitat in the lower Mokelumne River.

Location: Lower Mokelumne River from Camanche Dam to Mackville Road.

Narrative description: The presence of Camanche Dam and the use of Camanche Reservoir for flood control has resulted in the absence of flushing flows necessary to cleanse and prevent sedimentation of spawning gravels in the lower Mokelumne River. BioSystems (1992) reported that over 70% of the substrate samples taken in 1991 and 1992 from chinook salmon redds contained amounts of fine sediment less than 0.48 inch in diameter that are detrimental to egg survival (Chapman 1988). This and the presence of substrate armoring and compaction in the spawning sites (BioSystems 1992) indicate that spawning gravel quality is a limiting factor. Exact sources of these fines are not known, although possible culprits may be turbid flow releases below Camanche Dam, agricultural returns, and poor land use practices.

Flushing flows are needed from Camanche Reservoir to cleanse gravels. A pilot program involving mechanically loosening and cleaning the gravel should be conducted from an upstream to downstream direction to see if such an action would prove effective.

Related actions that may impede or augment the action: Streamflows necessary to move 1/2-inch-diameter gravel may be in excess of 3,000 cfs (Envirosphere 1988). Because some of the substrate is compacted and armored, even higher flows may be required. This would possibly result in some flooding downstream and damage to existing levees (Taylor, USFWS, pers. comm.). A prototype gravel cleaning machine is being tested on the Tuolumne River by EA Engineering. Another gravel cleaning device has been designed and used for 2 years at the Tehama-Colusa Canal and is effective for specific-sized gravel.

Agency and organization roles and responsibilities: EBMUD directly controls flows in the lower Mokelumne River via releases from Camanche Reservoir. DFG would be the lead agency for purposes of permitting under CEQA, CVRWQCB, and the Corps. Technical advice and perhaps the loan of a machine may be needed from EA Engineering.

Potential obstacles to implementation: Access to the river for gravel restoration projects will require land owner cooperation. Mechanical gravel cleaning may not prove to be a viable action.

Predicted benefits: Spawning gravel quality may improve substantially.

Action 5: Prevent sedimentation of spawning gravels.

Objective: To improve the quality of spawning habitat in the lower Mokelumne River.

Location: Lower Mokelumne River from Camanche Dam to Mackville Road.

Narrative description: The presence of Camanche Dam and the use of Camanche Reservoir for flood control has resulted in the absence of flushing flows necessary to cleanse and prevent sedimentation of spawning gravels in the lower Mokelumne River. BioSystems (1992) reported a significant inverse relationship between mean survival of eggs in wild salmon redds and the percentage of fines in three size categories. They also reported that more than 70% of the substrate samples taken in 1991 and 1992 from chinook salmon redds contained amounts of fine sediment (less than 0.48 inch) in diameter that are detrimental to egg survival (Chapman 1988). This indicates that spawning gravel quality is a limiting factor. Exact sources of these fines are unknown, although possible culprits may be turbid flow releases below Camanche Dam, agricultural returns, and poor land use practices.

Camanche Reservoir should be managed so as to minimize sediment levels in flow releases. A multilevel outlet structure should be constructed at Camanche Dam so that turbid releases can be avoided while adequate water temperatures are maintained. Cattle should be excluded from grazing along the river's edge. Outfencing projects should be promoted with land owners to establish a buffer zone and to allow the re-establishment of riparian vegetation and to prevent bank erosion.

Related actions that may impede or augment the action: Gravel cleaning may affect habitat downstream from the cleaning sites. Bottom releases necessary for maintaining recommended water temperatures may have increased turbidity.

Agency and organization roles and responsibilities: EBMUD manages flow releases from Camanche Reservoir and would play the lead role in any construction taking place at the dam. Cooperation with private land owners would be essential to making any out-fencing program work.

Potential obstacles to implementation: Low-turbidity releases may not be compatible with EBMUD-preferred management practices of Camanche Reservoir. EBMUD will likely resist the installation of a multilevel outlet structure due to construction costs involved. Land owner cooperation will be needed to restore riparian habitat that was destroyed by livestock grazing and protect what remains.

Predicted benefits: Spawning gravel quality may improve substantially.

Action 6: Restrict flow fluctuations and reductions.

Objective: Prevent redd de-watering and stranding of juvenile salmonids.

Location: Mokelumne River from below Camanche Dam to confluence with the San Joaquin River.

Narrative description: Losses of chinook salmon eggs have occurred due to flow reductions in the lower Mokelumne River (Meinz 1985). Additional losses were suspected due to the stranding of juvenile salmon on large gravel bars or in isolated pools or channels. A stranding model (Envirosphere 1988) showed that exposed strandable area increased most with downramping events involving flows at or below 400 cfs. Steady flows during the peak spawning, egg incubation, and juvenile rearing period (October through April) would prevent the desiccation of redds and stranding of juvenile salmonids on gravel bars and in potholes on the lower Mokelumne River (DFG 1991).

Flow fluctuation limits recommended by DFG to avoid loss of aquatic productivity and stranding should be implemented: daily flow fluctuations shall not exceed 10% of the average flow within any 24-hour period and weekly fluctuations shall not exceed 20% of the average flow within any 7-day period. Should flows exceed 400 cfs for any 7-day period during the peak spawning season (October-December), flows shall not be reduced below 400 cfs for the duration of the spawning/incubation period (October-February). Flows should not be reduced by more than 300 cfs during any 6-day period.

Related actions that may impede or augment the action: The maintenance of steady flows throughout the periods mentioned above would make flow ramping unnecessary. Storm events where flows are no longer controlled may make meeting the fluctuation criteria impossible.

Agency and organization roles and responsibilities: EBMUD directly controls flows in the lower Mokelumne River via releases from Camanche Reservoir.

Potential obstacles to implementation: Flow ramping schedules may not be compatible with EBMUD management practices of Camanche Reservoir releases. Storm events may make ramping impossible.

Predicted benefits: Instances where redd de-watering and/or the stranding of juvenile salmons occur would be eliminated. Impacts on aquatic productivity due to flow alterations may be lessened.

Action 7: Remove Woodbridge Dam or delay installing the dam flashboards until July.

Objective: Reduce losses of salmon smolts to predation.

Location: Immediately below Woodbridge Dam.

Narrative description: High spring flows can attract striped bass and squawfish to the base of Woodbridge Dam. During Camanche Reservoir flood flow releases in spring 1993, striped bass were attracted to the base of Woodbridge Dam (EBMUD 1994). Based on analysis of striped bass stomach contents, diver surveys, and the time period when striped bass were present, EBMUD biologists estimate that between 11 to 51% of the 1993 salmon smolt production was lost to striped bass predation (Boyd 1994).

In 1994, Camanche Reservoir releases of approximately 150 cfs resulted in spill conditions over the top of Woodbridge Dam. Dave Vogel, conducting experiments to determine the extent of physical injury to salmon smolts passing over the top of Woodbridge Dam, observed heavy predation by squawfish on salmon smolts passing through a pool from the fish ladder entrance discharge (EBMUD 1994). Vogel noted that the predation losses could easily be the highest single mortality to juvenile salmon within the Mokelumne River. A pilot predator removal project for the area just below Woodbridge Dam is presently planned for spring 1995 (Vogel Environmental Services pers. comm.).

Alternative methods of diverting water by the WID should be investigated so that Woodbridge Dam could be removed altogether. If the dam cannot be permanently removed, the flashboards should not be installed until after the smolt outmigration has ended.

Related actions that may impede or augment the action: Increased spring flows may increase the attraction of predators to the tailwaters of Woodbridge Dam.

Agency and organization roles and responsibilities: WID would need to spearhead the process of looking for alternative methods of water withdrawal to meet its needs. Removal of Woodbridge Dam would likely involve WID, USFWS, DFG, the Corps, and others. Permission would also have to be obtained from WID to gain access to the river to remove predators that concentrate at the base of the dam. DFG would have to agree to issue permits that would allow for the removal of the fish predators.

Potential obstacles to implementation: WID would likely object to any proposed changes to its diversion operations. The city of Lodi and/or the recreational users of Lake Lodi may protest the removal of the lake. Alternative water sources during the time that the flashboards would be removed may not be available or adequate. DFG may have a difficult time justifying the removal of fish predators because striped bass are a game fish and squawfish are a native species. Because striped bass are one of the fish species populations to be doubled under the CVPIA, the removal of striped bass predators from the area below Woodbridge Dam may be in conflict with the anadromous fish doubling goal.

Predicted benefits: Removal of Woodbridge Dam would eliminate the problem of concentrating predators and smolts in one small area, thus predation problems may be eliminated entirely. A conservative estimate of the benefits that might accrue from reduced predation on salmon smolts would be an improvement of salmonid smolt survival of 10%.

Action 8: Reduce or eliminate mortality and delays of juvenile salmonids associated with passage past the WID diversion and Woodbridge Dam.

Objective: Improve survival of juvenile salmonids past the WID diversion and Woodbridge Dam.

Location: WID diversion and dam.

Narrative description: WID's diversion and Woodbridge Dam may result in mortality and/or delays of juvenile salmonids migrating downstream past them. Possible causes of the above are: 1) inadequate access and/or attraction flows to the fish bypass, 2) faulty rubber seals on the rotating drum screens, 3) lack of a comprehensive fish facilities monitoring and maintenance program, 4) inadequate fish screen bypass flows, 5) predation and high water temperatures in Lake Lodi, 6) injury to fish when flow over the dam occurs, and 7) inadequate flows released below the dam.

Alternative methods of diverting water by the WID should be investigated so that Woodbridge Dam could be removed altogether. If the dam cannot be removed permanently, the flashboards should not be installed until after the smolt outmigration has ended. If the flashboard installation cannot be delayed, the screening and bypass facilities should be closely monitored and maintained to DFG standards. Flows recommended in Action 1 should be implemented so as to reduce the percentage of the flow diverted by WID. Studies should be conducted looking at: 1) the impact of Lake Lodi on juvenile salmonid survival and its possible use as a rearing area, 2) the efficiency of existing fish screen and bypass facilities, and 3) the extent/causes of delays to the downstream migration of juvenile salmonids that may occur.

Related actions that may impede or augment the action: The amount of flows through Lake Lodi and the percentage of the water diverted by WID may alter the effectiveness of the management actions. Important limiting factors that may negate benefits would be predation losses below Woodbridge Dam, unsuitable water temperatures in the central Delta, and entrainment losses at the water project pumps.

Agency and organization roles and responsibilities: Removal of Woodbridge Dam would likely involve WID, USFWS, DFG, the Corps, and others. WID and DFG will need to coordinate facility inspections and maintenance. EBMUD will need to release the flows from Camanche Reservoir to meet recommendations for below Woodbridge. WID, DFG, EBMUD and USFWS should cooperate in conducting any studies concerning Lake Lodi and/or WID facilities.

Potential obstacles to implementation: Cost would be the major obstacle for making the improvements in this section. WID would likely object to any proposed changes to its diversion operations. The city of Lodi and/or the recreational users of Lake Lodi may protest the removal of the lake. Alternative water sources needed during the time when the flashboards would be removed and the filling of Lake Lodi delayed, or made necessary due to the removal of Woodbridge Dam, may be unavailable or inadequate. EBMUD would likely resist any increases in flows required below Woodbridge Dam.

Predicted benefits: Should Woodbridge Dam be removed, or the flashboards be removed during smolt outmigration, juvenile salmonid mortality and delays in their downstream migration may be eliminated entirely in this reach. Increased flows will eliminate the need for trapping juvenile salmonids at Woodbridge Dam and trucking them to the Delta and may result in increased escapement due to improved imprinting by juvenile chinook salmon.

Action 9: Eliminate barriers to efficient and timely migration of adult salmonids.

Objective: Improve passage conditions at Woodbridge Dam for adult salmonid migration.

Location: Woodbridge Dam.

Narrative description: The tailwater elevation below Woodbridge Dam is too low relative to the fishway entrance during low-flow conditions. Access and/or attraction to the fishway entrance may be inadequate, resulting in physical injury to upstream migrating salmon attracted to dam spillage. Under the current design, adult salmon passing up the lower ladder must swim through a series of small rectangular openings (23.6 x 35.5 inches) where there is currently no resting habitat between chambers (EBMUD 1994). The pool and weir system would provide the necessary hydraulic conditions for better fish passage. Spill can place water into the Denil fishway, making it a blind channel for migrants, when Lake Lodi is high (FERC 1993). Flow restriction in the high stage fish ladder occurs due to the gate valve at the top.

Alternative methods of diverting water by the WID should be investigated so that Woodbridge Dam could be removed. If the dam cannot be removed permanently, the flashboards should not be installed until after the smolt outmigration has ended. If the flashboard installation cannot be delayed, the following improvements should be made: 1) attraction flows to the fish access should be optimized, 2) the gate valve at the top of the high stage fish ladder should be removed, 3) access to the Denil fishway should be denied to migrants when Lake Lodi is high, and 4) the lower portion of the ladder should be converted into a pool and weir system. Flows recommended in Action 1 should be implemented to eliminate fish passage problems associated with low flows during adult salmonid migrations.

Related actions that may impede or augment the action: The flows past Woodbridge Dam will affect the ability of the adult salmon to locate and ascend the fish ladders.

Agency and organization roles and responsibilities: Removal of Woodbridge Dam would likely involve WID, USFWS, DFG, Corps, and others. EBMUD will need to release the flows from Camanche Reservoir to meet recommendations for below Woodbridge. Permission will be needed from DFG and WID to modify the fish ladders at Woodbridge Dam.

Potential obstacles to implementation: No funding sources have been identified to modify and improve the fish passage conditions at Woodbridge Dam. WID would likely object to any proposed changes to its diversion operations. The city of Lodi and/or the recreational users of Lake Lodi may protest the removal of the lake. Because this is not a hydropower project, FERC is unlikely to mandate any improvements to this facility. EBMUD will likely oppose any changes in flow requirements below Woodbridge Dam.

Predicted benefits: Although it is difficult to quantify benefits, the natural salmon spawning escapement to the lower Mokelumne River should increase because adult salmon will not be delayed in their upstream migration.

Action 10: Screen all diversions in the lower Mokelumne River to DFG standards.

Objective: Prevent entrainment or loss of juvenile salmonids at lower Mokelumne River diversions.

Location: Mokelumne River from below Camanche Dam to Lake Lodi.

Narrative description: Unscreened or improperly screened diversions can result in the loss or entrainment of juvenile salmonids. From the rearing areas near Camanche Dam downstream to Lake Lodi, over 50 river pumps withdraw water from the river for irrigation, and few, if any, are screened (BioSystems 1992). The NSJCD, operating the second largest diversion below Camanche Dam, had DFG install a temporary fish screen during the 1993 irrigation season.

The operation of riparian pumps should be evaluated because many of the diverters are operating under their own guidelines. Should evaluations show problems at any given diversion, it should be screened to meet DFG standards. The NSJCD diversion should be screened to meet DFG criteria whenever it is operated.

Related actions that may impede or augment the action: The timely outmigration of smolts may have juveniles susceptible to loss or entrainment out of the river before most water diversion occurs.

Agency and organization roles and responsibilities: DFG would investigate and screen up to its standards any diversions that pose problems to juvenile salmonids. Those operating diversions would need to cooperate.

Potential obstacles to implementation: Water diverters may not want to cooperate with any investigation of potential diversion problems and may object to the cost and inconvenience of screening their diversions.

Predicted benefits: Loss and entrainment problems associated with unscreened diversions would be reduced or eliminated.

Action 11: Maintain suitable water temperatures for all salmonid life stages.

Objective: Provide for timely migrations and increased survival of adult and juvenile salmonids.

Location: Mokelumne River from below Camanche Dam to confluence with the San Joaquin River.

Narrative description: Downstream of Camanche Dam, water temperature depends on Camanche Reservoir release water temperature, prevailing meteorological conditions, and flow rate (FERC 1993). From April to mid-October, the closure of Woodbridge Dam and subsequent filling of Lake Lodi effectively slows the water, allowing it to heat. Temperatures downstream of Woodbridge Dam are also affected by a reduction in flow as a consequence of the water withdrawal at the WID diversion. Differences in water temperature between Camanche and Woodbridge dams have been measured up to 16.2°F (9°C) during hot, dry years (Walsh et al. 1992). In 1990, water temperatures at RM 29.5 (Ray Road) regularly exceeded 77°C (25°C) from the end of April to mid-September, and regularly exceeded 86°F (30°C) from early June to early August (Walsh et al. 1992). DFG (1991) describes the preferred range of temperatures for fry and outmigrant juvenile salmon as 7.0-14.6°C (45-58°F), while Raleigh et al. (1986) recommends that from the time fry emerge from the gravel until they migrate out of the river the temperature should not exceed 18°C (64°F).

A minimum pool in Camanche Reservoir of 190 feet from April through September, and a minimum pool of 170 feet from October through March, should be maintained. Instream flows recommended in Action 1 should be implemented. Pardee Reservoir flow releases should be balanced with those from Camanche Reservoir to optimize thermal conditions. Alternative methods of diverting water by the WID should be investigated so that Woodbridge Dam could be removed and Lake Lodi eliminated. Alternatives that would help provide optimal water temperatures include constructing a pipeline from Pardee Reservoir to the base of Camanche Dam and/or constructing a multilevel outlet structure at Camanche Dam. Further studies are needed on Pardee and Camanche Dam water temperature dynamics so that reservoir management practices can optimize water temperatures downstream.

Related actions that may impede or augment the action: There may be a tradeoff in water temperature benefits from increased springtime flows below Woodbridge Dam and increased losses of smolts from fish predators that are attracted to the base of Woodbridge Dam by the higher flows.

Agency and organization roles and responsibilities: EBMUD is responsible for Pardee and Camanche Dam operations and would bear primary responsibility in construction projects at Pardee and Camanche dams. Removal of Woodbridge Dam would likely involve WID, USFWS, DFG, the Corps, and others.

Potential obstacles to implementation: Water shortages resulting from the implementation of this action during dry years and costs involved with proposed construction projects will likely meet with resistance from EBMUD. WID would likely object to any proposed changes to its diversion operations. The city of Lodi and/or the recreational users of Lake Lodi may protest the removal of the lake. Alternative water sources needed due to the removal of Woodbridge Dam may not be available or adequate.

Predicted benefits: Suitable water temperatures provided for all life stages of salmonids will result in timely adult and smolt migrations, increased emergence, and increased survival of fry and smolt stages.

Action 12: Enhance and maintain the riparian corridor.

Objective: Improve streambank and channel rearing habitat for juvenile salmonids.

Location: Mokelumne River from below Camanche Dam to confluence with the San Joaquin River.

Narrative description: The lower Mokelumne River's riparian vegetation is diminishing over time (USFWS 1993a). In many areas there is no regeneration along the relatively thin riparian corridor (DFG 1991). Riprapping of long lengths of streambank such as above and below Elliot Road has reduced tree growth and therefore fostered increased river temperatures by reducing shading (EBMUD 1994). The reach with the most obvious deficiency in riparian vegetation is at Lake Lodi, which has large areas of shallow water without vegetation (FERC 1993). Bankside erosion has potentially affected salmonid production in several small areas where cattle grazing is permitted along the river corridor (Miyamoto 1994). Sustained flows at or near bankfull discharge, or even overbank flows, during the period of seed set and vegetation growth in spring, would provide for a healthy riparian vegetative community (Chapman 1992).

Sustained flows of at least 3,000 cfs should be provided to flood the lower alluvial surfaces during wet years, and slightly higher surfaces could be inundated periodically with releases from Camanche Reservoir. The response of the riparian community to these flows should be monitored. An active riparian restoration and management plan should be established for the lower Mokelumne River. A riparian restoration project should be conducted at Lake Lodi. Cattle and horses should be fenced out where they now graze down to the river's edge. Stream bank conservation easements could be purchased to widen the riparian corridor.

Related actions that may impede or augment the action: Flushing flows recommended for cleansing spawning gravels may be sufficient to provide benefits to the riparian community as well.

Agency and organization roles and responsibilities: EBMUD directly controls flows in the lower Mokelumne River via releases from Camanche Reservoir. DFG would be the lead agency for purposes of monitoring the effects of the above-mentioned flows. Cooperation with private land owners would be an essential element to make an out-fencing program work. Property adjacent to the river might be purchased using State Wildlife Conservation Board funds, or property owners may be given an incentive through a favorable property tax program if they establish a natural riparian corridor with an out-fencing program. The Nature Conservancy could provide technical advise on establishing and implementing an active riparian restoration and management plan.

Potential obstacles to implementation: EBMUD will likely oppose any major changes in its flow management practices. Land owners may be unwilling to participate in any riparian restoration program. Funds needed for the purchase of conservation easements may be unavailable.

Predicted benefits: Riparian regeneration and maintenance may take place. Impacts on spawning gravels due to erosion will be reduced. An improved riparian corridor may lower water temperatures. Rearing habitat availability and quality will probably be increased.

Action 13: Set and enforce water quality standards.

Objective: Provide optimal water quality for all life stages of salmonids.

Location: Mokelumne River from below Camanche Dam to confluence with the San Joaquin River.

Narrative description: The management of Camanche Reservoir elevations and Pardee Reservoir inflows have not consistently provided water of suitable quality to the Mokelumne River Fish Facility (MRFF) and the lower Mokelumne River fishery (USFWS 1993a). Occurrences of low dissolved oxygen, elevated hydrogen sulfide, and elevated heavy metal levels at critical times of the year for fisheries and other aquatic resources have been documented, occasionally resulting in fish kills. Camanche Reservoir releases have regularly exceeded EPA criteria for the maintenance and protection of aquatic resources. To gain an accurate and complete account of Mokelumne River water quality conditions and their effects on fishes, and to fully assess the impact of EBMUD's operations on the lower Mokelumne River, a water quality monitoring program that includes a greater number of sampling sites and more frequent sampling of the lower river than presently sampled is needed.

EPA water quality standards for the protection and maintenance of aquatic resources should be met at all times for Camanche Reservoir releases. USFWS guidelines for a water quality monitoring plan, submitted to EBMUD in 1993, should be used to establish a working program. A multilevel outlet structure should be constructed at Camanche Dam so that turbid releases can be avoided while adequate water temperatures are maintained. EBMUD should manage Camanche Reservoir in a way that bottom sediments are not resuspended and subsequently released downstream.

Related actions that may impede or augment the action: The maintenance of a minimum pool in Camanche Reservoir may help prevent the re-suspension of bottom sediments high in heavy metal concentrations.

Agency and organization roles and responsibilities: EBMUD, EPA, and USFWS would work together in implementing a water quality monitoring program. EBMUD would manage releases so that water quality below Camanche Dam would meet EPA standards.

Potential obstacles to implementation: EBMUD will likely resist the installation of a multilevel outlet structure due to construction costs and difficulties involved and resist any changes in current operational procedures regarding releases.

Predicted benefits: Improved water quality would lessen the likelihood of any adverse impacts on incubating salmon eggs and juvenile salmonids and eliminate the potential for fish kills in the future.

Action 14: Eliminate adverse effects of poaching and angling on salmonid production.

Objective: Protect adult salmon and steelhead spawners.

Location: Mokelumne River from below Camanche Dam to confluence with the San Joaquin River.

Narrative description: Poaching in the lower Mokelumne River can seriously limit salmonid production with losses up to 50% during low-flow years (BioSystems 1992). Historically, most of the poaching occurs below Woodbridge Dam, but poaching has also occurred in the river adjacent to the MRFF (Estey 1992) and at Highway 88 (Boyd 1992). The Mokelumne River is open to fishing from January 1 through October 16 each year, with a daily bag and possession limit of two salmon and/or steelhead per angler. Hartwell (1994) reported that biologists conducting redd surveys on the lower Mokelumne River routinely observed anglers wading on and around the redds in these areas after the fishing season opens. Roberts and White (1992) have shown that anglers wading on trout redds can significantly affect their hatching success.

A cooperative program established in 1993 between DFG and WID based on wardens knowing the current status of the salmon migration should be continued. Consideration should be given to extending the sport fishing closure from beyond December 31 to March 31, especially during dry years. Consideration might also be given to posting signs warning anglers about trampling on redds during the spawning/incubation period in all public access areas, and at Mokelumne Day Use Area in particular. DFG, with possible assistance from local sports's clubs, could conduct weekly patrols on the river from Woodbridge Dam to Thornton to locate and remove potential fish barriers and discourage poachers.

Related actions that may impede or augment the action: The removal of Woodbridge Dam would reduce the availability of easy prey to potential poachers. Increased flows would reduce the susceptibility of adult salmon to poaching.

Agency and organization roles and responsibilities: WID and DFG will need to continue the information exchange used to alert wardens to any increased potential for poaching to occur due to the presence of migrating salmon. DFG would lead any investigation on possible fishing regulation changes concerning the Mokelumne River and would determine what enforcement presence would be necessary to reduce salmon poaching. EBMUD and/or DFG would post the "redd trampling" warning signs. Local sports's clubs could get involved in river patrols.

Potential obstacles to implementation: DFG has a limited budget to increase its enforcement presence on the lower Mokelumne River. Sport fishers will likely protest changes to restrict fishing on the lower Mokelumne River.

Predicted benefits: Escapement to the spawning grounds would increase due to a reduced take by poachers and/or the sport fishery.

Action 15: Evaluate the feasibility of increasing available rearing habitat.

Objective: Maximize suitable rearing habitat in the lower Mokelumne River.

Location: Mokelumne River approximately 1 mile downstream from McIntire Road to 3 miles downstream of Mackville Road.

Narrative description: To improve salmon rearing habitat, FERC (1993) recommends increasing the number of small pools with velocities greater than 0.49 fps that are interconnected with river channels. Such habitat might be developed by using abandoned gravel dredging and mine sites along the river. The abandoned gravel dredging areas are located approximately 1 mile downstream from McIntire Road to 3 miles downstream of Mackville Road. Similarly, FERC (1993) recommends using abandoned gravel pit mines to provide rearing habitat by connecting them with the Mokelumne River and enhancing them with riparian plantings. The most suitable gravel pits are located between Highway 88 and Mackville Road. FERC (1993) states the ponds would be useful during the March through May rearing period before water temperatures become unsuitable.

Prior to creating new habitat, the use by rearing salmonids of existing habitat similar to that described above should be evaluated. Habitat should be created only if it would provide a net benefit to natural production of salmonids.

Related actions that may impede or augment the action: River flows may affect the interconnection of the new riparian wetland habitat. Many of the gravel pits contain populations of largemouth bass that may pose predation threats to juvenile salmonids (EBMUD 1994).

Agency and organization roles and responsibilities: Cooperation with private land owners will be an essential element to make this program work. Property adjacent to the river might be purchased using State Wildlife Conservation Board funds.

Potential obstacles to implementation: Funding sources for this program may be limited to fully implement this program.

Predicted benefits: The available rearing habitat for juvenile salmonids would be increased.

Cosumnes River -

Limiting factors and potential solutions - Following is a list of factors that may limit chinook salmon production within the Cosumnes River basin (Table 3-Xc-12).

Table 3-Xc-12. Limiting factors for fall-run chinook salmon on the Cosumnes River and potential solutions.

Limiting factor	Potential solutions
Instream flow	1. Set instream flow requirements 2. Restrict diversions during critical migration periods 3. Purchase existing water rights
Migration barriers	1. Evaluate existing barriers for adult and juvenile fish passage and remedy problem ones 2. Remedy passage problems as identified above via dam removal, operational changes, or improved ladders 3. Enforce Fish and Game Codes that prohibit construction of unlicensed dams
Juvenile entrainment	Effectively screen all diversions
Riparian habitat	1. Establish riparian corridor protection zone 2. Rehabilitate damaged areas

Restoration actions -

Action 1: Determine and set instream flow requirements.

Objective: Ensure adequate instream flows for all life stages.

Location: Entire river where salmonids are found (RM 41 downstream).

Narrative description: Low flows in fall appear to be the most critical limiting factor to the run. The lower stretch of river is often dry until fall rains occur, and contiguous flow may not exist until spring. Thus, fall spawning passage of migrating adult salmon is blocked. Young-of-the-year salmon must leave the river by early May to avoid high temperatures and low flows. The current flow and temperature regime, however, prohibits the year-long presence of chinook salmon or steelhead.

The mainstem of the Cosumnes River and its smaller tributaries have 157 registered appropriative water rights. In addition, 58 statements of water diversions and use (pre-1914 and riparian rights), 123 stock ponds, and three small domestic registered diversions are on file with the Division of Water Rights. (The stock ponds are generally less than 10 af and usually are filled from diversions during the first few storms, thus delaying the increased flows that are needed downstream to allow for salmon migration.) There are additional registered water diversions on the three forks of the Cosumnes River. Most water is being diverted from the first rains in fall through early summer. This, of course, coincides with the time that salmon are in the system.

DFG's Region 2 files have no information regarding any minimum instream flow, and no IFIM studies appear to have been conducted on the Cosumnes River. There is documentation, however, that the flow remains discontinuous below the spawning area through fall and early winter in dry years and until heavy rains in normal years. In years when salmon spawn successfully, young-of-the-year salmon must leave the system by early May due to high water temperatures and low flows.

During the baseline period, the current escapement goal was met in 1968, 1969, and 1972 (Table 3-Xc-13). The average monthly flow for October in those years was approximately 1,000 cfs (average daily flow of 32 cfs). Therefore, until better information exists, a minimum instream flow of 32 cfs from October through May, measured at the Michigan Bar flow gage, provides conditions suitable for salmonid production.

Table 3-Xc-13. Escapement estimates and monthly total flow for October and May during the baseline period for the Cosumnes River.

Year	Escapement estimate	October flow	May flow
1967	500	1,467	5,988
1968	1,500	482.7	40,331
1969	4,400	1,654	11,687
1970	600	803	21,296
1971	500	901	10,529
1972	1,600	936	22,096
1973	900	1,533	24,557

Year	Escapement estimate	October flow	May flow
1974	285	NE	NE
1975	725	2,510	3,036
1976	NE	431.9	1,502
1977	NE	0	28,264
1978	100	670	30,457
1979	150	1,332	17,708
1980	200	927	6,013
1981	5	876.9	39,284
1982	NE	6,273	68,770
1983	200	2,468	15,139
1984	1,000	2,131	7,807
1985	220	878	13,160
1986	NE	1,262	2,704
1987	NE	301	3,252
1988	100	11.53	7,082
1989	NE	1,746	4,080
1990	NE	231.7	10,217
1991	NE	513.9	2,364

Note: "NE" indicates no estimate is available.

Predicted benefits: Providing adequate instream flow will ensure salmon utilization in the Cosumnes River on a consistent basis. An IFIM study will aid in determining best utilization of the available flow.

Action 2: Restrict water diversions during critical periods for salmonids.

Objective: Ensure adequate instream flows for all life stages and provide better passage for adults and juveniles.

Location: Water diversions where passage problems are evident.

Narrative description: Refer to Action 1. DFG and DWR should work with diverters to encourage them to reduce or stop diversions during critical times for salmonids (October through May). Diversion dams could be constructed later and disassembled earlier. The stock ponds could be filled in winter, allowing for an initial storm pulse to create contiguous flow for adult migrants in fall.

Predicted benefits: Any action to increase the amount of water in the river will have direct and immediate benefits to fish and likely help attain the restoration goal.

Action 3: Purchase existing water rights.

Objective: Ensure adequate instream flows for all life stages.

Location: Entire river where anadromous salmonids are found (RM 41 downstream).

Narrative description: Refer to Action 1. Purchasing existing water rights for fish is a possible means to maintain adequate flows. DFG should contact all water diverters to identify willing sellers. Water purchased farther upstream will likely provide more habitat if diverters below do not tap into it. Potentially, diverters downstream could be encouraged to request their full right while leaving excess in the stream. Subsequently, no new water appropriations should be allowed.

Predicted benefits: Any and all water that remains in the stream will have immediate benefits to fish. This action will lead to achieving the restoration goal.

Action 4: Evaluate diversion dams and barriers for passage problems.

Objective: Ensure adequate passage of adult and juvenile salmonids.

Location: Diversion within anadromous salmonid habitat (RM 41 downstream).

Narrative description: Small flashboard dams and some illegal dirt and gravel dams exist on the lower Cosumnes River. They do not appear to be major barriers to upstream migration; however, they may cause problems for downstream migration of young of the year. This needs to be examined. DFG should develop a prioritized list of problem barriers. Dams with severe problems should be noted so they can be dealt with immediately.

Predicted benefits: Identifying dams with passage problems will assist in developing means to remedy the situation. This will increase the amount of available spawning habitat and reduce loss of outmigrating juveniles.

Action 5: Remedy passage problems as identified in Action 4.

Objective: Ensure adequate passage of adult and juvenile salmonids.

Location: Dams identified as passage problems in Action 4.

Narrative description: Refer to Action 4. Potential means to resolve passage problems include dam removal, operational changes, and installation or modification of fish ladders. The feasibility of consolidating several smaller diversions into one should be investigated. DFG should work with DWR and water diverters to improve passage at these dams.

Additionally, approximately 41 RMs upstream of the mouth, there is a barrier to upstream migration. However, at extremely high flows, a secondary channel allows for possible upstream access. Attempts to eradicate this barrier have not been successful. According to a DFG report by Robert Reavis, the barrier was removed in 1947 or 1948. Salmon were able to migrate upstream of the old barrier and spawn for only a few years before the barrier re-formed. There is good spawning habitat for about 5 miles above this barrier.

Approximately 11 miles upstream of this barrier exists another barrier, impassible at all flows. The additional distance that would have to be traveled by the downstream migrants and the existence of approximately 15 miles of spawning gravel downstream of the barrier offset the value of removing it.

Predicted benefits: Providing adequate passage at dams and barriers will increase the amount of available salmonid habitat, which will likely increase production.

Action 6: Enforce Fish and Game Codes that prohibit construction of unlicensed dams.

Objective: Ensure adequate passage of adult and juvenile salmonids.

Location: Illegally constructed dams.

Narrative description: It is suspected that several diversion dams are constructed illegally. DFG should identify these dams and take action.

Predicted benefits: Eliminating these diversions will provide better fish passage and potentially keep more water in the river. Accomplishing this action will help attain the restoration goals.

Action 7: Effectively screen all diversions.

Objective: Prevent loss of juveniles to entrainment.

Location: All unscreened diversion in anadromous salmonid habitat (RM 41 downstream).

Narrative description: Most diversion on the Cosumnes River are unscreened and likely entrain juvenile salmonids. DFG should work with water diverters to effectively screen all diversions.

Predicted benefits: Effectively screening diversion will reduce fish loss to entrainment.

Action 8: Establish riparian corridor protection zone.

Objective: Preserve existing salmonid habitat from incompatible land use and moderate water temperature.

Location: Entire river.

Narrative description: DFG is developing a strategy that would establish a stream corridor protection zone. This would prevent incompatible land use from occurring near stream margins. This concept should be supported by all public resource agencies and applied to future developments. The county planning commission should be made aware of this.

Predicted benefits: Establishing a riparian corridor protection zone will prevent incompatible land use from effecting the current salmonid habitat.

Action 9: Rehabilitate damaged areas.

Objective: Remedy incompatible land use practices that have increased sedimentation of the river and elevate water temperature.

Location: Entire river.

Narrative description: The section of the Cosumnes River with the best spawning gravel is also characterized by extensive stretches of willow/cottonwood corridors that provide decent stream bank stabilization and prevent rapid warming of the river. However, some reaches have been denuded of the riparian corridor, causing warming trends and siltation and pollution of the water, in addition to reducing streamside vegetation. Incompatible land use practices have an effect on salmonid habitat and needed to be remedied. Recommendations include fencing and providing off-stream watering for cattle, and either revegetating the denuded sections or leaving them fenced to recover naturally. DFG should pursue rehabilitation efforts.

Predicted benefits: Rehabilitating areas of high erosion will provide better spawning substrate due to reduced sedimentation of the gravel.

Calaveras River -

Limiting factors and potential solutions -

Instream flows - Insufficient instream flow currently limits anadromous fish production in the Calaveras River, especially in dry years. Release schedules are not uniform and the system is over allocated. No dedicated fishery flows or minimum instream flow exists.

Attraction flows at the confluence of the San Joaquin River can be insufficient to move chinook salmon into the Calaveras River (Richardson 1993). Flows in late February and March must be sufficient to allow upstream migrants to swim past Bellota Weir into the spawning areas. Sustained flows between New Hogan Dam and Bellota are required for the spawning grounds. If flows are cut off too early in the season, redds will be dewatered. Incubation is generally from about April through September (for winter-run salmon; Vogel and Marine 1991) and flows in the Calaveras River typically begin to fall off in September. During the recent drought years, flows have been very low even in the spawning ground area that is above most of the diversions. Juveniles are likely moving out of river with the flows in March and April, rather than during the fall. Juveniles may overwinter because of insufficient flow to move them seaward (USFWS 1993).

Water temperature - Water temperature problems are directly linked to New Hogan Dam release schedules (USFWS 1993). Maximum temperatures can climb above the physiological tolerance of chinook salmon during dry years, hot summers, or low flows (S. Schoenberg pers. comm.). Temperatures must also be sufficiently low to attract fish into the Calaveras River; pre-spawning chinook salmon require temperatures between 41°F and 60°F (Vogel and Marine 1991).

Migration barriers - The dam at Bellota discourages passage at certain water levels (DFG 1982). Various check dams that can block migrations exist on both Morman Slough and the Calaveras River (DFG 1993).

Diversions- Most existing diversions are not screened or are inadequately screened (DFG 1993). Nearly all water in the river is diverted, especially during some seasons. The Stockton diverting canal removes water before the river empties into the San Joaquin River. Delta diversions from both the CVP and the SWP affect migrations between the Calaveras River and the Pacific Ocean.

Bank and streambed modification - Reductions in streamflow will have decreased the salmonid food base productivity compared to production with no dewatering of insect habitat (Gislason 1985). Reductions in streamflow tend to alter the streambank by facilitating riparian encroachment. This has occurred on the old channel of the Calaveras River, but this area is downstream of the spawning, incubating, and rearing area.

At the present time, flows are so limiting that bank and streambed modification are considered minor limiting factors and therefore are not further discussed under "Options for Restoration." These factors may become more important once enhanced instream flows encourage increased salmonid production.

Angling - Yearling chinook salmon have been taken by anglers. Chinook salmon poaching has been reported, and at times there has been heavy fishing pressure on rainbow trout (DFG 1984). Most of the spawning ground area is not easily accessible to anglers. Any efforts to enhance chinook salmon production will also enhance rainbow trout production, thereby increasing angler pressure. For these reasons, angling pressure could become a problem once salmonid production is increased.

Table 3-Xc-14. Limiting factors and potential solutions for Calaveras River chinook salmon.

Limiting factors	Potential solutions
Insufficient instream flows	1. Protect and increase instream flows 2. Further refine instream flow needs 3. Monitor fish production as a function of increased flows
Warmwater temperature	1. Protect and increase instream flows 2. Establish a minimum pool size at New Hogan Reservoir
Migration barriers	1. Remove temporary irrigation dams in the Calaveras River, Morman Slough, and Stockton Diverting Canal that block migration 2. Install fish passage facilities at Bellota Weir, Clements Dam, and Cherryland Dam 3. Monitor the effectiveness of fish passage facilities and alter as necessary
Entrainment at diversions	1. Identify screening needs and install screens as needed 2. Restrict further water diversions

Limiting factors	Potential solutions
Angling	1. Monitor rainbow trout fishery and change regulations to protect winter-run chinook salmon if this becomes necessary 2. Monitor for poaching

Restoration actions -

Action 1: Establish and protect adequate instream flows.

Objective: Protect winter-run chinook salmon (all life stages) and other salmonids.

Location: Instream flow protection needed from New Hogan Dam to Bellota for spawning and incubation; attraction and passage flows require protection to tidewater.

Narrative description: Protection of instream flows in the Calaveras River could be accomplished as follows:

- Establish minimum instream flow objectives to protect winter-run chinook salmon (spawning, rearing, and migration) (USFWS 1993).
- Complete a more thorough study to further refine instream flow needs (DFG 1993).
- Monitor fish production as a function of increased flows (Hunter 1991).

USFWS (1993) completed a preliminary instream flow study that clearly outlined the need for more instream flow than currently is allocated to the river. Recommendations based on this work are shown in Table 3-Xc-15. Estimated flow requirements for winter-run chinook salmon vary between 50 and 225 cfs, depending on year type and time of year. Provision of these estimated flow requirements would provide necessary attraction, spawning ground, rearing, and outmigration flows.

Table 3-Xc-15. Instream flow regimes recommended to facilitate doubling production of winter-run chinook salmon in the Calaveras River for each of three water-year types.

Month	Flows (cfs) for three year types[a,b]		
	Wet	Normal	Dry
February 19-29	225[c]	70	50
March 1-20	225[c]	225[c]	225[c]
March 21-30	225[c]	225[c]	120[d]
March 31-September 15	200[d]	160[d]	120[d]
September 16-October 31	100[e]	100[e]	100[e]
November 1-February 18	70[f]	70[f]	50[f]

[a] No current agreement exists to maintain releases for fisheries purposes.

[b] Flow recommendations modified from USFWS (1993). Flows for spawning and incubation, rearing, and temperature control are needed only to Bellota because most fish remain above where most diversions occur. However, 50 to 70 cfs left instream to tidewater would help maintain the overall health of the river system.

[c] Flows of 225 cfs are needed for attraction and passage of adults and smolts. Flows based on past recommendations by DFG. Estimates include yearling outmigration. Flows are required to mouth of San Joaquin River.

[d] Flows needed for spawning and incubation. Flows based on preliminary instream flow measurements (few transects and flows evaluated). Estimates for winter- and fall-run chinook salmon were made using habitat criteria for fall-run chinook salmon on the Stanislaus, Yuba, and American rivers. Spawning, incubation, and rearing flows for wet, normal, and dry years are those flows that yielded 100%, 80%, and 60% of the optimal WUA of physical habitat.

[e] Flows needed for juvenile rearing, including temperature protection.

[f] Flows needed for juvenile rearing.

The Calaveras River system is already over allocated, and therefore retaining water instream for salmonids may reduce water available for offstream uses. For this reason, it may eventually be necessary to more precisely determine instream flow needs by conducting a complete instream flow study. Also, as the instream flow needs are met, other limiting factors may become more important and the study could help identify these.

Finally, it is important to check that actions are working as expected. The number of salmonids passing Bellota Weir could be counted, or spawning surveys could be done, to confirm that instream flow augmentation is benefiting salmonid production. Monitoring should continue for 5-10 years (Hunter 1991).

Related actions that may impede or augment the action: Efforts to manage water temperatures for salmonids (Action 2) will need to be coordinated with this action. Efforts to enhance salmonid production in the Calaveras River should be coordinated with the "Stanislaus River Basin and Calaveras River Water Use Program" (DWR and USBR 1991). Actions as a result of this planning process could affect salmon production within the Calaveras River. Calaveras County and Stockton East Water Districts are investigating various water transfer projects that could (positively or negatively) affect Calaveras River instream flows (S. Schoenberg pers. comm.).

Agency and organization roles and responsibilities: Securing the adequate flows in the Calaveras River will require significant effort on the part of state and federal agencies. New Hogan Dam is operated by the Corps, and USBR contracts water to the state of California. These two agencies have the potential to manage water so that enhanced salmon production in this stream is possible. In addition, stream flow needs could be addressed through the SWRCB. Stockton East Water District would need to be involved in negotiations, as well as the City of Stockton, the Calaveras County Water District, DWR, USFWS, DFG, and other interested parties.

Potential obstacles to implementation: Substantial negotiation efforts would need to take place because the water in the system is already over allocated and, simultaneously, there are significant increases in demand for water because of residential development. Negotiations should stress flexibility in operation of New Hogan Reservoir. For example, operation schedules for New Hogan Dam could incorporate options to enhance salmonid production, including trout. The release schedule now used for agriculture is compatible with winter-run salmon (but not fall-run salmon) and this point should be stressed. Diversions occur mainly downstream of spawning and rearing areas, and thus some of the water requested for fish is still available for other uses downstream. However, attraction flows, which are seasonal, represent increased releases over those now made.

Predicted benefits: Flow protection is critical to chinook salmon for migration, spawning, rearing, aquatic food base production, and maintenance of coldwater temperatures. Chinook salmon production is very low and this measure, in combination with the other measures, will likely increase production at least to levels previously observed (a run size of 400-1,000 chinook salmon). These measures will contribute to the doubling goal, though there are insufficient data to state that the population will be doubled.

These flows have a high probability of increasing winter-run salmon production for the following reasons. First, there were approximately 400 spawning salmon prior to the recent prolonged drought period. In 1993, when flows were higher than during the drought period, some chinook salmon were seen around Morman Slough and the Stockton Diverting Canal (S. Schoenberg pers. comm.), suggesting that when water is present, fish will use the Calaveras River. Second, physical habitat conditions are adequate for salmon spawning and rearing (DFG 1993). For example, there is sufficient gravel of the correct size to support spawning and the existing riparian canopy is adequate (USFWS 1993). Third, the migration distance is short, reducing the number of obstacles that the fish must negotiate. Finally, New Hogan Reservoir is large relative to the size of the Calaveras River and therefore has the potential to provide cold water throughout the year (USFWS 1993). These factors combined suggest that a winter-run salmon population could be supported in the Calaveras River with the provision of sufficient flows. DFG (1993) ranks the Calaveras River as "C1" priority (i.e., restoration action benefits small populations of anadromous species and has significant long-term or permanent benefits).

Action 2: Manage water temperatures for all salmonid life stages, including spawning, incubation, rearing, juvenile outmigration, and adult migration.

Objective: Provide suitable water temperatures for salmonid survival.

Location: New Hogan Dam to Bellota, and to the San Joaquin during fish passage.

Narrative description: Water temperatures in the Calaveras River are closely associated with instream flows, reservoir release schedules, and New Hogan pool size (USFWS 1993). Temperatures climb above the physiological tolerance of chinook salmon, causing stress, migration delays, or death. Temperatures must be sufficiently low to attract fish into the Calaveras River. Required temperatures for chinook salmon are as follows (Vogel and Marine 1991):

- Pre-spawning: 5-15°C (42-60°F)
- Incubation: 5-14°C (41-60°F)
- Rearing: 6-18°C (43-64°F)

Water temperature protection could be achieved through a combination of flow protection and determination of minimum pool size at New Hogan Reservoir (USFWS 1993). Methods to establish flow protection were discussed previously. Initial minimum pool size could be determined according to the USFWS (1993) study, followed by further effort to identify the most appropriate pool size for temperature protection. For example, temperature modeling could be completed as a part of the instream flow study discussed previously.

The best available data suggest that temperatures could be kept cool enough for chinook salmon production with a release schedule as described in Table 3-Xa-1 and a minimum New Hogan pool size of 85,000 af (USFWS 1993).

Related actions that may impede or augment the action: Efforts to establish and protect adequate instream flows (Action 1) should consider and contribute to management of water temperatures.

Agency and organization roles and responsibilities: Representatives from the Corps, USBR, USFWS, DFG, Stockton East Water District, the City of Stockton, the Calaveras County Water District, DWR, and other interested parties may wish to be involved in determining a minimum pool size at New Hogan that will ensure low enough temperatures for chinook salmon production.

Potential obstacles to implementation: See potential obstacles discussed for Action 1.

Predicted benefits: Temperature protection, which is related to flow, will ensure that water temperatures do not exceed physiological tolerances of chinook salmon. In combination with flow and migration protection, this measure will increase chinook salmon production in the Calaveras River as discussed under instream flows.

Action 3: Remove migration barriers affecting salmonids.

Objective: Improve upstream and downstream migration.

Location: Bellota Weir to San Joaquin River (including Morman Slough).

Narrative description: Three specific parts to this action will ensure better upstream passage. First, remove temporary irrigation dams in the Calaveras River, Morman Slough, and Stockton Diverting Canal that partially or totally block migration (DFG 1993). Second, install fish passage facilities at Bellota Weir, Clements Dam, and Cherryland Dam (USFWS 1993, DFG 1993). Third, monitor the effectiveness of any fish passage facilities installed to ensure that the anticipated result was achieved (Hunter 1991).

These barriers definitely block upstream migrants, but may also be influencing downstream migration. Bellota Weir is removed between October 11 and March 30 (USFWS 1993); however, late-arriving fish are still blocked.

Related actions that may impede or augment the action: Provision of adequate instream flows, especially fish passage flows, should contribute to improved upstream and downstream migration.

Agency and organization roles and responsibilities: Stockton East Water District, USFWS, DFG, and other affected parties could be involved in determination of options for solving migration barrier problems at Bellota Weir, Clements Dam, Cherryland Dam, and temporary dams.

Potential obstacles to implementation: Fish passage facilities can be expensive to install and irrigators may object to removing temporary dams for fish passage if this reduces their water supply. These issues will need to be negotiated with affected parties for the best long-term result. Affected parties could seek solutions that allow fish migration and support existing water diversions.

Predicted benefits: Chinook salmon must be able to migrate upstream to the spawning grounds above Bellota; if they are blocked from this area, no production will occur even with adequate flows and water temperatures. Therefore, in combination with flow and temperature protection, this measure will increase chinook salmon production in the Calaveras River as discussed under instream flows.

Action 4: Evaluate screening needs and install screens as needed on existing diversions that may affect juvenile outmigrants (USFWS 1993).

Objective: Protect outmigrants.

Location: New Hogan Dam to San Joaquin River.

Narrative description: Many of the agricultural diversions are not screened or are inadequately screened. Nearly all water in the river is diverted, especially during the crop-growing season. Each of these diversions needs to be evaluated, and those that are likely causing salmonid mortality or delay should be properly screened. Screen effectiveness should be monitored to ensure that the screens are working successfully and as anticipated.

Outmigrants and all salmonid life stages would be better protected by restricting further water diversions for offstream uses. At a minimum, adequate instream flow protection could be required if diversions are from other basins.

Related actions that may impede or augment the action: Efforts to enhance salmonid production in the Calaveras River should increase the need to screen diversions.

Agency and organization roles and responsibilities: Individual irrigators, USFWS, DFG, Stockton East Water District, and other interested parties could be welcomed to negotiations on options for correcting screening problems, potential screening benefits, and cost of implementation.

Potential obstacles to implementation: The determination of screening needs, followed by screen placement, maintenance, and monitoring, will be costly.

Predicted benefits: Compared to the first three restoration actions, this action is less important. However, when production is improved through flow, temperature, and migration protection, loss of juveniles through unscreened diversions could become important. Ensuring that new water developments include instream flow protection or flow enhancements will reduce the chance of further stressing the stream.

Action 5: Monitor sport fishing and regulations.

Objective: Protect chinook salmon and other salmonids.

Location: New Hogan Dam to Bellota.

Narrative description: Before the prolonged drought a rainbow trout fishery existed below New Hogan Dam (DFG 1987). This fishery will need to be monitored closely once efforts are undertaken to enhance chinook salmon production because these efforts will also increase trout production. If angler pressure increases, new regulations may have to be considered to protect winter-run chinook salmon, which could be taken as yearlings.

Related actions that may impede or augment the action: Efforts to enhance salmonid production in the Calaveras River could increase the need to monitor sport fishing.

Agency and organization roles and responsibilities: DFG would probably need to coordinate this action. Local sportfishing groups might want to be involved.

Potential obstacles to implementation: Local fishing groups may protest if not involved initially.

Predicted benefits: Of the recommended options for restoration, this is the least important factor. However, when salmonid production is improved through flow, temperature, and migration protection, losses attributable to angling and poaching could become important.

D. SAN JOAQUIN BASIN

Development of Flow Recommendations

Vernalis flow -

Regression model - The equation relating escapement of chinook salmon to April-June flow and exports during the year of outmigration was derived by Dr. Carl Mesick of Carl Mesick Consultants, using data supplied by DFG, DWR, and USGS (CMC 1994).

DFG has previously presented regression equations describing the relationship between adult escapement into the Stanislaus and Tuolumne rivers and San Joaquin Basin outflow at the time of outmigration (DFG 1992, 1993). Dr. Mesick's analyses differ from DFG's in three important respects: 1) Dr. Mesick's analyses separated 2- and 3-year-old salmon according to the year when they were juveniles outmigrating through the Delta[1]; 2) the data used covered a longer period of time (1951-1993); and 3) in addition to San Joaquin Basin outflow, individual and combined effects of spawning stock numbers, ocean harvest, El Niño, Delta water quality, and total Delta exports were evaluated.

Escapement was best predicted by a model based on the ratio of Vernalis flow (Q_V) to maximum monthly exports at the SWP and CVP pumping facilities ($X_{F,S}$) from April-June (adj-R^2=0.76, p=0.000) and by a model incorporating April-June Vernalis flow and April-June maximum monthly exports as separate terms (adj-R^2=0.68, p_1= 0.000, p_2 = 0.014). Spawning stock numbers, ocean harvest, El Niño conditions, and fall water quality were discarded because their relative contributions to prediction of escapement proved to be insignificant.

Selection of regression model - In developing Vernalis flow recommendations for the purposes of the AFRP, the model relying on the Q_V:$X_{F,S}$ ratio was rejected in favor of the model incorporating Q_V and $X_{F,S}$ as separate terms in the equation. Although the ratio model accounts for a slightly greater portion of

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[1]DFG regressed spring flow at Vernalis on escapement 2 years later; for each year escapement estimates were based on 3-year-old salmon, which were juveniles 2 years earlier, and 2-year-old salmon, which were juveniles 1 year earlier. Therefore, in the DFG regression, the portion of escapement composed of 2-year-old fish was not influenced by spring flow at Vernalis 2 years earlier.

the total variance associated with escapement, it has disadvantages associated with its greater potential for selecting flow and export combinations outside the range of observed conditions. For example, while a Q_V:$X_{F,S}$ ratio of 10 could be achieved by setting Q_V=100 and $X_{F,S}$=10 or by setting Q_V=10,000 and $X_{F,S}$=1000, it is unlikely that both scenarios would provide equal benefits for salmon.

Development of April-June Vernalis flow and export recommendations - The initial assumption was that doubling average baseline-period production (as indicated by escapement) of chinook salmon would require conditions that were better than those that occurred during the baseline period. With this in mind, $X_{F,S}$ was set to equal 200 taf/month (3,360 cfs), which is equivalent to about 50% of the mean export rate during the baseline period. Two hundred taf/month is the average value for $X_{F,S}$ over the five San Joaquin Basin water year types. $X_{F,S}$ was adjusted for each year type to reflect by year type distribution of total unimpaired runoff during the period of record (1922-1990) (Table 3-Xd-1). Thus $X_{F,S}$ would exceed 200 taf/mo in above-normal and wet years, but would be lower than 200 taf/mo in below-normal, dry, and critical years.

Table 3-Xd-1. Allocation of total combined Delta exports (CVP and SWP) by percent occurrence of total unimpaired runoff (1922-1990).

Year type	Percent of total unimpaired runoff (1922-1990)	Total monthly exports for 5 years		Maximum monthly exports	
Critical	0.09	x	(200 x 5)	=	90
Dry	0.13	x	(200 x 5)	=	130
Below normal	0.19	x	(200 x 5)	=	190
Above normal	0.23	x	(200 x 5)	=	230
Wet	0.35	x	(200 x 5)	=	350

When $X_{F,S}$ = 200 taf/month, the regression model indicates that a Q_V of 9,000 cfs is required to double escapement of chinook salmon into the Stanislaus and Tuolumne rivers. As with exports, total Q_V was adjusted for year type to reflect percent distribution of total unimpaired runoff between year types during the period of record (1922-1990) (Table 3-Xd-2).

Table 3-Xd-2. Allocation of San Joaquin River flow at Vernalis based on percent occurrence of total unimpaired runoff (1922-1990).

Year type	Percent of total unimpaired runoff (1922-1990)	Total monthly flow for 5 years		Mean monthly flow	
Critical	0.09	x	(9,000 x 5)	=	4,050
Dry	0.13	x	(9,000 x 5)	=	5,850

Year type	Percent of total unimpaired runoff (1922-1990)		Total monthly flow for 5 years		Mean monthly flow
Below normal	0.19	x	(9,000 x 5)	=	8,550
Above normal	0.23	x	(9,000 x 5)	=	10,350
Wet	0.35	x	(9,000 x 5)	=	15,750

Assuming that year types occur with equal frequency, the regression model predicts that implementing these standards would double the average baseline period escapement into the Tuolumne and Stanislaus rivers. Application of weighting factors to account for differences in year type frequency will be considered as a possible future refinement.

Another key assumption is that the unimpaired hydrograph (1922-1990) generally provides the best indication of the optimum timing of flow for chinook salmon. On the basis of this assumption, Vernalis flow was allocated between April, May, and June to reflect the pattern exhibited by unimpaired runoff. For example, on the average, distribution of total April-June unimpaired runoff during wet years was 25%, 39%, and 36% for April, May, and June, respectively. Thus, based on the wet-year flow value in Table 3-Xd-2, recommendations would be (0.25 X [3 X 15,570]) = 11,677 cfs in April, (0.39 X [3 X 15,570]) = 18,217 cfs in May, and (0.36 X [3 X 15,570]) = 16,816 cfs in June.

Tributary flow recommendations -

Tributary flow recommendations were developed using estimated flow needs at Vernalis, unimpaired runoff from 1922 through 1990, and findings of previous IFIM studies. The following assumptions were applied:

1) In a given water year, flow at Vernalis is an index of conditions upstream in the tributaries and upstream in the San Joaquin River.

2) In a given month, unimpaired conditions represent the optimum distribution of total San Joaquin Basin outflow between the tributaries and the mainstem river.

3) Within a given water year, flow during April, May, and June is an index of flow during the other months of the year.

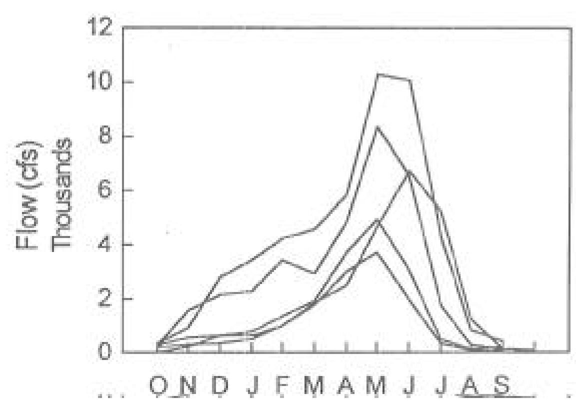
4) In a given water-year type, within each tributary and the mainstem, the unimpaired hydrograph represents optimum distribution of flow between months.

5) An exception to 4 applies to the tributaries during late summer and fall. Unimpaired flows in the reaches that are currently accessible to salmon were often extremely low prior to and

during spawning. Because access to upstream habitat has been prevented by the dams, higher than unimpaired flows are needed in most years to provide suitable conditions for spawning and incubation.

6) Flow should not be reduced between the onset of spawning and peak outmigration. Except during years when flows greater than unimpaired flows are released for spawning, this follows from assumption 3 above.

7) Although the regression model was based on combined escapement into the Stanislaus and Tuolumne rivers, the flows generated by the model were considered to be an index of conditions in the Merced River. Thus, Merced River flows were derived in the same manner as flows for the Stanislaus and Tuolumne rivers.



For April, May, and June, tributary and upper mainstem river flows were developed by allocating total basin outflow (Vernalis flow) on the basis of mean, historic contribution to unimpaired runoff by year. Using the example for a wet year above, percent contributions to flow were 19% for the Stanislaus River, 28% for the Tuolumne River, 16% for the Merced River, and 38% for the mainstem San Joaquin River. Thus, the May flow recommendations would be 3,461 cfs, 5,101 cfs, 2,915 cfs, and 6,922 cfs for the Stanislaus River, the Tuolumne River, the Merced River, and the mainstem San Joaquin River (at Stevinson), respectively.

Within each year type, flows for October-March and July-September were developed using their proportional relationship to April-July flow under mean unimpaired conditions. On the average, for 1922-1990, wet-year flows in the Stanislaus River are distributed as follows: October - 1%, November - 2%, December - 6%, January - 8%, February - 10%, March - 11%, April - 14%, May - 24%, June - 18%, July - 6%, August - 1%, and September - 1%. Returning to the original example, if AFRP \-generated wet-year flows for the Stanislaus River in April, May, and June are 1,985 cfs, 3,461 cfs, and 2,522 cfs, respectively. In an average wet year, 56% of the total annual unimpaired outflow for the Stanislaus River occurs during April-June. Flows for other months were obtained through multiplication of the percentage of the total annual flow occurring in each month by (1,985 + 3,461 + 2,522)/0.56. Flows developed using this approach generally range from 30% to 50% of those that would have occurred under unimpaired conditions.

Under unimpaired conditions, late summer and fall flows in the lower reaches of the Stanislaus, Tuolumne, and Merced rivers were probably insufficient to support chinook salmon spawning and over-summer rearing. Prior to the construction of dams, a large percentage of all spawning and rearing probably occurred upstream of the reaches that are currently accessible. Because flow recommendations developed by allocating Vernalis flow range from 30% to 50% of unimpaired flows, they cannot be expected to provide adequate conditions for spawning and rearing in the lower reaches of the rivers during dryer year types. To compensate for this deficiency, the July-December tributary flows extrapolated from the $Q_V/X_{F,S}$ regression model were replaced with IFIM flows in cases in which the IFIM flows were higher. All values were subsequently adjusted to ensure that no reductions in flow occurred between the onset of spawning in October and peak outflow, which generally occurred in May.

Merced River

Limiting factors and potential solutions -

Table 3-Xd-3. Limiting factors and potential solutions for San Joaquin Basin fall-run chinook salmon in the Merced River.

Limiting factors	Potential solutions
1. Timing and magnitude of low are inadequate to provide conditions required for adult migration, spawning, incubation, rearing, and juvenile outmigration	Implement a flow schedule that will provide suitable conditions for all life stages of chinook salmon
2. Water temperature problems: (a) Elevated fall water temperatures delay adult migration and spawning, which may result in delayed out-migration and reduced survival of juveniles (b) Elevated spring water temperatures reduce survival of juvenile outmigrants	1. Manage New Exchequer Dam, McSwain Dam, and Crocker-Huffman Diversion to reduce temperature of water discharged to the Merced River during fall 2. Modify timing and magnitude of flow 3. Restore bank and riparian vegetation
3. Egg mortality, redd dewatering, and juvenile stranding resulting from peaking power operation of hydroelectric facilities and rapid changes in reservoir discharge for other purposes	1. Prevent redd dewatering by prohibiting flow reduction from the completion of spawning through emergence 2. Reduce stranding by establishing suitable ramping rates 3. Evaluate benefits and impacts of redirecting flows released to meet peaking power demands into the canal system 4. Reduce egg mortality resulting from substrate mobilization by reducing the magnitude of peaking

Limiting factors	Potential solutions
	power fluctuations. 5. Re-regulate or stabilize flow fluctuations using Crocker-Huffman Dam.
4. Past and ongoing alteration of stream, riparian, and floodplain habitat	1. Provide funding to increase enforcement of state and federal laws pertaining to stream channel alteration 2. Increase public awareness; provide incentives for reporting violations 3. Provide funding for stream habitat restoration projects
5. Sedimentation of remaining spawning gravel	1. Facilitate transport of fine sediments by restoring the balance between river channel configuration and flow regime 2. Mechanically clean spawning gravels that have been degraded as a result of sedimentation 3. Construct retention basins and support land use practices that reduce sediment input.
6. Lack of spawning gravel recruitment	1. Increase spawning gravel recruitment from banks and floodplain by reestablishing river/floodplain hydrology and dynamics 2. Replenish spawning gravel from outside sources
7. Reduction in overall quantity of accessible spawning and rearing habitat resulting from obstruction of migration by dams	Determine feasibility of modifying major dams to reestablish adult chinook salmon access to upstream habitat and provide safe passage for outmigrating juvenile salmon
8. Entrainment of juvenile chinook salmon at six	1. Provide other water sources and eliminate diversions

Limiting factors	Potential solutions
medium-sized diversions and 68 small pumps	2. Screen or otherwise modify pumps and diversions to prevent entrainment of juvenile chinook salmon
9. Predation on rearing and outmigrating juvenile chinook salmon	1. Increase harvest limits on predator species and/or enlist anglers to implement a concerted predator reduction program 2. Eliminate or isolate predator habitat
10. Poor water quality resulting from point and nonpoint discharge of pollutants and toxic compounds	1. Provide funding to increase enforcement of state laws pertaining point- and nonpoint-source pollution 2. Strengthen existing water quality standards to provide protection for chinook salmon as needed 3. Increase public awareness; provide incentives for reporting violations 4. Manage reservoirs to provide sufficient flow to dilute existing pollutant and toxic chemical loading
11. Straying of adult chinook salmon into the mainstem San Joaquin River upstream of the Merced River confluence and into Salt and Mud Sloughs	1. Continue to install a fall barrier in the San Joaquin River upstream of the Merced River confluence 2. Provide adequate attraction flows in the Merced River
12. Illegal harvest of adult chinook salmon	1. Provide additional law enforcement from Crocker-Huffman Diversion downstream to the confluence with the San Joaquin River during times when adult salmon are in the river 2. Increase incentives for reporting violations

Restoration actions -

Action 1: Modify existing flow schedule (Table 3-Xd-4).

Objective: Manage flows to benefit all life stages of chinook salmon.

Location: Merced River from Crocker-Huffman Diversion downstream to the confluence with the San Joaquin River.

Narrative description: New Exchequer Dam impounds Lake McClure, the largest reservoir (1.0-maf capacity) in the Merced River Basin; Crocker-Huffman Diversion is the barrier for upstream migration of salmon (Reynolds et al. 1993).

Existing flow requirements for the lower Merced River are from two sources: a Davis-Grunsky Contract, which requires Merced Irrigation District to maintain a continuous flow of 180-220 cfs from November 1 to April 1 in the reach from Crocker-Huffman Diversion to Shaffer Bridge; and FERC license no. 2179 for flow measured at Shaffer Bridge (Reynolds et al. 1993).

Current reservoir releases are insufficient to accommodate chinook salmon migration, spawning, egg incubation, juvenile rearing, and smolt emigration (Reynolds et al. 1993). Summer flows of 15-25 cfs are usually depleted by riparian diversions before reaching the river mouth, allowing water temperatures to exceed acceptable criteria for salmon (Reynolds et al. 1993). Additionally, water temperatures are often too high during adult migration and spawning in fall and during juvenile rearing and outmigration in spring.

A revised flow schedule for the lower Merced River has been formulated by DFG based on results of the Stanislaus River instream flow study and smolt survival data from the other San Joaquin River tributaries (Reynolds et al. 1993); although this schedule represents an improvement over existing conditions, it is not believed to be optimum or even adequate to meet the needs of all life stages of chinook salmon. Although further revision is planned by DFG following completion of instream flow and outmigration studies and water temperature modeling (Reynolds et al. 1993), the San Joaquin Basin Technical Team has recommended a flow schedule that it believes will achieve the goals of the Anadromous Fish Restoration Program (AFRP).

Table 3-Xd-4. Existing and AFRP-generated flow (cfs) schedules, Merced River, Crocker-Huffman Diversion to San Joaquin River confluence by year type.

Month	Existing [a]		AFRP[b]				
	Wet/ Normal	Dry	Wet	Above Normal	Below Normal	Dry	Critical
October	50	15-60	350[c]	300[c]	300[c]	250[c]	250[c]
November	180-200	180-200	350[c]	350[c]	300[c]	300[c]	250[c]
December	180-200	180-200	600[e]	550[e]	300[c]	300[c]	250[c]

Month	Existing [a]		AFRP[b]				
	Wet/ Normal	Dry	Wet	Above Normal	Below Normal	Dry	Critical
January	180-200	180-200	1,100[e]	600[e]	300[c]	300[d]	250[d]
February	180-200	180-200	1,450[e]	1,050[e]	500[d]	300[d]	250[d]
March	180-200	180-200	1,500[e]	1,050[e]	600[d]	450[d]	400[d]
April	75	60	1,800[f]	1,350[f]	1,150[f]	950[f]	750[f]
May	75	60	2,950[f]	2,300[f]	1,750[f]	1,200[f]	850[f]
June	25	15	2,850[f]	1,450[f]	1,150[f]	650[f]	450[f]
July	25	15	1,150[g]	400[g]	250[h]	200[h]	200[h]
August	25	15	350[h]	300[h]	250[h]	200[h]	200[h]
September	25	15	350[h]	300[h]	250[h]	200[h]	200[h]
Total (taf)	66-80	72-84	894	604	429	321	260
Baseline (taf)	NA	NA	1,449	1,043	647	799	499
Unimpaired (taf)	NA	NA	1,605	1,069	718	512	364

Note: All flows have been rounded to the nearest 50 cfs.

[a] Existing flows stipulated in 1967 Davis-Grunsky Contract (Reynolds et al. 1993) and FERC license agreement.

[b] Water-year type for existing flow schedules based on Lake McClure storage and inflow; water-year type for proposed flow schedules based on San Joaquin Basin 60-20-20 Index.

[c] Flow based on IFIM spawning flow recommendations for similar-size drainages (Reynolds et al. 1993) and the assumption that flows greater than historical flows are needed to compensate for elimination of access to upstream habitat.

[d] Based on IFIM flow recommendations for similar-size drainages and the assumption that, to prevent redd dewatering or stranding of rearing juveniles, flow should not be reduced between spawning and outmigration.

[e] Based on historical (1922-1990) percent monthly distribution of total annual unimpaired runoff for the Merced River Basin and the assumption that, to prevent redd dewatering or stranding of rearing juveniles, flow should not be reduced between spawning and outmigration.

[f] Based on Vernalis flow requirement and historical (1922-1990) percent monthly contribution to total annual unimpaired runoff.

[g] Based on historical (1922-1990) percent monthly contribution to total annual unimpaired runoff.

[h] Flow based on IFIM flow recommendations for similar-size drainages (Reynolds et al. 1993) and the assumption that flows greater than historical flows are needed to compensate for elimination of access to upstream habitat.

Related actions: Existing Davis-Grunsky and FERC flow agreements. Vernalis flow recommendations. Section 3408(h), purchase of land and water from willing sellers.

Agency and organization roles and responsibilities: If the proposed flow recommendations were to be implemented, Merced Irrigation District, which operates New Exchequer and McSwain dams, would be responsible for providing flows to meet the AFRP flow schedule. USFWS and DFG would be responsible for monitoring and adjusting flow recommendations to ensure maximum benefits for chinook salmon.

Potential obstacles to implementation: Flows currently required or recommended are considerably lower than flows believed necessary to double natural production of chinook salmon in the Merced River. Because Lake McClure and Lake McSwain are not CVP impoundments, meeting technical team recommendations would require cooperation with water agencies and water right holders and acquisition of water from willing sellers.

Projected benefits: The San Joaquin Basin Technical Team believes that implementation of this flow schedule, in concert with other recommended actions, would double production of fall-run chinook salmon in the Merced River.

Action 2: Adjust reservoir operations and releases to meet chinook salmon temperature requirements.

Objective: Maintain water temperature within ranges suitable for chinook salmon spawning, incubation, rearing, and outmigration.

Location: Merced River from Crocker-Huffman Diversion downstream to the confluence with the San Joaquin River.

Narrative description: Insufficient flows allow water temperatures to exceed acceptable levels for salmon. Other factors contributing to higher water temperatures include a degraded riparian corridor and gravel capture pits. Water temperatures are often too high during adult migration in fall and during juvenile rearing and smolt outmigration in spring. High temperatures are thought to delay migration and spawning (DFG 1992), reduce egg survival, and increase mortality of rearing and outmigrating juveniles (Reynolds et al. 1993). The following water temperatures should be maintained to the downstream boundary of the spawning area during fall and to the mouth of the river during spring.

Dates	Water temperature
October 15 - February 15	56°F
April 1 - June 31	65°F

Related actions: Flow recommendations and stream habitat restoration. Section 3408(h), purchase of land and water from willing sellers.

Agency and organization roles and responsibilities: If this action is implemented, Merced Irrigation District would be responsible for operating New Exchequer Dam and Lake McClure to meet temperature standards. USFWS and DFG would be responsible for monitoring and adjusting flow recommendations to ensure maximum benefits for chinook salmon.

Potential obstacles to implementation: Maintaining adequate temperatures may require flows higher than those specified under Action 1. Increasing the proportion of water allocated to meeting fish needs would reduce water available to meet needs of other user groups. Therefore, implementation would require purchase of additional water. Maintaining water temperature of 65°F during June may not be possible.

Projected benefits: The San Joaquin Basin Technical Team believes that meeting these prescribed temperature standards, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the Merced River.

Action 3: Reduce impacts of rapid flow fluctuations.

Objective: Increase hatching success and juvenile survival by reducing ramping rates and eliminating flow fluctuation during key periods.

Location: Merced River from Crocker-Huffman Diversion downstream to the San Joaquin River confluence.

Narrative description: Potential adverse impacts of rapid flow fluctuations resulting from peaking power operation and short-duration reservoir releases for other purposes may disrupt adult salmon migration and spawning, scour or dewater redds, mobilize spawning gravel and kill eggs during incubation, and affect emerging salmon fry by stranding, downstream displacement, and exposure to predation (Reynolds et al. 1993). The potential for adverse impacts is especially great during January and February, when fry are abundant and rely on passive dispersal to reach suitable habitat (Reynolds et al. 1993). Stranding of juvenile salmon following rapid changes in discharge has been documented at several sites along the lower Merced River and may be a principal factor affecting salmon survival in years when power peaking occurs (Reynolds et al. 1993).

The window of vulnerability for adverse impacts of rapid flow fluctuation corresponds to the period when juvenile fish are present in the river, essentially from the onset of spawning in October through outmigration in late May or early June. The team recommends establishing periods when flow fluctuation is prohibited or incorporating standards for ramping rates that will prevent premature downstream transport and stranding. Peaking power operation has the potential to be used as a tool to stimulate outmigration if ramping rates are maintained within a range suitable to prevent stranding. Redirection of flow into canal systems has been proposed by other groups to allow continued peaking power operation while minimizing impacts on anadromous fish (Reynolds et al. 1993). This type of scheme should be evaluated to determine effectiveness and costs in terms of reduced ability to meet needs of fish and other water user groups at other times of the year. Also, the potential of Crocker-Huffman Dam to re-regulate or stabilize flow fluctuations should be investigated.

Dates	Recommendation
October 1 - March 31	Cease peaking power operation or establish a minimum stage to prevent redd dewatering and ramping rates to prevent premature transport and stranding of juvenile fish. Reduce magnitude of fluctuations to prevent sediment mobilization.
April 1 - May 1	Reduce the rate of recession for peaking flows to prevent stranding of juvenile fish.

Related actions: Flow and temperature recommendations.

Agency and organization roles and responsibilities: Merced Irrigation District and FERC in cooperation with DFG and USFWS would be responsible for establishing the schedule and standards for ramping rates.

Potential obstacles to implementation: Modifying hydroelectric plant operations to protect juvenile fish could restrict operational flexibility and reduce revenues generated by the sale of electricity during periods of high demand. Redirection of peaking flows into canals could reduce the quantity of water available during other times and for other uses.

Projected benefits: The San Joaquin Basin Technical Team believes that implementation of this action, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the Merced River.

Action 4: Conduct sequential restoration of instream and riparian habitat.

Objective: Ensure the long-term sustainability of physical, chemical, and biological conditions needed to meet production goals for chinook salmon through restoration and protection of the stream ecosystem.

Location: Crocker-Huffman Diversion downstream to the confluence with the San Joaquin River.

Narrative description: Physical habitat for salmon spawning and rearing has deteriorated as a result of a number of factors, many of them related to reduced instream flow. Problems include siltation of spawning gravel, loss of side channels and channel diversity, and reduced recruitment of spawning gravel to the active stream channel (Reynolds et al. 1993).

Gold dredging in the early 1900s removed substantial quantities of spawning gravel from the river channel. In many riffles, substantial armoring has occurred, with only large cobble remaining. Dams currently prevent recruitment of additional gravel from upstream in the watershed. Consequent depletion of gravel in reaches downstream of dams has resulted in channel incision and reduction in floodplain width (Reynolds et al. 1993). During periods of high discharge, river stage within the incised channel may increase dramatically, and high velocities and lack of cover may result in premature downstream displacement of juvenile salmon.

Gravel mining has also resulted in the creation of onstream ponds that provide ideal habitat for predators and function as barriers to outmigrating juvenile salmon (DWR 1994). On-channel gravel pits are prevalent downstream of Highway 59. Loss of juvenile salmon to bass predation is not well documented but is potentially high, particularly under drought conditions, when flow during outmigration is low. Gravel pits may also act as traps for gravel mobilized during high flows.

Abandonment of much of the historical floodplain has resulted in confinement of riparian communities to narrow corridors within the banks of the incised channel (Reynolds et al. 1993). Riparian vegetation has also been removed to facilitate agricultural practices, grazing, urban development, and gravel mining. Reduced coverage by riparian vegetation is probably an important factor contributing to increased ambient air and water temperatures in river reaches that are currently used by chinook salmon (Reynolds et al. 1993).

Description of the proposed action:

1) Spawning gravel restoration, replacement, and maintenance.

2) Elimination of connected, off-channel pools that increase water temperature and provide habitat for predators.

3) Surveying to determine possible and practical goals for restoration of river/floodplain functions under the probable flow regime.

4) Acquisition of floodplain and riparian lands required to meet restoration goals established under 3.

5) Reestablishment of channel configuration and river/floodplain and riparian relationships.

6) Management of the watershed to reduce inputs of sediment, pesticides, and other substances with potential deleterious effects. Measures considered would include land purchase, incentives to improve land use practices, and construction of sediment retention basins.

Related actions: Flow and water temperature actions.

Agency and organization roles and responsibilities: The action would require cooperation and coordination between multiple federal, state, and local agencies and numerous private land owners and interest groups.

Potential obstacles to implementation: Available funds may be insufficient for purchasing lands needed for comprehensive restoration. Accelerating development and construction within the river floodplain will increase opposition to acquisition and restoration. Land owners and others may object to changes and restrictions in allowed uses for riparian lands.

Projected benefits: The team believes that implementing this action has the potential to reduce the magnitude of flows needed to restore natural production of chinook salmon in the Merced River. Reestablishing the natural stream channel, eliminating on-channel gravel pits, and restoring riparian vegetation would contribute to reducing water temperature. Reducing bank and floodplain erosion and increasing sediment transport capability by reconfiguring the stream channel should increase egg survival by maintaining clean spawning gravel. Increases in clean gravel should increase production of invertebrates that provide food to juvenile salmon and other species. Increased instream cover would be expected to reduce juvenile mortality by providing refuge from predators. The technical team believes that implementation of this action, in concert with other recommended actions, would double production of fall-run chinook salmon in the Merced River. A return to more natural conditions would be expected to benefit native fish species besides chinook salmon and steelhead. Although Section 3406(b)(1) does not establish goals for these species, implementing actions that will provide benefits for them is consistent with the intent of the CVPIA.

Action 5: Install and maintain fish protection devices at riparian pumps and diversions; prior to installation, restrict pumping to daylight hours.

Objective: Reduce or eliminate loss of juvenile chinook salmon resulting from entrainment by pumps and diversions.

Location: Merced River from Crocker-Huffman Diversion downstream to the San Joaquin River confluence.

Narrative description: Substantial numbers of juvenile salmon are potentially vulnerable to entrainment at six medium-sized irrigation diversions within the salmon spawning reach of the Merced River. Although the magnitude of the resulting losses is not known, there are indications it could be substantial (Hallock and Van Woert 1959). Rock screens have been installed at four of these diversions, but these have been only moderately effective at preventing juvenile salmon entrainment. In addition, there are 68 small pump irrigation diversions, none of which are adequately screened to prevent juvenile salmon entrainment.

The available data for chinook salmon is other systems indicate that much of the downstream movement of fry occurs at night (Healy 1991). To reduce entrainment prior to installation of fish protection devices, interim guidelines restricting pumping and diversion to daylight hours should be adopted.

Related actions: CVPIA screening program (3406[b][21]) required by Title 34.

Agency and organization roles and responsibilities: DFG has already begun an inventory of riparian diversions. USFWS will be administering a screening program as one element of the CVPIA.

Potential obstacles to implementation: Protection devices might reduce the efficiency of diversions or require additional maintenance effort on the part of diverters.

Projected benefits: The San Joaquin Basin Technical Team believes that installation of effective protection devices, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the Merced River.

Action 6: Provide additional law enforcement.

Objective: Increase spawning success, reduce entrainment, and prevent additional destruction of stream habitat.

Location: Merced River from Crocker-Huffman Diversion downstream to the confluence with the San Joaquin River.

Narrative description: Provide additional law enforcement coverage to protect salmon habitat downstream of Crocker-Huffman Diversion through diligent enforcement of screening, water pollution, and streambed alteration Fish and Game Code sections (DFG 1993). If this cannot be accomplished through year-round appointments, at least increase law enforcement efforts during the period of October-December to curb poaching losses (San Joaquin River Management Program Advisory Council 1993).

Related actions: Installation of fish protection devices; habitat restoration and protection.

Agency and organization roles and responsibilities: Implementation of this action would primarily be the responsibility of DFG, although other law enforcement or regulatory authorities might be involved.

Potential obstacles to implementation: DFG funding and manpower constraints.

Projected benefits: The San Joaquin Basin Technical Team believes that implementation of this action, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the Merced River.

Action 7: Provide fish passage around reservoirs.

Objective: Increase production and minimize impacts on water interests by providing access to additional spawning/rearing habitat upstream of reservoirs.

Location: Lake McClure, Lake McSwain, and Crocker-Huffman Diversion.

Narrative description:

1) Evaluate feasibility, benefits, and costs in terms of fish production and impacts on water users and other interest groups.

2) Depending on the outcome of the evaluation, design and construct fish passage structures.

3) Modify operation of reservoirs to facilitate downstream migration of juvenile salmon.

Related actions: Because it has the potential to reduce the level of restoration needed in the lower reach of the river, providing passage around dams is related to all other actions. Reservoir drawdown to facilitate juvenile outmigration has the potential to affect downstream flow. Providing adequate reservoir releases to maintain suitable water temperatures for migrating chinook salmon during spring and fall would continue to be important.

Agency and organization roles and responsibilities: Evaluating feasibility would be the responsibility of DFG, USFWS, and the appropriate reservoir management authority. Implementation would necessitate cooperation between multiple agencies and water users groups.

Potential obstacles to implementation: The feasibility of this approach has not been evaluated, and the costs of constructing functional fish passage structures for juvenile and adult salmon would probably be high. The suitability of habitat for meeting anadromous salmonid life history requirements in stream reaches above existing reservoirs is not well known. Operation of reservoirs to facilitate fish passage could entail higher water costs than meeting fish flow needs in downstream reaches. Feasibility and cost/benefit analyses would be conducted in the evaluation phase and would determine whether this action presents a viable option for anadromous fish restoration. The types of activities required to move fish around reservoirs may not be consistent with provisions and the intent of Title 34.

Projected benefits: The team believes that providing access to stream reaches above reservoirs could result in increases in natural production that would exceed the goals established under the AFRP. By increasing the quantity of habitat available for spawning and rearing, installation of functional fish passage structures has the potential to reduce the scope of restoration actions required in the reach from Crocker-Huffman Diversion to the San Joaquin River confluence and reduce costs to other user groups. Providing access to reaches upstream of dams may be essential if restoration efforts are going to have any benefits for steelhead production in the Merced River.

Tuolumne River

Limiting factors and potential solutions -

Table 3-Xd-5. Limiting factors and potential solutions for San Joaquin Basin fall-run chinook salmon in the Tuolumne River.

Limiting factor	Potential solutions
1. Timing and magnitude of flow are inadequate to provide conditions required	Implement a flow schedule that will provide suitable conditions for all life stages of chinook salmon

Limiting factor	Potential solutions
for adult migration, spawning, incubation, rearing, and juvenile outmigration	
2. Water temperature problems: (a) Elevated fall water temperatures delay adult migration and spawning, which may result in delayed outmigration and reduced survival of juveniles (b) Elevated spring water temperatures reduce survival of juvenile outmigrants	1. Manage New Don Pedro and LaGrange reservoirs to reduce temperature of water discharged to the Tuolumne River during fall 2. Modify timing and magnitude of flow 3. Restore bank and riparian vegetation
3. Egg mortality, redd dewatering, and juvenile stranding resulting from peaking power operation of hydroelectric facilities and rapid changes in reservoir discharge for other purposes	1. Prevent redd dewatering by prohibiting flow reduction from the completion of spawning through emergence 2. Reduce stranding by establishing suitable ramping rates 3. Evaluate benefits and impacts of redirecting flows released to meet peaking power demands into the canal system 4. Reduce egg mortality due to substrate mobilization by reducing the magnitude of peaking power fluctuations. 5. Re-regulate or stabilize flow fluctuations using LaGrange Dam.
4. Degradation of conditions for chinook salmon resulting from alteration of stream, riparian, and floodplain	1. Provide funding to enforce state and federal laws pertaining to stream channel alteration 2. Increase public awareness; provide incentives for

Limiting factor	Potential solutions
habitat	reporting violations 3. Provide funding for stream habitat restoration
5. Sedimentation of remaining spawning gravel	1. Facilitate transport of fine sediments by restoring the balance between river channel configuration and flow regime 2. Mechanically clean spawning gavels that have been degraded as a result of sedimentation 3. Construct retention basins and support land use practices that reduce sediment input.
6. Lack of spawning gravel recruitment	1. Increase spawning gravel recruitment from banks and floodplain by reestablishing river/floodplain hydrology and dynamics 2. Replenish spawning gravel from outside sources
7. Reduction in overall quantity of accessible spawning and rearing habitat as a result of obstruction of migration by dams	Determine feasibility of modifying major dams to reestablish adult salmon access to upstream habitat and provide safe passage for outmigrating juvenile salmon.
8. Entrainment of juvenile chinook salmon at 36 small, unscreened pump diversions	1. Provide other water sources and eliminate diversions 2. Screen or otherwise modify pumps and diversions to prevent entrainment of juvenile chinook salmon
9. Predation on rearing and outmigrating juvenile chinook salmon	1. Increase harvest limits on predator species and enlist anglers to implement a concerted predator reduction/control program 2. Eliminate or isolate predator habitat
10. Poor water quality resulting from point and nonpoint discharge of pollutants and	1. Provide funding to increase enforcement of state laws pertaining point- and nonpoint-source pollution

Limiting factor	Potential solutions
toxic compounds	2. Strengthen existing water quality standards to provide protection for chinook salmon as needed 3. Increase public awareness; provide incentives for reporting violations 4. Manage reservoir releases to provide adequate dilution of pollutants and toxic compound loading rates
11. Illegal harvest of adult chinook salmon	1. Provide additional law enforcement from LaGrange Dam downstream to the confluence with the San Joaquin River during times when adult salmon are in the river 2. Increase incentives for reporting violations

Restoration actions -

Action 1: Modify existing flow schedule (Table 3-Xd-6).

Objective: Provide adequate flow for all life stages of chinook salmon.

Location: Tuolumne River from LaGrange Dam downstream to the confluence with the San Joaquin River.

Narrative description: New Don Pedro Reservoir is the largest reservoir (2.0 maf) on the Tuolumne River; LaGrange Dam is the downstream barrier to salmon migration. In 1964, FERC issued a license to the Turlock and Modesto Irrigation Districts (TID/MID) to operate the New Don Pedro Project. The license agreement included minimum instream flow requirements. Additionally, Article 39 of the license called for a 20-year fisheries evaluation by cooperating agencies, including TID/MID, DFG, and USFWS, to determine measures needed to ensure continuation and maintenance of the lower Tuolumne River chinook salmon populations. At the end of the evaluation period, all parties were to submit recommendations to FERC. This study began in 1971 and, because of the extended drought conditions, is ongoing. In 1986, the study agreement was amended to include two additional flow schedules for normal water-year conditions.

The 1986 agreement does not provide adequate flow for adult migration, spawning, egg incubation, juvenile rearing, smolt emigration, or oversummering rearing of yearlings (Reynolds et al. 1993). In 1992, the districts reached an agreement with DFG on a revised flow schedule for a 10-year interim period or until issuance of a new FERC license order. The districts filed results of their studies pursuant to Article 39; however, the agreement has not been implemented because of lack of FERC approval. USFWS and the City and County of San Francisco have been unwilling to sign the agreement and have filed their own instream flow recommendations with FERC (TID/MID 1992).

FERC is presently preparing an EIS that will address fisheries issues for the New Don Pedro Project. Various entities with an interest in the FERC process are attempting to reach a negotiated settlement with the assistance of a federal mediator.

There is a positive relationship between smolt survival and spring flow in the Tuolumne River. Under the 1986 agreement, DFG allocates as much flow as possible to the spring smolt migration period, but the total amount of water available is insufficient to meet needs during all times of the year. Instream flow studies by DFG and USFWS indicate that substantially higher flows are needed for salmon spawning and rearing on the lower Tuolumne River than are possible with the present flow allocations. Summer flows are too low to sustain either salmon or steelhead but are sufficient to sustain large populations of predator fish that contribute to losses of young salmon.

Table 3-Xd-6. Existing and AFRP-generated flow schedules for the Tuolumne River from LaGrange Dam to the San Joaquin River confluence (cfs) by year type.

Month	Existing[a]	AFRP[b]				
		Wet	Above normal	Below normal	Dry	Critical
October	150-300	750[c]	300[c]	300[c]	200[c]	150[c]
November	200-300	1,250[d]	800[d]	350[c]	300[c]	150[c]
December	150-250	1,400[d]	1,050[d]	350[c]	350[c]	200[d]
January	150-250	1,700[d]	1,150[d]	500[d]	400[c]	250[d]
February	250	2,100[d]	1,700[d]	950[d]	700[d]	500[d]
March	300-250	2,300[d]	1,700[d]	1,300[d]	1,000[d]	900[d]
April	250-500	2,950[e]	2,450[e]	2,350[e]	1,900[e]	1,500[e]
May	100-200	5,150[e]	4,200[e]	3,350[e]	2,500[e]	1,850[e]
June	3	5,000[e]	3,250[e]	2,600[e]	1,550[e]	1,000[e]
July	3	2,150[f]	900[f]	650[f]	250[f]	200[f]
August	3	450[f]	200[f]	100[g]	100[g]	50[g]
September	3	350[g]	150[g]	150[g]	100[g]	50[g]
Total (taf)	128	1,544	1,078	782	564	411

Month	Existing[a]	AFRP[b]				
		Wet	Above normal	Below normal	Dry	Critical
Baseline (taf)	NA	1,291	737	355	327	155
Unimpaired (taf)	NA	2,892	2,074	1,499	1,091	805

Note: All flows have been rounded to the nearest 50 cfs.

[a] Year type based on San Joaquin Basin 60-20-20 Index.

[b] Existing flows based on FERC license agreement with TID/MID.

[c] Based on USFWS IFIM spawning flow recommendations (USFWS unpublished data) and the assumption that flows greater than historical flows are needed to compensate for elimination of access to upstream habitat.

[d] Based on historical (1922-1990) percent monthly distribution of total annual unimpaired runoff for the Tuolumne River Basin and the assumption that flow should not be reduced between spawning and outmigration to prevent redd dewatering or stranding of rearing juveniles.

[e] Based on Vernalis flow requirement and historical (1922-1990) percent monthly contribution to total annual unimpaired runoff.

[f] Based on historical (1922-1990) percent monthly distribution of total annual unimpaired runoff.

[g] Flow based on USFWS IFIM recommendations.

Related actions: Existing flow agreement, recommendations, and FERC negotiation process. Vernalis flow recommendations. Section 3408(h), purchase of land and water from willing sellers.

Agency and organization roles and responsibilities: If the proposed flow recommendations were to be implemented, TID/MID, which jointly operate New Don Pedro Reservoir, would be responsible for meeting the AFRP flow schedule. USFWS and DFG would be responsible for monitoring and adjusting flow recommendations to ensure maximum benefits for chinook salmon.

Potential obstacles to implementation: Flows currently required or recommended are considerably lower than flows that the San Joaquin Basin Technical Team believes would be required to double production of chinook salmon in the Tuolumne River. Because Don Pedro Reservoir is not a CVP impoundment, meeting technical team recommendations would require acquisition of water from willing sellers.

Projected benefits: The San Joaquin Basin Technical Team believes that implementation of this flow schedule, in concert with other recommended actions, would double production of fall-run chinook salmon in the Tuolumne River.

Action 2: Adjust reservoir operations and releases to meet chinook salmon temperature requirements.

Objective: Maintain water temperature within ranges suitable for chinook salmon migration, spawning, incubation, rearing, and outmigration.

Location: Tuolumne River from LaGrange Dam downstream to the confluence with the San Joaquin River.

Narrative description: Elevated water temperature can delay migration and spawning activity in fall, decrease egg survival, and increase mortality of outmigrating smolts in spring (Reynolds et al. 1993).

Water temperatures in October frequently exceed acceptable levels for salmon spawning in at least a portion of the reach of the river used by spawning salmon (Reynolds et al. 1993). This condition contributes to delayed upstream migration and spawning. During the recent drought, the first spawners arrived in the lower Tuolumne River in early November, rather than in October as in previous years.

Elevated water temperatures in the lower Tuolumne River during the spring migration period may be a significant factor affecting smolt survival. Smolts migrating from the Tuolumne River during April and May commonly encounter water temperatures that approach lethal levels (DFG 1992).

Description of the proposed action:

Dates	Water Temperature
October 15 - February 15	56°F
April 1 - June 31	65°F

Related actions: Flow recommendations, restoration of riparian and instream habitat. Riparian and instream habitat restoration and protection measures (Action 4) would facilitate efforts to maintain suitable water temperatures in the Tuolumne River.

Agency and organization roles and responsibilities: If this action is implemented, TID/MID would be responsible for operating New Don Pedro Reservoir to meet the AFRP flow schedule. USFWS and DFG would be responsible for monitoring temperatures and adjusting flow and reservoir operation recommendations to ensure maximum benefits for chinook salmon.

Potential obstacles to implementation: Maintenance of adequate temperatures may require flows higher than those recommended in Action 1. Increasing the proportion of water allocated to meeting fish needs would reduce water available to meet needs of other user groups. Implementation would require the purchase of additional water. Maintaining a water temperature of 65^{o}F during June may not be possible

Projected benefits: The San Joaquin Basin Technical Team believes that implementation of this action, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the Tuolumne River.

Action 3: Reduce impacts of rapid flow fluctuations.

Objective: Increase hatching success and juvenile survival by reducing ramping rates and eliminating flow fluctuation during key periods.

Location: Tuolumne River from LaGrange Dam downstream to the San Joaquin River confluence.

Narrative description: Hydroelectric power releases into the lower Tuolumne River from the New Don Pedro Project during the late spawning and rearing period (December through February) can cause fluctuations in downstream flow that commonly range from 200 cfs to 4,500 cfs over a 24-hour period. These releases are typically made in water years when there are no diversions for irrigation and when releases are made in anticipation, or as a direct result, of flood control requirements.

Potential adverse impacts of rapid flow fluctuations resulting from peaking power operation and short-duration reservoir releases for other purposes may disrupt adult salmon migration and spawning, scour or dewater redds, and affect emerging salmon fry by stranding, downstream displacement, and exposure to predation (Reynolds et al. 1993). The potential for adverse impacts is especially great during January and February, when fry are abundant and rely on passive mechanisms of dispersal to reach suitable habitat (Reynolds et al. 1993). Stranding of juvenile salmon following rapid changes in discharge has been documented at several sites along the lower Tuolumne River and may be a principal factor affecting salmon survival in years when power peaking releases occurs (Reynolds et al. 1993).

The window of vulnerability for adverse impacts of rapid flow fluctuations corresponds to the period when juvenile fish are present in the river, essentially from the onset of spawning in October through outmigration in late May or early June. The team recommends establishing periods when flow fluctuation is prohibited or incorporating standards for ramping rates that will prevent premature transport and stranding. If ramping rates were low enough to prevent stranding, peaking flows could be used to stimulate and facilitate juvenile outmigration during April and May. Redirection of flow into canal systems has been proposed by other groups to allow continued peaking power operation while minimizing impacts on anadromous fish (Reynolds et al. 1993).

Dates	Recommendation
October 1 - March 31	Cease peaking power operation or establish minimum stream stage to prevent redd dewatering and ramping rates to prevent premature transport and stranding of juvenile fish. Reduce magnitude of fluctuations to prevent sediment mobilization.
April 1 - May 1	Reduce the rate of recession for peaking flows to prevent stranding of juvenile fish.

Related actions: Flow and temperature recommendations.

Agency and organization roles and responsibilities: MID/TID and FERC, in cooperation with DFG and USFWS, would be responsible for establishing the schedule and standards for ramping rates.

Potential obstacles to implementation: Modifying hydroelectric plant operations to protect juvenile fish could result reduced operational flexibility and a reduction in revenues generated by the sale of electricity during period of high demand. Redirection of peaking flows into canals could reduce the quantity of water available during other times and for other uses.

Projected benefits: The San Joaquin Basin Technical Team believes that implementation of this action, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the Tuolumne River.

Action 4: Conduct sequential restoration of instream and riparian habitat.

Objective: Ensure the long-term sustainability of physical, chemical, and biological conditions needed to meet production goals for chinook salmon through restoration and protection of the stream ecosystem.

Location: LaGrange Dam downstream to the confluence with the San Joaquin River.

Narrative description: Physical habitat for salmon spawning and rearing has deteriorated as a result of a number of factors, many of them related to reduced instream flow. Problems include siltation of spawning gravel, loss of side channels and channel diversity, and reduced recruitment of spawning gravel to the active stream channel (Reynolds et al. 1993).

In-channel gravel mining has removed spawning gravel and resulted in the creation of onstream ponds that provide ideal habitat for predators and function as barriers to outmigrating juvenile salmon (DWR 1994). Loss of juvenile salmon to predation is not well documented but is potentially high, particularly under drought conditions, when flow during outmigration is low.

Dams have eliminated the natural process of gravel recruitment from upstream reaches. As a consequence, gravel in reaches downstream of dams has become depleted, resulting in channel incision and reduction in floodplain width (Reynolds et al. 1993). During periods of high discharge, river stage within the incised channel may increase dramatically, and high velocities and lack of cover may result in premature downstream displacement of juvenile chinook salmon.

Abandonment of much of the historical floodplain has resulted in confinement of riparian communities to narrow corridors within the banks of the incised channel (Reynolds et al. 1993). Riparian vegetation has also been removed to facilitate agricultural practices, cattle grazing, urban development, and gravel mining. Reduced coverage by riparian vegetation is an important factor contributing to increased ambient air and water temperatures in river reaches that are currently used by chinook salmon (Reynolds et al. 1993).

The proposed action consists of the following:

1) Spawning gravel restoration, replacement, and maintenance.

2) Elimination of connected, off-channel pools that increase water temperature and provide habitat for predators.

3) Surveying to determine possible and practical goals for restoration of river/floodplain functions under the probable flow regime.

4) Acquisition of floodplain and riparian land required to meet restoration goals established under 3.

5) Reestablishment of channel configuration and river/floodplain and riparian relationships.

6) Management of the watershed to reduce inputs of sediment, pesticides, and other substances with potential deleterious effects. Measures considered would include land purchase, incentives to improve land use practices, and construction of sediment retention basins.

Related actions: Flow and water temperature recommendations.

Agency and organization roles and responsibilities: Action would require cooperation and coordination between multiple federal, state, and local agencies and numerous private land owners and interest groups.

Potential obstacles to implementation: Available funds may be insufficient for purchasing lands needed for comprehensive restoration. Land owners and others may object to changes and restrictions in allowed uses for riparian lands. Accelerating development and construction within the river floodplain will increase opposition to acquisition and restoration.

Projected benefits: The team believes that implementing this action has the potential to reduce the magnitude of flows needed to restore natural production of chinook salmon in the Tuolumne River. Reestablishing the natural stream channel, eliminating on-channel gravel pits, and restoring riparian vegetation would contribute to reducing water temperature. Reducing bank and floodplain erosion and increasing sediment transport capability by reconfiguring the stream channel should increase egg survival by maintaining clean spawning gravel. Increase in clean gravel should increase production of invertebrates that provide food to juvenile salmon and other species. Increased instream cover would be expected to reduce juvenile mortality by providing refuge from predators. The technical team believes that implementation of this action, in concert with other recommended actions, would double production of fall-run chinook salmon in the Tuolumne River. A return to more natural conditions would be expected to benefit native fish species besides chinook salmon and steelhead. Although Section 3406(b)(1) does not establish goals for these species, implementing actions that will provide benefits for them is consistent with the intent of the CVPIA.

Action 5: Install fish protection devices at riparian pumps and diversions; prior to installation, restrict pumping to daylight hours.

Objective: Reduce or eliminate loss of juvenile chinook salmon resulting from entrainment by pumps and diversions.

Location: Tuolumne River from LaGrange Dam downstream to the San Joaquin River confluence.

Narrative description: Thirty-six small pump diversions, none of which are adequately screened to protect juvenile salmon, are located on the lower Tuolumne River (Reynolds et al. 1993). The cumulative loss of young salmon at these diversions resulting from entrainment is not known but is potentially substantial (Hallock and Van Woert 1959).

The available data for chinook salmon in other systems indicate that downstream movement of fry occurs mainly at night (Healy 1991). To reduce entrainment prior to installation of adequate fish protection devices, interim guidelines restricting pumping and diversion to daylight hours should be adopted.

Related actions: The CVPIA screening program (3406[b][21]) required by Title 34 is a likely source of funding.

Agency and organization roles and responsibilities: A DFG survey of unscreened diversions in the San Joaquin Basin is underway. The action would be implemented by USFWS and DFG under 3406(b)(21) and would require cooperation with private land owners and other water right holders.

Potential obstacles to implementation: Protection devices might reduce the efficiency of diversions or require additional maintenance effort on the part of diverters.

Projected benefits: The San Joaquin Basin Technical Team believes that installing fish protection devices at riparian diversions, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the Tuolumne River.

Action 6: Provide additional law enforcement coverage to protect against illegal take of salmon, stream alteration, and water pollution and to ensure adequate protection for juvenile salmon at pumps and diversions.

Objective: Increase spawning success, reduce entrainment, improve water quality, and prevent additional destruction of stream habitat.

Location: Tuolumne River from LaGrange Dam to the confluence with the San Joaquin River.

Narrative description: Increased enforcement of sections of the Fish and Game Code pertaining to illegal harvest of adult salmon, screening, water pollution, and streambed alteration would provide additional protection for chinook salmon (Reynolds et al. 1993).

Related actions: Continuing prohibition on recreational harvest, screening, and habitat restoration and protection.

Agency and organization roles and responsibilities: Implementation of this action would primarily be the responsibility of DFG, although other law enforcement or regulatory authorities might be involved.

Potential obstacles to implementation: DFG funding constraints.

Projected benefits: The San Joaquin Basin Technical Team believes that increased enforcement of the specified sections of the California Fish and Game Code, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the Tuolumne River.

Action 7: Provide fish passage around reservoirs.

Objective: Increase production and minimize impacts of anadromous fish restoration on water interests by providing access to additional spawning/rearing habitat upstream of reservoirs.

Location: LaGrange and New Don Pedro reservoirs.

Narrative description:

1) Evaluate feasibility, benefits, and costs in terms of fish production and impacts on water users and other interest groups.

2) Depending on the outcome of the evaluation, design and construct fish passage structures.

3) Modify operation of reservoirs to facilitate downstream migration of juvenile salmon.

Related actions: Because it has the potential to reduce the level of restoration needed in the lower reach of the river, providing passage around dams is related to all other actions. Reservoir drawdown to facilitate juvenile outmigration has the potential to affect downstream flow. Providing adequate reservoir releases to maintain suitable water temperatures for migrating chinook salmon during spring and fall would continue to be important.

Agency and organization roles and responsibilities: Evaluating feasibility would be the responsibility of DFG, USFWS, and the appropriate reservoir management authority. Implementation would necessitate cooperation between multiple agencies and water user groups.

Potential obstacles to implementation: The feasibility of this approach has not been evaluated, and the costs of constructing functional fish passage structures for juvenile and adult salmon would probably be high. The suitability of habitat for meeting anadromous salmonid life history requirements in stream reaches above existing reservoirs is not well known. Operation of reservoirs to facilitate fish passage could entail higher water costs than meeting fish flow needs in downstream reaches. Feasibility and cost/benefit analyses would be conducted in the evaluation phase and would determine whether this action presents a viable option for anadromous fish restoration. The types of activities required to move fish around reservoirs may not be consistent with provisions and the intent of Title 34.

Projected benefits: The team believes that providing access to stream reaches above reservoirs could result in increases in natural production that would exceed the goals established under the AFRP. By increasing the quantity of habitat available for spawning and rearing, installation of functional fish passage structures has the potential to reduce the scope of restoration actions required in the reach from LaGrange Dam to the San Joaquin River confluence and reduce costs to other user groups. This action may be essential if restoration is going to benefit steelhead production in the Tuolumne River.

Stanislaus River

Limiting factors and potential solutions -

Table 3-Xd-7. Limiting factors and potential solutions for San Joaquin Basin fall-run chinook salmon in the Stanislaus River.

Limiting factors	Potential solutions
1. Timing and magnitude of flow are inadequate to provide conditions required for adult migration, spawning, incubation, rearing, and juvenile outmigration	Implement a flow schedule that will provide suitable conditions for all life stages of chinook salmon
2. Water temperature problems: (a) Elevated fall water temperatures delay adult migration and spawning, which may result in delayed outmigration and reduced survival of juveniles (b) Elevated spring water temperatures reduce survival of juvenile outmigrants	1. Manage New Melones, Tulloch, and Goodwin reservoirs to reduce temperature of water discharged to the Stanislaus River during fall 2. Modify timing and magnitude of flow 3. Restore bank and riparian vegetation 4. Modify or remove Old Melones Dam to facilitate fall release from New Melones Reservoir of water within the temperature range suitable for spawning and incubation
3. Degraded instream, riparian, and floodplain habitat	1. Provide funding to increase enforcement of state and federal laws pertaining to stream channel alteration

Limiting factors	Potential solutions
	2. Increase public awareness; provide incentives for reporting violations 3. Provide funding for stream habitat restoration
4. Sedimentation of remaining spawning gravel	1. Facilitate transport of fine sediments by restoring the balance between flow regime and river channel configuration 2. Mechanically clean spawning gravel that have been degraded as a result of sedimentation 3. Construct retention basins and support land use practices that reduce sediment input
5. Lack of spawning gravel recruitment	1. Increase spawning gravel recruitment from banks and floodplain by reestablishing river/floodplain hydrology and dynamics 2. Replenish spawning gravel from outside sources
6. Reduction in overall quantity of accessible spawning and rearing habitat as a result of obstruction by dams	Determine feasibility of modifying major dams to reestablish adult salmon access to upstream habitat and provide safe passage for outmigrating juveniles
7. Entrainment of juvenile chinook salmon at 44 small, unscreened pumps	1. Provide other water sources and eliminate diversions 2. Screen or otherwise modify pumps and diversions to prevent entrainment of juvenile chinook salmon
8. Predation on rearing and outmigrating juvenile chinook salmon	1. Increase harvest limits on predator species and enlist anglers to implement a concerted predator reduction program 2. Eliminate or isolate predator habitat

Limiting factors	Potential solutions
9. Poor water quality resulting from point and non-point source discharge of toxic chemicals and other pollutants	1. Provide funding to enforce state laws pertaining to point- and nonpoint- source pollution 2. Strengthen existing water quality standards to provide protection for chinook salmon as needed 3. Increase public awareness; provide incentives for reporting violations 4. Provide funding for stream habitat restoration projects
10. Illegal harvest of adult chinook salmon	1. Provide additional law enforcement from Goodwin Dam downstream to the confluence with the San Joaquin River during times when adult salmon are in the river 2. Increase public awareness and incentives for reporting violations

Restoration actions -

Action 1: Modify existing flow schedule (Table 3-Xd-8).

Objective: Manage flows to benefit all life stages of chinook salmon.

Location: Stanislaus River from Goodwin Dam downstream to the confluence with the San Joaquin River.

Narrative description: While New Melones Reservoir is the largest impoundment (2.4 maf) in the Stanislaus River Basin, Goodwin Dam is the downstream barrier for salmon migration (Reynolds et al. 1993). Existing releases to meet needs of chinook salmon in the lower Stanislaus River are specified in a 1987 study agreement between DFG and USBR (DFG and USBR 1987). This agreement specifies interim annual flow allocations of 98,300 af to 302,100 af, depending on New Melones Reservoir carryover storage and inflow. Since the agreement was signed, water shortages have limited the quantity of water allocated to meeting fish needs to 98,300 af in all years. This quantity has proven to be inadequate for survival of all life stages of chinook salmon (Loudermilk 1994). New Melones Reservoir releases to meet Sacramento-San

Joaquin Delta water quality requirements have provided additional benefits for Stanislaus River chinook salmon in some years.

The DFG/USBR agreement provides for a 7-year study with seven study elements that are in various stages of completion. To date, results of smolt survival studies by DFG and a 1992 instream flow study by USFWS have yielded sufficient data to allow formulation of minimum instream flow schedules with increased allotments for fish. In August 1992, DFG submitted revised flow schedules to USBR and DWR. The revised flows range from 185,280 af to 381,498 af (Reynolds et al. 1993). DFG has indicated that these are minimum flows that are subject to revision upon completion of the remaining studies (Reyno1ds et al. 1993). The purpose of establishing minimum flows is to maintain the current population or prevent further decline as water demands increase (Reynolds et al. 1993); a key assumption of the technical team was that doubling natural production would require flows higher than the specified minimum flows.

Escapement of adult chinook salmon into the Stanislaus River is associated with spring outflow in both the San Joaquin River at Vernalis and the Stanislaus River at Ripon (DFG 1987). Delay of adult migrating and spawning resulting from factors related to low flow in fall is also a concern (DFG 1992). Unfortunately, the existing allocation has proven insufficient to meet both fall and spring flow needs.

The San Joaquin Basin Technical Team has recommended a flow schedule that it believes will achieve the goal of doubling natural production (Table 3-Xd-8).

Table 3-Xd-8. Existing and proposed flow schedules for the Stanislaus River from Goodwin Dam to the San Joaquin River confluence (cfs) by year type.

Month	Existing[a]	AFRP[b]				
		Wet	Above normal	Below normal	Dry	Critical
October	--	350[c]	350[c]	300[c]	250[c]	250[c]
November	--	400[c]	350[c]	300[c]	300[c]	250[c]
December	--	850[e]	650[e]	300[c]	300[c]	250[c]
January	--	1,150[e]	800[e]	300[d]	300[d]	250[d]
February	--	1,450[e]	1,150[e]	700[e]	450[d]	300[d]
March	--	1,550[e]	1,150[e]	850[e]	650[e]	550[e]
April	--	2,100[f]	1,800[f]	1,750[f]	1,250[f]	950[f]
May	--	3,500[f]	2,750[f]	2,050[f]	1,400[f]	900[f]
June	--	2,650[f]	1,600[f]	1,300[f]	700[f]	450[f]
July	--	900[g]	400[g]	350[h]	200[h]	250[h]

Month	Existing[a]	AFRP[b]				
		Wet	Above normal	Below normal	Dry	Critical
August	--	350[h]	300[h]	250[h]	200[h]	200[h]
September	--	350[h]	300[h]	250[h]	200[h]	200[h]
Total (taf)	98 - 302	943	701	525	375	290
Baseline (taf)		1,015	722	406	242	269
Unimpaired (taf)		1,772	1,291	920	631	449

Note: All flows have been rounded to the nearest 50 cfs.

[a] Year type based on San Joaquin Basin 60-20-20 Index.

[b] Existing flows based on agreement between USBR and DFG (DFG and USBR 1987). Actual schedule determined on an annual basis.

[c] Flow based on USFWS IFIM spawning recommendations (Aceituno 1993, Reynolds et al. 1993) and the assumption that flow greater than unimpaired flow is needed at this time of the year to compensate for elimination of access to upstream habitat.

[d] Based on USFWS IFIM spawning flow recommendations and the assumption that flow should not be reduced between spawning and outmigration to prevent redd dewatering and stranding of rearing juveniles.

[e] Based on historical (1922-1990) percent monthly contribution to total annual unimpaired runoff for the Stanislaus River Basin and the assumption that flow should not be reduced between spawning and outmigration to prevent redd dewatering or stranding of rearing juveniles.

[f] Stanislaus River contribution to Vernalis flow standard. Based on historical monthly contribution of the Stanislaus River to total unimpaired runoff for the San Joaquin River Basin, 1922-1990.

[g] Based on historical (1922-1990) percent monthly contribution to total annual unimpaired runoff for the Stanislaus River Basin.

[h] Based on USFWS IFIM flow and assumption that flow greater than unimpaired flow is needed to compensate for eliminations of access to upstream habitat.

Related actions: Existing flow agreement between USBR and DFG. Vernalis flow recommendations. Section 3406(b)(2) of Title 34, annual dedication of 800,000 af of water for fish, wildlife, and habitat restoration purposes. Section 3408(h), purchase of land and water from willing sellers.

Agency and organization roles and responsibilities: Implementation of this action will require cooperation and coordination between USFWS, DFG, USBR, and numerous water user groups and irrigation districts.

Potential obstacles to implementation: Neither the existing USBR/DFG agreement nor the 800,000 af of water dedicated to fish and wildlife purposes by 3406(b)(2) of Title 34 are sufficient to meeting flow needs identified by the AFRP. Implementing this flow schedule would reduce water available to meet needs of other user groups and would thus require purchase of additional water.

Projected benefits: The San Joaquin Basin Technical Team believes that implementation of this flow schedule, in concert with other recommended actions, would double production of fall-run chinook salmon in the Stanislaus River.

Action 2: Operate New Melones, Tulloch, and Goodwin reservoirs to meet chinook salmon temperature requirements.

Objective: Maintain water temperature within ranges suitable for chinook salmon spawning, incubation, rearing, and outmigration.

Location: Stanislaus River from Goodwin Dam downstream to the confluence with the San Joaquin River.

Narrative description: Water temperature in the lower Stanislaus River is influenced by ambient air temperature, flow, channel width, New Melones Reservoir storage, diversions and thermocline development, and Tulloch Reservoir temperatures and operations (Reynolds et al. 1993). When fall storage in New Melones Reservoir is low, water temperature throughout spawning reaches of the river can exceed 56^{o}F until November (Pisano 1992). During the recent drought, the initial date on which salmon entered the river to spawn was delayed from October until mid-November (DFG 1992). In addition to delaying the onset of spawning, temperatures in excess of 56^{o}F may result in increased mortality of eggs (Pisano 1992).

In spring, elevated water temperatures in the Stanislaus River, the San Joaquin River, and the Delta reduce survival of outmigrating smolts. During May, salmon smolts migrating downstream in the Stanislaus River typically encounter water temperatures that cause physiological stress (DFG 1992). Because their emergence and migration are delayed, the progeny of late-spawning fish are at greater risk of being exposed to stressful or lethal water temperatures (DFG 1992).

Although there is good evidence to support the need for a temperature standard, the understanding of the relationship between temperature and flow in the Stanislaus River is incomplete. Linking an existing USBR temperature model (Rowell 1993) with a USFWS instream flow model (Aceituno 1993) should provide the additional information needed for managing water temperatures by modifying timing and magnitude of reservoir releases.

The proposed action consists of the following:

Dates	Water temperature
October 15-February 15	56°F
April 1-June 31	65°F

Related actions: Flow recommendations, comprehensive restoration of riparian and instream habitat, and modification of Old Melones Dam. Riparian and instream habitat restoration and protection measures (Action 4) would facilitate efforts to maintain suitable water temperatures in the Stanislaus River.

Agency and organization roles and responsibilities: USBR would be responsible for operating New Melones Reservoir to meet temperature standards. USFWS and DFG would be responsible for monitoring and adjusting recommendations to ensure maximum benefits for chinook salmon.

Potential obstacles to implementation: Maintenance of adequate temperatures may require higher flows than those recommended under Action 1. Increasing the proportion of water allocated to meeting fish needs would reduce water available to meet needs of other user groups. Therefore, implementation would require purchase of additional water. Maintaining a water temperature of 65°F during June may not be possible.

Projected benefits: The San Joaquin Basin Technical Team believes that meeting the recommended temperature criteria, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the Stanislaus River.

Action 3: Conduct sequential restoration of instream and riparian habitat.

Objective: Ensure the long-term sustainability of physical, chemical, and biological conditions needed to meet production goals for chinook salmon.

Location: Stanislaus River from Goodwin Dam downstream to the confluence with the San Joaquin River.

Narrative description: Physical habitat for salmon spawning and rearing has deteriorated as a result of a number of factors, many of them related to reduced instream flow. Problems include siltation of spawning gravel, loss of side channels and channel diversity, and reduced recruitment of spawning gravel to the active stream channel (Reynolds et al. 1993).

In-channel gravel mining has removed spawning gravel and resulted in the creation of onstream ponds that provide ideal habitat for predators and function as barriers to outmigrating juvenile salmon (DWR 1994). Loss of juvenile salmon to bass predation is not well documented but is potentially high, particularly under drought conditions, when flow during outmigration is low.

Upstream of the town of Riverbank, habitat has been lost as of result of relocation and channelization to accommodate construction of Highway 108-120 (Reynolds et al. 1993). In contrast, the river downstream of Riverbank has retained much of its original sinuosity (Reynolds et al. 1993). High sinuosity is associated with greater habitat diversity and relatively good retention of gravel during flood events (Reynolds et al. 1993).

Dams have eliminated the natural process of gravel recruitment from upstream reaches. As a consequence, gravel in reaches downstream of dams has become depleted, resulting in channel incision and reduction in floodplain width (Reynolds et al. 1993). During periods of high discharge, river stage within the incised channel may increase dramatically, and high velocities and lack of cover may result in premature downstream displacement of juvenile chinook salmon (Reynolds et al. 1993).

Abandonment of much of the historical floodplain has resulted in confinement of riparian communities to narrow corridors within the banks of the incised channel (Reynolds et al. 1993). Reduced coverage by riparian vegetation is an important factor contributing to increased ambient air and water temperatures in river reaches that are currently used by chinook salmon (Reynolds et al. 1993).

The proposed action consists of the following:

1) Spawning gravel restoration, replacement, and maintenance.

2) Elimination of connected, on-channel ponds that increase water temperature and provide habitat for predators.

3) Surveying to determine possible and practical goals for restoration of river/floodplain functions under the probable future flow regime.

4) Acquisition of floodplain and riparian land required to meet restoration goals established under 3.

5) Reestablishment of channel configuration and river/floodplain and riparian relationships.

6) Management of the watershed to reduce inputs of sediment, pesticides, and other substances with potential deleterious effects. Measures considered would include land purchase, incentives to improve land use practices, and construction of sediment retention basins.

Related actions: Flow and water temperature actions.

Agency and organization roles and responsibilities: This action would require cooperation and coordination between multiple federal, state, and local agencies and numerous private land owners and interest groups.

Potential obstacles to implementation: Available funds may be insufficient to purchase lands needed for comprehensive restoration. Land owners and others may object to changes and restrictions in allowed uses for riparian lands. Accelerating development and construction within the river floodplain will increase opposition to acquisition and restoration.

Projected benefits: The team believes that implementing this action has the potential to reduce the magnitude of flows needed to restore natural production of chinook salmon in the Stanislaus River. Reestablishing the natural stream channel, eliminating on-channel gravel pits, and restoring riparian vegetation would contribute to reducing water temperature. Reducing bank and floodplain erosion and increasing sediment transport capability by reconfiguring the stream channel should increase egg survival by maintaining clean spawning gravel. Increases in clean gravel should increase production of invertebrates that provide food to juvenile salmon and other species. Increased instream cover would be expected to reduce juvenile mortality by providing refuge from predators. The technical team believes that implementation of this action, in concert with other recommended actions, would double production of fall-run chinook salmon in the Stanislaus River. A return to more natural conditions would be expected to benefit native fish species besides chinook salmon and steelhead. Although Section 3406(b)(1) does not establish goals for these species, implementing actions that will provide benefits for them is consistent with the intent of the CVPIA.

Action 4: Install and maintain fish protection devices at riparian pumps and diversions.

Objective: Reduce or eliminate loss of juvenile chinook salmon resulting from entrainment by pumps and diversions.

Location: Stanislaus River from Goodwin Dam downstream to the San Joaquin River confluence.

Narrative description: Forty-four small pump diversions, none of which are adequately screened to protect juvenile salmon, are located on the lower Stanislaus River. The cumulative loss of young salmon at these diversions resulting from entrainment is not known but is potentially substantial (Hallock and Van Woert 1959).

The available data for chinook salmon in other systems indicate that downstream movement of fry occurs mainly at night (Healy 1991). To reduce entrainment prior to installation of fish protection devices, interim guidelines restricting pumping an diversion to daylight hours should be adopted.

Related actions: CVPIA screening program (3406[b][21]) required by Title 34.

Agency and organization roles and responsibilities: A DFG survey of unscreened diversions in the San Joaquin Basin is underway. This action would be implemented by USFWS and DFG under 3406(b)(21) and would require cooperation with private land owners and other water right holders.

Potential obstacles to implementation: Protection devices might reduce efficiency of diversions or require additional maintenance effort on the part of diverters.

Projected benefits: The San Joaquin Basin Technical Team believes that installation of effective protection devices, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the Stanislaus River.

Action 5: Provide additional law enforcement to protect against illegal take of salmon, stream alteration, and water pollution and to ensure adequate screening of pumps and diversions.

Objective: Increase spawning success, reduce entrainment, improve water quality, and prevent additional destruction of stream habitat.

Location: Stanislaus River from Goodwin Dam to the confluence with the San Joaquin River.

Narrative description: Increased enforcement of sections of the Fish and Game Code pertaining to illegal harvest of adult salmon, screening, water pollution, and streambed alteration would provide additional protection for chinook salmon (Reynolds et al. 1993).

Related actions: Installation of fish protection devices; habitat restoration and protection.

Agency and organization roles and responsibilities: Implementation of this action would primarily be the responsibility of DFG, although other law enforcement or regulatory authorities might be involved.

Potential obstacles to implementation: DFG funding and manpower constraints.

Projected benefits: The San Joaquin Basin Technical Team believes that implementation of this action, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the Stanislaus River.

Action 6: Remove or modify Old Melones Dam.

Objective: Reduce fall water temperatures in the Stanislaus River.

Location: New Melones Reservoir.

Narrative description: Warm water temperatures during the fall are believed to result in delayed spawning, decreased egg survival, and high juvenile mortality (DFG 1992). Fall water temperatures depend partially on the late summer reservoir storage level, thermocline development, and the depth of diversions from New Melones Reservoir (Reynolds et al. 1993). When fall storage is low, Old Melones Dam, which is located within the reservoir, limits deep circulation and results in the release of water drawn directly from the reservoir surface (Reynolds et al. 1993). When these conditions occur, fall water temperatures may exceed 56°F throughout most of the spawning reaches of the Stanislaus River (Reynolds et al. 1993); this deleterious condition prevails until ambient air temperatures cool the river, usually in November (Hallock and Van Woert 1959).

Related actions: Flow and temperature recommendations.

Agency and organization roles and responsibilities: As the agency in charge of operating New Melones Reservoir, USBR would have the primary responsibility for implementing this action.

Potential obstacles to implementation: Cost and feasibility are currently unknown.

Projected benefits: The San Joaquin Basin Technical Team believes that implementation of this action, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the Stanislaus River.

Action 7: Provide fish passage around reservoirs.

Objective: Increase production and minimize impacts of anadromous fish restoration on water interests by providing access to additional spawning/rearing habitat upstream of reservoirs.

Location: Goodwin, Tulloch, and New Melones reservoirs.

Narrative description:

1) Evaluate feasibility, benefits, and costs in terms of fish production and impacts on water users and other interest groups.

2) Depending on the outcome of the evaluation, design and construct fish passage structures.

3) Modify dams and operation of reservoirs to facilitate downstream migration of juvenile salmon.

Related actions: Because it has the potential to reduce the level of restoration needed in the lower reach of the river, providing passage around dams is related to all other actions. Reservoir drawdown to facilitate juvenile outmigration has the potential to affect downstream flow. Providing adequate reservoir releases to maintain suitable water temperatures for migrating chinook salmon during spring and fall would continue to be important.

Agency and organization roles and responsibilities: Evaluating feasibility would be the responsibility of DFG, USFWS, and the appropriate reservoir management authority. Implementation would necessitate cooperation between multiple agencies and water user groups.

Potential obstacles to implementation: The feasibility of this approach has not been evaluated, and the costs of constructing functional fish passage structures for juvenile and adult salmon would probably be high. The suitability of habitat for meeting anadromous salmonid life history requirements in stream reaches above existing reservoirs is not well known. Operation of reservoirs to facilitate fish passage could entail higher water costs than meeting fish flow needs in downstream reaches. Feasibility and cost/benefit analyses would be conducted in the evaluation phase and would determine whether this action presents a viable option for anadromous fish restoration. The types of activities required to move fish around reservoirs may not be consistent with provisions and the intent of Title 34.

Projected benefits: The team believes that providing access to stream reaches above reservoirs could result in increases in natural production that would exceed the goals established under the AFRP. By increasing the quantity of habitat available for spawning and rearing, installation of functional fish passage structures has the potential to reduce the scope of restoration actions required in the reach from Goodwin Dam to the San Joaquin River confluence and reduce costs to other user groups. This action may be essential if restoration efforts are going to benefit steelhead production in the Stanislaus River.

Mainstem San Joaquin River

Limiting factors and potential solutions -

Table 3-Xd-9. Limiting factors and potential solutions for San Joaquin Basin fall-run chinook salmon in the San Joaquin River.

Limiting factors	Potential solutions
1. Direct and indirect impacts of exports at Harvey O. Banks (SWP) and Tracy (CVP) pumping plants on juvenile chinook salmon migrating through the lower San Joaquin River and Delta	1. Increase San Joaquin River flow to facilitate migration of juvenile fish through the lower San Joaquin River and Delta 2. Reduce exports when juvenile chinook salmon are migrating through the lower San Joaquin River and Delta 3. Reduce entrainment by installing the head of Old River barrier during juvenile outmigration 4. Improve survival of fish entrained at fish salvage facilities 5. Reduce or eliminate predators in channels leading to pumps 6. Reduce pumping at night
2. Unsuitable temperatures for juvenile chinook salmon in the mainstem San Joaquin River and Delta	1. Restore riparian and bank vegetation along the mainstem and tributaries 2. Operate reservoirs to reduce the temperature of discharged water 3. Evaluate strategies for reducing temperature by increasing tributary and mainstem outflow during outmigration
3. Entrainment of juvenile chinook salmon at the Patterson, El Soyo, West Stanislaus, and Banta-Carbona diversions on the mainstem San Joaquin River	1. Install and maintain effective screens or other fish exclusion devices during the period when juvenile chinook salmon are migrating through the mainstem San Joaquin River 2. Reduce diversion rates when juvenile chinook salmon are migrating through the mainstem San Joaquin River

Limiting factors	Potential solutions
4. Dissolved oxygen and ammonia barrier to adult migration in the San Joaquin River at Stockton	1. Prohibit dredging in the Stockton ship channel during periods when chinook salmon are migrating through the lower San Joaquin River 2. Establish stronger standards for City of Stockton wastewater discharge 3. Increase flows in the San Joaquin River at Stockton when chinook salmon are present (could include installation of the head of Old River barrier) and monitoring indicates that water quality is unsuitable
5. Effects of legal harvest of migrating adult salmon in the Delta reach of the San Joaquin River from Mossdale to Chipps Island	Extend the prohibition on the harvest of adult salmon from Mossdale downstream to Chipps Island
6. Illegal harvest of adult salmon in the San Joaquin River upstream of Mossdale and in the tributaries from their confluences with the San Joaquin River upstream to the dams	1. Increase law enforcement efforts during periods when adult salmon are in the river 2. Increase general public and angler awareness to improve compliance and encourage reporting of poaching
7. Loss of genetic integrity/diversity	1. Reduce risk by implementing habitat restoration measures 2. Investigate feasibility of establishing a gene bank to ensure preservation of genetic material of San Joaquin River fall-run chinook salmon 3. Selectively harvest hatchery fish 4. Use "natural" fish in captive breeding programs

Limiting factors	Potential solutions
	5. Complete genetic differentiation studies for San Joaquin Basin fall-run chinook salmon stocks 6. Establish a genetic advisory committee to review impacts of hatchery operations and release strategies and examine Merced River Hatchery practices and develop strategies to ensure that further increases in hatchery production do not adversely affect wild stocks. 7. If the decline of San Joaquin chinook salmon continues, and extinction appears imminent, consider hatchery spawning and rearing of wild fish as an interim measure
8. Straying of adult chinook salmon into the mainstem San Joaquin River upstream of the Merced River confluence, and into Salt and Mud Sloughs	1. Continue to install a fall barrier in the San Joaquin River upstream of the Merced River confluence 2. Provide adequate fall attraction flows in the Merced River
9. Entrainment of juvenile chinook salmon at four major diversions and numerous smaller diversions on the mainstem San Joaquin River	1. Reduce or prohibit operation of pumps and diversions at times when juvenile salmon are present 2. Install screens or other protective devices to prevent entrainment when pumps or diversions are being operated
10. Limits imposed by over-allocation of existing water supply	1. Evaluate and, if feasible, establish a conjunctive water use program 2. Pursue opportunities for land fallowing and purchase of water from willing sellers 3. Investigate opportunities for water augmentation

Restoration actions -

Action 1: Implement Vernalis flow schedule (Table 3-Xd-10) or measures that provide equivalent protection for San Joaquin fall-run chinook salmon.

Objective: Provide adequate flow for all life stages of chinook salmon.

Location: San Joaquin River at Vernalis.

Narrative description: The timing, amount, and quality of flow affects the migration and survival of both juvenile and adult chinook salmon. Declines in escapement to San Joaquin Basin tributaries have been attributed to inadequate streamflow in the mainstem San Joaquin River and its tributaries (DFG 1987). During spring, low basin outflow and Delta exports result in both direct and indirect mortality of outmigrating smolts and fry (Reynolds et al. 1993); conversely, higher smolt survival has been observed in years when spring flows in the mainstem river and tributaries have been high (CMC 1994, Reynolds et al. 1993). In some years, upstream migration of adult salmon into San Joaquin River tributaries is delayed because of the lack of attraction flow, elevated water temperatures, and low dissolved oxygen concentration (DOC), which commonly occur in the San Joaquin River in fall (SJRMP1993, DFG 1992). Diversion of water through Delta facilities, Port of Stockton operations, City of Stockton waste discharges, channel dredging, tidal action, and San Joaquin River inflow are important factors that are mediated by flow and that affect survival of outmigrating juvenile salmon. There are no specific flow requirements in place in the mainstem San Joaquin River to meet the needs of migrating salmon.

In estimating Vernalis flow needed to meet the goal of doubling natural production of San Joaquin fall-run chinook salmon, maximum export rates from April through June were assumed to be restricted to one half of the average for the baseline period (1967-1991). If combined state and federal exports were further reduced, the regression equation predicts that doubling could be achieved with lower San Joaquin River flow; conversely, higher export rates would necessitate higher flow. Disadvantages of lower spring flow include elevated water temperatures and reduced habitat quality for juveniles in the tributaries.

Table 3-Xd-10. San Joaquin River flow (cfs) at Vernalis.

		AFRP[a]				
Month	Existing[b]	Wet	Above normal	Below normal	Dry	Critical
October	--	1,450[c]	950[c]	900[c]	700[c]	650[c]
November	--	2,000[c]	1,500[c]	950[c]	900[c]	650[c]
December	--	2,850[c]	2,250[c]	950[c]	950[c]	700[c]

Month	Existing[b]	AFRP[a]				
		Wet	Above normal	Below normal	Dry	Critical
January	--	3,950[c]	2,550[c]	1,100[c]	1,000[c]	750[c]
February	--	5,000[c]	3,900[c]	2,150[c]	1,450[c]	1,050[c]
March	--	5,350[c]	3,900[c]	2,750[c]	2,100[c]	1,850[c]
April	--	12,000[d]	8,250[d]	7,300[d]	5,850[d]	4,450[d]
May	--	18,600[d]	13,700[d]	10,200[d]	7,400[d]	5,200[d]
June	--	17,300[d]	9,750[d]	7,650[d]	4,600[d]	2,950[d]
July	--	4,200[c]	1,700[c]	1,250[c]	650[c]	650[c]
August	--	1,150[c]	800[c]	600[c]	500[c]	450[c]
September	--	1,050[c]	750[c]	650[c]	500[c]	450[c]
Total (taf)	--	4,521	3,019	2,200	1,606	1,196
Baseline (taf)		4,691	3,020	1,609	1,617	1,042
Unimpaired (taf)		10,417	6,830	4,648	3,375	2,361

Note: All flows have been rounded to the nearest 50 cfs. Flow schedule would have to be implemented in conjunction with appropriate export restrictions (Table 3-Xd-11).

[a] Year type based on San Joaquin Basin 60-20-20 Index.

[b] Existing flow requirements dictated by December 15, 1994 Delta Accord.

[c] Sum of flow from the Stanislaus, Tuolumne, and Merced rivers.

[d] Flow required to meet salmon production goals based on the following regression relationship:

$$E_{S,T} = (1.820Q_V)-(0.051X_{F,S})-18,417.3 \text{ (CMC 1994)}$$

where, for a given year class, $E_{S,T}$ is the sum of escapement into the Stanislaus and Tuolumne rivers of 2- and 3-year-olds, Q_V is average San Joaquin River flow (cfs) at Vernalis from April 1 through June 30 in the year of outmigration, and $X_{F,S}$ is total combined monthly exports (af) for the federal (CVP) and state (SWP) water projects from April 1 through June 30 in the year of outmigration. Flow is allocated between April, May, and June on the basis of historical occurrence of unimpaired runoff.

Related actions: Existing flow requirements and flow recommendations for San Joaquin River tributaries. Section 3408(h), purchase of land and water from willing sellers.

Agency and organization roles and responsibilities: Implementation of this action would require cooperation between multiple government agencies and private entities.

Potential obstacles to implementation: Flows are higher than those that have been recommended in other forums. Implementing these flow standards would reduce the quantity of water available to other user groups.

Projected benefits: The San Joaquin Basin Technical Team believes that implementation of the proposed flow schedule, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the lower San Joaquin basin tributaries.

Action 2: Implement proposed export restrictions for the state (SWP) and federal (CVP) Delta pumping plants.

Objective: Reduce direct and indirect mortality of outmigrating San Joaquin chinook salmon smolts.

Location: CVP and SWP pumping plants.

Table 3-Xd-11. Combined maximum exports (cfs)
at SWP and CVP pumping facilities.

Month	Year type[a]				
	Wet	Above normal	Below normal	Dry	Critical
April	6,950[b]	3,950[b]	3,100[b]	2,200[b]	1,550[b]
May	6,950[b]	3,950[b]	3,100[b]	2,200[b]	1,550[b]
June	6,950[b]	3,950[b]	3,100[b]	2,200[b]	1,550[b]
Total (af)	1,254	713	560	397	280

Notes: All exports have been rounded to the nearest 50 cfs.

Restrictions would have to be implemented in conjunction with AFRP flows (Table 3-Xd-10) to double natural production of San Joaquin basin chinook salmon.

[a] Year type based on San Joaquin Basin 60-20-20 Index.

[b] Flow required to meet salmon production goals based on the following regression relationship:

$$E_{S,T} = (1.820Q_V)\text{-}(0.051X_{F,S})\text{-}18{,}417.3 \text{ (CMC 1994)}$$

where, for a given year class, $E_{S,T}$ is the sum of escapement into the Stanislaus and Tuolumne rivers of 2- and 3-year-olds, Q_V is average San Joaquin River flow (cfs) at Vernalis from April 1 through June 30 in the year of outmigration, and $X_{F,S}$ is total combined monthly exports (af) for the federal (CVP) and state (SWP) water projects from April 1 through June 30 in the year of outmigration.

Related actions: Related to flow recommendations. Higher export rates require higher flow at Vernalis to meet production goals. Section 3408(h), purchase of land and water from willing sellers.

Agency and organization roles and responsibilities: Restricting exports would require cooperation between multiple agencies and private entities.

Potential obstacles to implementation: Export restrictions would reduce the quantity of water available to other user groups. Because state pumping facilities are not under the authority of the CVP, there is little incentive for them to adhere to export restriction for the purposes of the AFRP.

Projected benefits: The San Joaquin Basin Technical Team believes that implementing the recommended export restrictions, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in lower San Joaquin Basin tributaries.

Action 3: Establish Stevinson flow standards.

Objective: Manage instream flow to benefit all life stages of chinook salmon.

Location: San Joaquin River at Stevinson (immediately upstream of the confluence with the Merced River).

Table 3-Xd-12. Existing and AFRP-generated flow schedules
for the San Joaquin River at Stevinson (cfs) by year type.

		AFRP[b]				
		Wet	Above normal	Below normal	Dry	Critical
April	--	5,150[c]	2,650[c]	2,050[c]	1,750[c]	1,250[c]
May	--	7,000[c]	4,450[c]	3,050[c]	2,300[c]	1,600[c]
June	--	6,800[c]	3,450[c]	2,600[c]	1,700[c]	1,050[c]
Total (taf)	--	1,141	637	464	347	235

Note: All flows have been rounded to the nearest 50 cfs.

[a] There are no existing flow requirements at this site.

[b] Year type based on San Joaquin Basin 60-20-20 Index.

[c] San Joaquin River contribution to Vernalis flow standard. Based on Vernalis flow standards and the historical percent contribution of the San Joaquin River to total unimpaired San Joaquin Basin runoff.

Related actions: Existing and proposed flow schedules for all tributaries. Section 3408(h), purchase of land and water from willing sellers. Temperature recommendations.

Agency and organization roles and responsibilities: Implementation of this action would require cooperation between multiple government agencies and private entities.

Potential obstacles to implementation: There are no existing flow requirements for the San Joaquin River above the Merced River confluence. Implementing a Stevinson flow standard would reduce the quantity of water available to other user groups. Although Millerton Reservoir, on the mainstem San Joaquin River, is a CVP impoundment, availability of water for the AFRP is uncertain.

Projected benefits: The San Joaquin Basin Technical Team believes that implementation of this action, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the lower San Joaquin basin tributaries.

Action 4: Install and maintain fish protection devices at the Banta-Carbona, West Stanislaus, Patterson, and El Soyo diversions.

Objective: Reduce or eliminate loss of juvenile chinook salmon resulting from entrainment by the four largest diversions on the San Joaquin River.

Location: Banta-Carbona, West Stanislaus, Patterson, and El Soyo diversions on the mainstem San Joaquin River between the Merced River confluence and the Delta.

Narrative description: There are four major unscreened diversions on the mainstem San Joaquin River downstream of the Merced River confluence. The El Soyo diversion has a maximum capacity of 80 cfs, and the Banta-Carbona, Patterson, and West Stanislaus diversions have a maximum capacity of 249 cfs each (Reynolds et al. 1993). Cumulatively, the four diversions are capable of withdrawing a substantial proportion of the total mainstem San Joaquin River flow, particularly during dry water-year types. Although impacts on juvenile chinook salmon are not well documented, there is evidence to suggest they may be substantial (Hallock and Van Woert 1959). Screens installed in the late 1970s were later abandoned; operation of these facilities in the ensuing period is believed to have contributed to low survival of outmigrating juveniles (SJRMP 1993).

The available data for chinook salmon in other systems indicate that downstream movement of fry occurs mainly at night (Healy 1991). To reduce entrainment prior to installation of fish protection devices, interim guidelines restricting pumping an diversion to daylight hours should be adopted.

Related actions: CVPIA screening program (3406[b][21]) required by Title 34.

Agency and organization roles and responsibilities: A DFG survey of unscreened diversions in the San Joaquin Basin is underway. USFWS will be administering a screening program as one element of the CVPIA. Implementation of a San Joaquin Basin screening program would require cooperation between USFWS, DFG, and the Banta-Carbona, West Stanislaus, Patterson, and El Soyo Irrigation Districts.

Potential obstacles to implementation: Screens might reduce efficiency of diversions or require additional maintenance effort on the part of the irrigation districts, although a substantial portion of the costs would probably be covered by funds available under 3406(b)(21).

Projected benefits: The San Joaquin Basin Technical Team believes that implementation of this action, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the lower San Joaquin basin tributaries.

Action 5: Install and maintain fish protection devices at small agricultural diversions.

Objective: Increase survival of juvenile salmon by reducing or eliminating entrainment at small pumps and diversions.

Location: San Joaquin River from the Merced River confluence downstream to the Delta.

Narrative description: Additional small- and medium-sized irrigation diversion on the mainstem San Joaquin River entrain juvenile salmon (Reynolds et al. 1993); cumulative effects are not known but have the potential to be substantial (Reynolds et al. 1993, Hallock and Van Woert 1959).

The available data for chinook salmon in other systems indicate that downstream movement of fry occurs mainly at night (Healy 1991). To reduce entrainment prior to installation of fish protection devices, interim guidelines restricting pumping an diversion to daylight hours should be adopted.

Related actions: CVPIA screening program (3406[b][21]) required by Title 34, install and maintain fish protection devices at major diversions.

Agency and organization roles and responsibilities: USFWS will be administering a screening program as one element of the CVPIA. DFG, which is in the process of conducting an inventory and assessment of San Joaquin Basin diversions, would be the agency likely to implement a screening effort. Cooperation and coordination with USFWS, irrigation districts, and land owners would be necessary.

Potential obstacles to implementation: Fish protection devices might reduce efficiency of diversions or require additional maintenance effort on the part of diverters, although most of the costs should be covered by funds available under 3406(b)(21).

Projected benefits: The San Joaquin Basin Technical Team believes that installing effective fish protection devices at small agricultural diversions, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the lower San Joaquin basin tributaries.

Action 6: Continue the prohibition on sport harvest of chinook salmon in the San Joaquin Basin upstream of Mossdale; extend closure on the mainstem San Joaquin River downstream to Chipps Island.

Objective: Increase spawning success by preventing the harvest of adult chinook salmon escaping into San Joaquin River tributaries.

Location: San Joaquin River upstream from Mossdale and the San Joaquin River tributaries.

Narrative description: When escapement is low, as it has been during the recent years of drought, legal harvest has the potential to remove a substantial percentage of the total number of spawning adults (SJRMP 1993) and, consequently, reduce juvenile production. Many of the adult salmon harvested in the San Joaquin River between Mossdale and Chipps Island are migrating to spawning grounds in the Stanislaus, Tuolumne, and Merced rivers (SJRMP 1993). Harvest of salmon is currently prohibited in the mainstem San Joaquin River upstream of Mossdale and in the tributaries upstream to the dams. The San Joaquin Basin Technical Team recommends extending the closure in the mainstem river downstream to Chipps

Island and leaving the closure in effect until it has been determined that San Joaquin Basin chinook salmon stocks have recovered.

Related actions: Additional law enforcement to reduce illegal harvest.

Agency and organization roles and responsibilities: Implementation of this action would primarily be the responsibility of DFG, although the involvement of local law enforcement authorities would increase chances for success.

Potential obstacles to implementation: Continued prohibition on recreational harvest has the potential to reduce support of anglers' groups for the restoration program.

Projected benefits: The San Joaquin Basin Technical Team believes that maintaining a prohibition on harvest of adult salmon will be necessary for recovery. The team believes that this action, in concert with other actions recommended by the team, would at least double natural production of fall-run chinook salmon in the three lower San Joaquin Basin tributaries.

Action 7: Prohibit the dredging of the Stockton ship channel during critical periods.

Objective: Prevent DOC sag during periods when adult or juvenile salmon are migrating through the lower San Joaquin River and Delta.

Location: San Joaquin River near Rough and Ready Island.

Narrative description: During fall, DOC is commonly low in the San Joaquin River near Stockton (DFG 1993, SJRMP 1993). Adult salmon migration is inhibited by exposure to DOC below 5 parts per million (ppm). Low DOC often results from dredging in the Stockton Ship Channel and turning basin, flow reversals resulting from high Delta exports, and effluent discharge from the Stockton Municipal Sewage Treatment Plant and other sources. DWR installs a rock barrier at the head of Old River in fall to improve DOC levels when the San Joaquin River flow at Vernalis drops below 1,800 cfs. Modifications of sewage treatment plant operation benefitted salmon by improving water quality. However, in fall 1992, a DOC sag occurred in the San Joaquin River near Rough and Ready Island; conditions in the Stockton Deepwater Ship Channel were associated with this oxygen sag.

Related actions: Head of Old River barrier, flow recommendations, and export limits, all of which would improve water quality in the mainstem San Joaquin River.

Agency and organization roles and responsibilities: Preventing future DOC sags in the San Joaquin River near Stockton will require coordination with the Corps regarding restrictions on timing and location of dredging, with DWR for installation of the head of Old River barrier, and with state and local water quality authorities on effects of point- and nonpoint-source discharge.

Potential obstacles to implementation: Lack of funding to adequately address point- and nonpoint-source discharge problems.

Projected benefits: The San Joaquin Basin Technical Team believes that alleviating conditions that lead to development of a dissolved oxygen barrier in the San Joaquin River near Stockton, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the lower San Joaquin basin tributaries.

Action 8: Install the head of Old River barrier.

Objective: Improve water quality for migrating adults and reduce entrainment of outmigrating smolts.

Location: San Joaquin River at the head of Old River.

Narrative description: DWR installs a rock barrier at the head of Old River in fall to improve DOC in the lower San Joaquin River when flow at Vernalis drops below 1,800 cfs (Reynolds et al. 1993). Beginning in 1992, the barrier was installed in spring (April 15-21) (DWR 1992) to reduce diversion and probable entrainment at the CVP and SWP pumping plants of chinook salmon smolts migrating down the San Joaquin River. Feasibility and benefits of the barrier are reduced when San Joaquin River flow is high.

Related actions: Flow recommendation, export restrictions, and measures to prevent DOC sag in the San Joaquin River near Stockton.

Agency and organization roles and responsibilities: DWR would be responsible for implementing this action. DFG and USFWS would be responsible for monitoring to determining benefits and impacts on other fish species.

Potential obstacles to implementation: Potential impacts on Delta smelt and other native species may limit the length of time for which the barrier can remain installed in the spring. It is uncertain what level of protection can be obtained by installing the barrier for only a portion of the period when smolts are actually present and vulnerable to entrainment.

Projected benefits: This action has the potential to improve water quality in the San Joaquin River, facilitate adult migration, and provide protection to outmigrating smolts with reduced water costs. Similar or higher levels of protection can be obtained by implementing recommended flow and export schedules.

Action 9: Establish spring and fall water temperature goals for the mainstem San Joaquin River. Goals would be achieved through a combination of changes in reservoir operations, enhanced flows, and riparian restoration.

Objective: In fall, prevent delays in adult migration and resulting increases in egg and juvenile mortality; in spring, increase survival of outmigrating juveniles by reducing stress and mortality associated with high water temperatures.

Location: San Joaquin River from Merced River confluence to the Delta.

Narrative description: Elevated fall water temperatures in the San Joaquin River are believed to delay upstream migration and spawning (DFG 1992). This may lead to delays in emergence and outmigration of juveniles (DFG 1992) and increase the risk of exposure to stressful or lethal water temperatures. Elevated water temperatures during spring result in conditions that have been found to reduce survival of juvenile salmon (DFG 1992, 1987). DFG has determined that when flow at Vernalis is 5,000 cfs or less in May, water temperatures are at levels associated with chronic stress to salmon (DFG 1987). The effects of such stress are cumulative and increase effects of other mortality factors, such as entrainment/impingement at water diversions, predation, and salvage handling at Delta fish facilities.

Following are recommended water temperature standards that should be maintained to the downstream boundary of the spawning area during fall and the mouth of the river during spring.

Dates	Water temperature
October 15-February 15	56°F
April 1-June 31	65°F

Related actions: Mainstem and tributary flow recommendations and sequential habitat restoration, especially recommendations to restore bank and riparian vegetation. Riparian and instream habitat protection and restoration proposals discussed in Action 4 should further reduce water temperatures.

Agency and organization roles and responsibilities: Implementation of this action would require cooperation and coordination of multiple government agencies and private entities and would probably require acquisition of additional water from willing sellers.

Potential obstacles to implementation: It is anticipated that meeting temperature goals may require greater quantities of water than those indicated by flow recommendations. This would result in a substantial reduction in the quantity of water available for other purposes. Restoration of riparian habitat could reduce the quantity of water necessary to meet temperature standards. Maintaining a water temperature of 65° F during June may not be possible.

Projected benefits: The San Joaquin Basin Technical Team believes that meeting the recommended temperature goals in the San Joaquin River, in concert with other actions recommended by the team, would double production of fall-run chinook salmon in the lower San Joaquin basin tributaries.

Action 10: Establish a basinwide Conjunctive Water Use Program.

Objective: Obtain adequate water to meet anadromous fish flow requirements while minimizing impacts on other water users.

Location: Entire San Joaquin River Basin.

Narrative description:

1) Evaluate benefits and costs of a conjunctive use program, including potential increases in water supply to meet fish needs.

2) Develop and implement a program, ensuring a net gain in water allocated to meeting anadromous fish requirements.

Related actions: Potential to increase the feasibility and reduce impacts of actions involving flow.

Agency and organization roles and responsibilities: Establishing an effective conjunctive use program would require cooperation and coordination between all government agencies and private entities involved in water use or resource management in the San Joaquin River Basin.

Potential obstacles to implementation: Net benefits for anadromous fish may be great but depend on many factors and have not been evaluated.

Projected benefits: A conjunctive use program has the potential to reduce the adverse impacts on other water users of implementing flow recommendations. Such a program may be an essential tool to obtain water needed to meet fish flow needs.

Action 11: Reduce predator populations.

Objective: Increase survival of juvenile salmon by reducing predator populations.

Location: San Joaquin River and tributaries.

Narrative description: Predatory fish such as largemouth and smallmouth bass are a potential cause of increased mortality of rearing and outmigrating salmon. Abandoned gravel pits on the tributaries provide excellent habitat for these species (Reynolds et al. 1993).

Following are the elements of this action:

1) Increase sport harvest of predators, primarily largemouth bass.

2) Reduce predator habitat, primarily abandoned gravel pits and other pools that are connected to river channels.

Related actions: Sequential habitat restoration on San Joaquin River tributaries; ongoing DWR/DFG habitat restoration efforts (DWR 1994).

Agency and organization roles and responsibilities: Increasing harvest would primarily be the responsibility of DFG. Reducing predator habitat would require cooperation and coordination between various agencies and riparian land owners.

Potential obstacles to implementation: Potential objection from some segments of the angling population. May not be practical or even possible. Magnitude of problems and benefits resulting from implementing this action are poorly documented.

Projected benefits: Impacts of predation on juvenile salmon are not known but are believed to be substantial under some conditions. Predation is generally lower when flow is high.

E. SACRAMENTO-SAN JOAQUIN DELTA

General Approach

The goal of the Delta Salmon and Steelhead Technical Team was to develop a list of actions that would double baseline (1965-1989) salmon smolt survival in the Delta for all races of chinook salmon. It is likely that as smolt survival increases, resulting adult production two and a half years later (1967-1991) will also increase.

Although we know that salmonid fry may rear in the Delta for up to several months (Kjelson et al. 1982), limiting factors for fry are generally not well understood. Relative comparisons between upper river and Delta fry survival have been made, but the relative importance of fry rearing in the Delta compared with that upstream has not been quantified (USFWS 1987).

Additionally, very little information exists on the limiting factors for adult salmon and steelhead migrating upstream through the Delta (Hallock 1970).

Although it is theoretically possible to double adult production by only doubling smolt survival in the Delta, actions that would benefit all life stages of salmonids (including steelhead) in the Delta were preferentially selected. In most cases the limiting factors and potential solutions identified for salmon smolts are likely to be similar for all salmonid juveniles rearing and/or migrating through the Delta. In cases in which the unique needs of the different salmonid life stages were known, they were incorporated into the list of actions, but there may be other areas that have not been adequately explored or addressed.

No action items targeted to improve juvenile salmonid survival were recommended for July-September because very few juveniles are present in the Bay or Delta during those months, presumably because of high water temperatures in the Delta that may be lethal to salmon (USFWS 1987).

Smolt survival between 1965 and 1989 was estimated using Delta salmon survival models that relate habitat conditions in those years to survival. Two separate models have been used, one for smolts emigrating from the Sacramento River (Kjelson et al. 1989, USFWS 1992a) and one for smolts emigrating from the San Joaquin River (Brandes 1994). The models are based on survival indices generated from coded-wire-tagged (CWT) fall-run hatchery smolts released at various locations in the Delta and recovered within a few weeks after release by midwater trawl at Chipps Island. Survival indices were calculated based on the number recovered at Chipps Island corrected for effort in both time and space (USFWS 1987).

Both models split the Delta into various reaches and use backward-stepping multiple-regression analyses to identify environmental variables (exports, flows, and temperature) important to survival in each reach. Professional judgment by the authors was used to some extent in choosing which variables were considered.

Both the Sacramento and San Joaquin models assume that smolts enter the various reaches of the model in the same proportion as flow.

The Delta smolt survival model, developed for fall-run smolts emigrating from the Sacramento River Basin, has been slightly modified to better index survival of Sacramento River juvenile winter-run and late fall-run, and Mokelumne River fall-run chinook salmon in the Delta. The equations used for each reach of the Sacramento and San Joaquin models and the modifications made for the various races are listed in Table 3-Xe-1. Temporal distribution in the Delta for each race of juvenile chinook salmon used to estimate annual Delta survival is listed in Table 3-Xe-2. Although none of the models estimate absolute survival, they are our best tool for obtaining an index of baseline survival, integrating the various action items, and determining what is needed for doubling survival.

Table 3-Xe-1. Formulas used in the models to calculate mortalities

Fall run, Sacramento	
Dayflow and Operation Study	
m1	(-2.45925+(0.0420748*Freeport temp)
m2	(-0.5916024)+(0.017968*Freeport temp)+(4.34E-05*(CVP+SWP))
m3	(-1.613493+(0.0319584*Freeport temp))
m23	((M2*P2)+(M3*(1-P2))
m123	(M1+M23-(M1*M23))
s123	(1-M123)
Late fall run, Sacramento	
Dayflow and Operation Study	
m1	(-2.45925+(0.0420748*Freeport temp)
m2	(-0.5916024)+(0.017968*Freeport temp)+(5.4E-05*(CVP+SWP))
m3	(-1.613493+(0.0319584*Freeport temp))
m23	((M2*P2)+(M3*(1-P2))
m123	(M1+M23-(M1*M23))
s123	(1-M123)
Winter run, Sacramento	
Dayflow and Operation Study	
m1	(-2.45925+(0.0420748*Freeport temp)
m2	(-0.5916024)+(0.017968*Freeport temp)+(5.4E-05*(CVP+SWP))
m3	(-1.613493+(0.0319584*Freeport temp))
m23	((M2*P2)+(M3*(1-P2))
m123	(M1+M23-(M1*M23))
s123	(1-M123)

Fall run, Mokelumne	
Dayflow and Operation Study	
m1	0.000
m2	(-0.5916024)+(0.017968*Freeport temp)+(4.34E-05*(CVP+SWP))
m3	0.000
m23	(M2*1)+(M3*(1-1))
m123	(0+M23-(0*M23))
s123	(1-M123)
Fall run, San Joaquin	
Dayflow and Operation Study	
m2	(1.01045-3E-05*Upper Old River Flow)
m3	(0.87634-7.1E-05*Stockton low)
m4	(-3.65867+0.058492*Jersey Pt temp+5.1E-05*(CVP+SWP))
m34	(M3+M4)-(M3*M4)
m234	(P2*M2)+(P3*M34)
s234	(1-M234)

Table 3-Xe-2. Assumed temporal distributions, by percent, of fall-, late fall-, and winter-run chinook salmon for the Sacramento, Mokelumne, and San Joaquin rivers. Distributions were input to survival models.

Race	River	Month							
		Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Fall run	Sacramento	0	0	0	0	0	17	65	18
	Mokelumne	0	0	0	0	0	17	65	18
	San Joaquin	0	0	0	0	0	45	55	0
Late fall run	Sacramento	25	50	25	0	0	0	0	0
Winter run	Sacramento	0	0	0	13	57	30	0	0

The models indicate that survival in the Delta cannot be doubled for Sacramento fall-, winter-, and late fall-run and Mokelumne River fall-run stocks of chinook salmon. The team believed that the Sacramento model underestimates the benefits associated with the elimination of CVP and SWP exports because many limiting factors for all juvenile salmonid life stages would cease to exist. Therefore, the team believed that if CVP and SWP exports were eliminated, juvenile salmonid survival in the Delta would likely greatly increase and adult production could potentially double. Although this was the technical team's first recommendation as the most likely to ensure doubled survival in the Delta, the team recognized the need to provide minimal exports to satisfy health and safety concerns. We have assumed that these health and safety concerns would be satisfied with combined CVP and SWP exports of 1,200 cfs.

For the races of juvenile salmon for which we were unable to double survival, we have proposed a combination of action measures that would have the greatest effect toward the doubling goal.

In some cases, restoration actions were not limited to the variables contained in the models. If available evidence indicated that there were other needs of salmonids in the Delta, restoration actions were developed to address these factors. Flow toward the western Delta (QWEST) is an example of this deviation. Many of the parameters selected as action items are similar to recommendations made in past reports by biologists familiar with juvenile salmon data from the Delta (USFWS 1992b).

In an effort to provide relevant information on the value of a specific action, we have summarized data in the narrative description. Although much of these data are included in the models that integrate many of the action items, we believed it was more straightforward to rely solely on the specific experiments and resulting data to justify the specific actions.

The smolt survival model for smolts emigrating from the San Joaquin River indicates that doubling baseline smolt survival in the Delta would be possible, and we have therefore proposed an action to achieve this, based on model simulations.

As noted initially, the Delta fish habitat team has attempted to meet the goal of doubling salmon production using only Delta restoration actions without considering potential benefits of upstream actions. This approach was taken to ensure that the goal of *at least* doubling production would be met. It is possible that a combination of Delta and upstream restoration actions could also achieve the goal of doubling production, but analysis of such a combination of actions has not been completed and is complicated by our inability to quantify the benefits of restoration actions both upstream and in the Delta. Further difficulties arise from other aspects of the population status and the time frame for meeting the restoration goal.

One could argue that, theoretically, if Delta actions provided salmon survival through the Delta at levels of the 1965-1989 baseline period and if upstream actions yielded a doubling of production there, the goal of doubling would be achieved. As additional knowledge is gained on the benefits of restoration actions, we will be better able to define how a combination of Delta and upstream actions can best meet the restoration goals.

There may be potential for compounding benefits resulting from restoration actions in both the Delta and upstream areas: improved salmon production one year could reflect greater production the next year and so on, if more adults return to unsaturated spawning grounds and harvest remains stable. Unfortunately, we do not know what potential there is for a compounding process to be realized, but even if such compounding is possible in part, it could allow the doubling production goal to be met more quickly or with less aggressive actions than if no compounding occurred.

It also should be noted that during a period of decline (as all natural Central Valley anadromous salmonid stocks are experiencing), compounding of negative effects may be occurring. Prompt action is imperative, and the longer declines are allowed to continue, the greater the magnitude of increase in production needed to realize the same benefit.

Limiting factors and potential solutions

Many of the limiting factors observed in the Delta are known or hypothesized to be either directly or indirectly related to exports. Indirect losses are defined as juvenile salmon mortalities attributed to the CVP and SWP export process that occur in the Delta outside the CVP intake and the entrance to the SWP's Clifton Court Forebay. These losses are considered to be of much greater magnitude than the direct losses; thus, they have been identified first in Table 3-Xe-3. These indirect losses are primarily tied to the increased diversion of juvenile salmon off the mainstem rivers and the higher mortality in the central and south Delta. The CVP and the SWP have actually increased the amount of water being diverted into the central and south Delta and are hypothesized to be responsible (at least in part) for the higher mortality observed in the central and southern Delta. The most likely mechanism for the increased mortality is the increase in reverse flows in the central and southern Delta (USFWS 1987, 1992b). In addition to these indirect losses, many direct losses result from CVP and SWP pumping and are listed in the Table 3-Xe-3.

Although some limiting factors cause mortality and lessen production, we have not included them as necessitating key actions critical in gaining the most benefit toward doubling survival. However, when the final restoration program is developed, all actions that are feasible and reasonable, however small their benefits, should be taken to aid in restoration.

Table 3-Xe-3. Key limiting factors in order of importance and potential solutions for chinook salmon and steelhead in the Delta.

Limiting factors	Potential solutions
1. Mortality of juvenile salmonids indirectly resulting from CVP and SWP impacts: (a) Increased diversion of juvenile salmon into the central and south Delta (where mortality is high) as a result of:	1. Prevent or decrease the number of juvenile salmon diverted off the mainstem rivers into the central and south Delta by: - closing the DCC gates (November-June); - increasing Delta inflow;

Limiting factors	Potential solutions
- construction of the Delta Cross Channel (DCC) for water conveyance by USBR in 1951, allowing a greater percentage of flow (and presumably juvenile salmon) to be diverted; - lower spring Delta inflows causing a higher proportion of flow to be diverted into the central and south Delta (Rick Oltman pers. comm.); - exports causing the percentage of flow diverted into upper Old River to increase (DWR pers. comm.); and - increased net flow toward the pumping plants	- reducing or eliminating reverse flows; - installing an acoustical barrier in Georgiana Slough; or - installing a full barrier at the head of upper Old River during the spring migration of San Joaquin smolts through the Delta
(b) Relatively high juvenile mortality in the central and south Delta, presumably resulting from: - inability of juveniles to "find" their way to the ocean as a result of net reverse flows and complex channel configurations; - a longer migration route (increased exposure time to mortality factors, such as predation); and	2. Increase survival in the central Delta by: - severely curtailing or eliminating CVP and SWP exports during the period when salmon are using the Delta (November-June); or - reducing or eliminating reverse flows by increasing San Joaquin River flows

Limiting factors	Potential solutions
- exposure to higher (relative to mainstem) spring water temperatures	
(c) Reduction of shallow-water and riparian habitat as a result of dredging and scouring in water conveyance channels and bank stabilization efforts (removal of riparian vegetation and bank armoring)	3. Increase riparian vegetation and decrease or eliminate bank stabilization efforts
(d) Reduction of spring inflow into and out of the Delta (causes decreases in transport flows for migration and increased temperatures as a result of upstream storage and diversion)	4. Increase Delta inflows
2. Mortality of juvenile salmonids directly resulting from CVP and SWP pumping plant impacts	1. Severely curtail or eliminate CVP and SWP exports during the period when salmon are using the Delta for rearing and migration (November-June) 2. Screen Clifton Court Forebay and combine the CVP and SWP diversion points
3. Substantial losses that occur as a result of the following factors, although the export facilities for both the CVP and the SWP include fish salvage facilities designed to prevent the loss of entrained fish: - Prescreen losses occur at the	3. Implement measures to reduce entrainment, handling, transport, and release losses associated with present facilities

Limiting factors	Potential solutions
trash racks of both fish facilities and in Clifton Court Forebay - The screen (louvers) systems at both facilities are less than 100% efficient in bypassing juvenile fish to the holding facilities - Losses occur with the bypass and holding facilities as a result of predation, debris, and other factors - Some losses occur during handling and trucking - Survival after release may be reduced by enhanced predatory fish densities at release sites	
3. Poor survival of San Joaquin smolts resulting from low San Joaquin River flows in the Delta	Increase flows at Vernalis
4. Poor water quality: (a) Mortality of fall-run smolts resulting from high spring water temperatures (b) Low dissolved oxygen at Stockton inhibiting migration of San Joaquin River fall-run adults	1. Decrease water temperature: - Restore riparian vegetation along Delta channels - Continue to evaluate ways to reduce Delta water temperatures 2. Increase dissolved oxygen levels at Stockton - Increase flows at Vernalis

Limiting factors	Potential solutions
	- Install the barrier at the head of upper Old River between September and December (DFG pers. comm.)
(c) In-Delta agricultural and industrial return flows of poor quality and a source of toxics	3. Reduce toxics - Reduce or eliminate agricultural drain water in or above the Delta - Treat agricultural runoff before it is returned to the river - Increase flows
5. Entrainment at in-Delta agricultural, municipal, and industrial diversions	1. Eliminate in-Delta agricultural and industrial diversions 2. Screen in-Delta diversions 3. Curtail diversions during critical periods
6. Other factors (losses from these other factors are exacerbated when populations are low and stressed as a result of the other limiting factors mentioned above): (a) Competition between natural and hatchery stocks	Keep natural salmonid populations as high and ecosystem as healthy as possible by providing favorable environmental conditions. Also, the following actions could be taken: - Investigate interactions between hatchery and natural stocks to ensure that natural stocks are not being displaced
(b) Interaction with exotic species	- Prevent introduction of exotic species into the system by supporting ballast water legislation, strict enforcement, and other measures
(c) Illegal fishing of races of low	- Continue education and enforcement to

Limiting factors	Potential solutions
abundance	reduce poaching

Restoration actions -

Action 1: Provide protection from direct and indirect impacts of CVP and SWP exports for juvenile salmonids migrating through the Delta from November 1 through June 30, equivalent to protection provided by restricting exports to minimal levels (those needed for health and safety, estimated at 1,200 cfs total).

Objective: Increase in-Delta survival of all juvenile salmonid life stages (and potentially adults) affected by CVP and SWP exports. These include juveniles migrating through the Delta using the mainstem rivers as well as juveniles diverted into the central and southern portions of the Delta and juveniles emigrating from the San Joaquin Basin.

Location: CVP's Tracy and SWP's Harvey O. Banks pumping plants.

Narrative description: Because there are a variety of limiting factors for juvenile salmonids in the Delta related to both the indirect and direct impacts of CVP and SWP pumping, the most comprehensive solution to Delta problems under the present system of using Delta channels for water conveyance would be to eliminate all CVP and SWP exports. As mentioned above, the team realized this was impractical and the final action item has allowed for minimal exports.

The effects of exports are most acute for San Joaquin Basin juveniles migrating through the Delta and for Sacramento Basin juvenile salmon diverted into the central Delta via the DCC, Georgiana Slough, and Threemile Slough.

Fall-run CWT smolts released in the North Fork, South Fork, and lower Mokelumne River show lower survival indices to Chipps Island than are shown by groups released in the mainstem Sacramento River (Ryde). Even lower survival is observed for smolts released into the southern Delta (lower Old River) (Table 3-Xe-4). In general, indices of survival appear to decline the closer the smolts are released to the CVP and SWP pumps. In contrast, salvage rates at the fish facilities tend to be greater the closer the smolts are released to the pumps. Even though smolts released near the pumping plants are salvaged in greater numbers, survival to Chipps Island is lower.

Table 3-Xe-4. Survival indices of CWT fall-run chinook salmon smolts released at several locations in the Delta from 1983 to 1986 and recovered by trawl at Chipps Island.

Release site	1983	1984	1985[a]	1986[a]

Above diversion[b] (Courtland gates open)		0.70	0.32 (0)	0.35 (8)
Above diversion (Courtland gates closed)	1.23			
Below diversion[c] (Ryde gates open)		0.73	0.77 (0)	0.68 (0)
Below diversion (Ryde gates closed)	1.39[d]			
N. Fork Mokelumne River[e]		0.56	0.28 (14)	0.37 (0)
S. Fork Mokelumne River[e]		0.70	0.23 (89)	0.26 (372)
Lower Mokelumne River[f]	1.17			
Lower Old River[g]	0.35	0.16	0.21 (14,774)	0.25 (6,190)

[a] Expanded fish facility (SWP/CVP) recoveries are included in parentheses for 1985 and 1986. No comparable fish facility sampling was conducted in 1983 and 1984.

[b] Release site 3.5 miles above Walnut Grove on the Sacramento River (Courtland site).

[c] Release site 3.0 miles below Walnut Grove on the Sacramento River (Ryde site).

[d] Release site at Isleton.

[e] Release site at Thornton Road.

[f] Release site 2 miles above the junction with the San Joaquin River.

[g] Release site at the southeast corner of Palm Tract.

This difference in survival between fall-run smolts released in the central Delta versus those released in the mainstem Sacramento River has been additionally confirmed by the results of paired CWT groups released at Ryde and in Georgiana Slough in 1992 and 1993. In six sets of experiments using fall-run and late fall-run CWT juvenile salmon, survival of smolts released at Ryde averaged 4.7 times greater than for corresponding groups of smolts released into Georgiana Slough. The difference ranged between 2.9 times and 8.3 times greater for the Ryde groups. Expanded salvage estimates at the CVP and SWP fish facilities are usually greater for smolts released at Georgiana Slough than for those released at Ryde (Table 3-Xe-5).

Table 3-Xe-5. Release dates, mean fork length (FL) of release groups, survival index (S), survival ratios, and expanded numbers of fish counted at federal (CVP) and state (SWP) salvage facilities from studies conducted with CWT fall-run (F) and late-fall-run (LF) chinook salmon smolts, April 6, 1992, through December 2, 1993.

Date	Race	Ryde releases			Georgiana Slough releases			Ryde/ Georgiana survival ratio
		FL (mm)	S	CVP/SWP	FL (mm)	S	CVP/SWP	
4/6/92	F	77	1.36	0/34	74	0.41	10/4	3.30
4/14/92	F	82	2.15	0/0	81	0.71	12/8	3.00
4/27/92	F	81	1.67	0/0	83	0.20	1/4	8.30
4/14/93	F	61	0.41	0/0	63	0.13	0/24	3.15
5/10/93	F	75	0.86	0/0	75	0.29	15/36	2.96
12/2/93	LF	129	1.95	0/9	119	0.28	93/149	7.71
								Avg. = 4.7

In most years, a very low percentage of the smolts released into the central and south Delta can be accounted for by expanded recaptures at Chipps Island and the fish facilities. These data also tend to support our conclusion that indirect losses are greater than the direct losses associated with the projects.

The mechanism behind the lower survival observed for smolts released in the central Delta is not well understood. Greater spring water temperatures in the central Delta relative to those in the mainstem Sacramento River, in combination with increased exposure time to those temperatures, are a problem for fall-run smolts diverted into the central Delta. However, the lower survival in the central Delta was also observed for late fall-run yearlings released in December, when temperatures were low (51°F) and predation would likely be less. Perhaps this indicates that changes in central Delta hydrology (reverse flows, net flows to the pumps, etc.) may be the most important contributor to the high central Delta mortality. The central and southern Delta also are characterized by a complex of channels exposed to tidal hydrology, adding to the diverse flow patterns salmon must face through that part of the Delta, even when flows are not reversed because of export pumping.

Although toxics may contribute to increased mortality in the central Delta, it is not thought to be the a major limiting factor because the CWT smolts used in our experiments were in the Delta for only a short time (average of 2-4 weeks) before recovery. Although reducing toxics via regulation or curtailment of agricultural return flows would be beneficial to salmon, it is unclear whether reducing or eliminating toxics would substantially contribute toward the doubling goal. Thus, no action item for the reduction of toxics is included in our recommended actions.

The longer migration route through the central and southern Delta exposes the smolts to a combination of mortality factors (such as predation and/or entrainment) for a longer time. It is likely that this accounts for at least part of the increased mortality observed for CWT smolts released into the central Delta. However, the route the smolts take once they get into the central Delta may be affected by project exports through reverse flows in the central and southern Delta.

Although the exact mechanisms for the high mortality in the central and southern Delta are unclear, it was the team's belief that eliminating exports would likely result in major benefits to juvenile salmon in the Delta. Reducing exports to 1,200 cfs would result in lesser benefits, which would likely be substantial as well, however.

Smolts migrating through the Delta that originate in the San Joaquin Basin are specifically subjected to diversion towards the pumping plants via upper Old River. Survival of smolts allowed to stay in the main San Joaquin River is about 2 times greater than that of smolts diverted into upper Old River (USFWS 1993). In high-flow years many of the CWT smolts released into upper Old River are observed in the salvage at the fish facilities, but during dry years very few even reach the fish facilities (USFWS 1993). It is unclear why this is the case or if it is related to the export pumps. Salvage numbers in the late 1980s and early 1990s have been much lower than those in the early 1980s. It is possible that the recent continued drought has caused the southern Delta to be more inhospitable to migrating salmon.

It is clear, however, that the export pumps do increase the amount of San Joaquin flow diverted toward the pumping plants at the upper Old River junction (DFG, Exhibit 15, July 1987). Presumably more salmon smolts are also diverted off the San Joaquin River as well, into an area where survival has been shown to be lower.

Related actions that may impede or augment the action: The closure of the DCC gates, combined with increases in net downstream flow from the San Joaquin River (QWEST), would further improve survival. In addition, storing increased amounts of water in upstream reservoirs would likely impede the action, while increasing Delta inflow (up to unimpaired levels) would likely augment the action.

Agency and organization roles and responsibilities: USBR and DWR are responsible for reducing exports.

Potential obstacles to implementation: Exports from the Delta provide water for agricultural and domestic use in the San Joaquin Valley and southern California. There is a reluctance to limit exports to the extent recommended.

Predicted benefits: Restricting exports to minimal levels (1,200 cfs) between November and June would decrease both the direct and indirect losses of juvenile salmon. The benefits are expected to be significant and by itself, this action could potentially double Delta survival for juvenile salmonids. Monthly average SWP and CVP exports have been as great as 11,000 cfs in some months during the baseline period (1965-1989). Future exports may likely be greater in some months.

Other items considered but not recommended: The team did not choose to recommend measures to reduce the loss of entrained fish at the CVP and SWP export facilities. The team believed that measures to reduce entrainment losses would have small population benefits relative to severely reducing exports, closing the DCC gates, and increasing San Joaquin and QWEST flows because the greatest losses are indirect and occur before the fish actually get to the fish facilities or Clifton Court Forebay (P. Coulston, DFG, pers. comm.).

The team also did not choose to identify an isolated Delta facility (DWR 1974) as a potential solution to the indirect and direct impacts of SWP and CVP pumping because benefits from its operation could not be realized for at least a decade. Additionally, with an estimated 15% loss associated with the facility's screens, operation of the facility would not improve Sacramento smolt survival as much as the combination of recommended actions.

The isolated Delta facility may have substantial benefits for smolts emigrating through the Delta that originate in the San Joaquin Basin. Based on past data on fish released at Mossdale, it is believed that benefits would likely depend on the amount of San Joaquin flow entering the Delta at Mossdale and the amount reaching the western Delta (Brandes 1994, DWR 1994). Many biologists believe that operation of an isolated Delta facility with proper flow criteria and operational conditions is likely to have better potential to increase survival of all species in the Delta than the continued present mode and amount of export.

Action 2: Close the DCC gates from November 1 to June 30.

Objective: Increase the survival of smolts migrating down the mainstem Sacramento River by reducing the number diverted into the central and southern Delta.

Location: DCC.

Narrative description: As juvenile salmon migrate through the Delta, they encounter several channels such as the DCC, Georgiana Slough, and Threemile Slough, that divert water off the mainstem Sacramento River. Significant amounts of the downstream flow during dry years is diverted into these channels. For example, when flows at Walnut Grove are approximately 10,000 cfs, the DCC and Georgiana Slough together divert approximately 70% (USFWS 1987). The DCC and Georgiana Slough are used to convey high-quality Sacramento River water to the CVP and SWP pumping plants in the southern Delta. The water diverted through these two major diversion channels moves into the central Delta and is then directed to the southernmost part of the Delta, where the pumping plants are located. Many juveniles are inadvertently diverted with the flow into the central Delta away from their main migration path on the Sacramento River. It should be noted, however, that without project pumping, habitat throughout the central and southern Delta for both migrating smolts and rearing fry likely would be improved and diversion into these areas would be less detrimental (and perhaps even a benefit) to their survival.

Mark-and-recapture studies using fall-run hatchery smolts have found that salmon smolts diverted into the central Delta via the DCC and Georgiana Slough have much lower survival than those migrating down the mainstem Sacramento River. Trawl recovery at Chipps Island of CWT salmon smolts released between 1984 and 1989 above and below the open DCC and Georgiana Slough have shown that, on average, smolt survival is about 3.3 times greater when smolts are released below both diversion channels. Similar experiments with CWT smolts in 1983, 1987, and 1988 revealed that survival of smolts released below the closed DCC and Georgiana Slough was about 1.1 to 2.4 times greater (average of 1.5 times greater) than survival of fish released above the closed DCC and Georgiana Slough (Table 3-Xe-6). We have subsequently found the same trends in survival for fish released above and below the DCC and Georgiana Slough with the gates open and closed (difference of 2.2 times and 1.2 times, respectively) using an index of survival based on recoveries of these marked fish as adults in the ocean fishery (Table 3-Xe-7).

Table 3-Xe-6. Comparisons of the survival indices (S_T) for CWT Chinook smolts released in the Sacramento River above and below the DCC and Georgiana Slough diversion channels between 1983 and 1989.

Channel condition	Year	Above[a]	Below[b]	Below/above
Open	1984	0.70	0.73	1.0

Channel condition	Year	Above[a]	Below[b]	Below/above
	1985	0.32	0.77	2.4
	1986	0.35	0.68	1.9
	1987	0.44	0.88	2.0
	1988	0.73	1.27	1.7
	1988[c]	0.02	0.34	17.0
	1989	0.84	1.20	1.4
	1989	0.35	0.48	1.4
	1989[d]	0.22	0.16	0.7
				Avg. = 3.3
Closed	1983	1.23	1.39	1.1
	1987	0.66	0.80	1.2
	1988	0.68	0.92	1.4
	1988	0.17	0.40	2.4
				Avg. = 1.5

[a] Courtland site (3.5 miles above Walnut Grove).

[b] Ryde site (3.0 miles below Walnut Grove).

[c] Temperatures at release were 76°F and 75°F for Courtland and Ryde, respectively.

[d] The Ryde group survival seemed unusually low compared to Ryde releases in other years.

Table 3-Xe-7. Ocean recovery rates for fall-run CWT chinook salmon smolts released above and below the DCC and Georgiana Slough from 1983 to 1989 and ratios of survival indices for smolts released above and below these channels.

Channel condition	Year	Above	Below	Below/above
Open	1984	.0058	.0042	.72

Channel condition	Year	Above	Below	Below/above
	1985	.0036	.0085	2.36
	1986	.0161	.0194	1.20
	1987	.0142	.0201	1.42
	1988 (May) (June)	.0091 .0007	.0249 .0053	2.74 7.60
	1989	.0049 .0008 .0009	.0082 .0016 .0002	1.67 2.00 .22
				Avg. = 2.21
Closed	1983	.0039	.0038	.97
	1987	.0196	.0312	1.59
	1988 (May) (June)	.0114 .0097	.0202 .0046	1.77 .47
				Avg. = 1.2

The similarity between survival indices of smolts released at Courtland with the DCC gates open and those released in the central Delta (Table 3-Xe-6) indicates that significant numbers of salmon smolts are diverted into the DCC and Georgiana Slough.

As discussed previously under Action 1, the lower survival rate of smolts diverted into the central Delta is evident when survival indices from CWT smolts released in the central Delta are compared with those of smolts released at Ryde on the mainstem Sacramento River downstream of the DCC and Georgiana Slough (Table 3-Xe-6).

Although we are uncertain of the exact percentage of smolts reaching Walnut Grove that are diverted, it appears from all the available data that many smolts are in fact diverted into the central Delta and their survival is lower than survival of smolts in the mainstem Sacramento River.

Related actions that may impede or augment the action: Net western Delta flow (QWEST) cannot be reduced (below the flow during the CWT experiments) or the benefit observed from the DCC gate closure will be reduced.

Agency and organization roles and responsibilities: USBR is responsible for operation of the DCC gates.

Potential obstacles to implementation: The action may cause water quality problems in the central Delta for agriculture and resident fish populations.

Other actions considered but not recommended: Another structural solution was evaluated by the team but was not recommended because implementation and sequential benefits would be at least a decade away; this solution was a new, gated, screened diversion from the Sacramento River to the Mokelumne River with adequate downstream flow and provision for upstream migrants with the permanent closure of the DCC and Georgiana Slough. This is somewhat similar to the isolated facility concept, but the central Delta would continue to be used for water conveyance with its negative impacts on fish present in the central and southern Delta.

One of these structural actions may in the future be determined to be the best long-term solution, but the team acknowledged that significant improvements for juvenile salmon were needed immediately and operational changes could provide immediate benefits. There is also the need to further define these structural solutions so that benefits can more accurately be assessed.

The acoustical (or physical) barrier in Georgiana Slough to prevent diversion of smolts into areas of high mortality was also not selected as a recommended action because of anticipated negative effects on other species and the general experimental nature of this barrier. Benefits resulting from decreases in export and the closure of the DCC gates are more certain and are recommended instead for attaining the desired increases in survival. If study results warrant the use of an acoustical (or physical) barrier in Georgiana Slough and no impacts on other species are expected, then we as a group would support its use, especially in combination with the other recommended actions.

Additionally, the sole use of a barrier at the head of upper Old River during spring was not endorsed by the team because of its apparent negative effects on other species (Delta smelt and winter-run chinook salmon). However, if significant augmentation of Vernalis flow and meaningful export curtailments are instituted simultaneously, likely negative effects on other species would be minimized and salmon smolt survival would likely be improved with the barrier. The barrier does not appear to substantially improve survival through the Delta, even when exports are low, if flows are not significantly augmented simultaneously (DWR 1994).

Predicted benefits: Closing the DCC gates appears to generally increase survival of smolts arriving at Walnut Grove by 36%-200%. The absolute benefits are estimated to be less when temperatures are higher and flows are lower (although the percentage increase is higher) and are estimated to be greater when flows are high and temperatures are lower.

Action 3: Maintain positive QWEST flows, or an equivalent measure of net seaward flows at Jersey Point, of 1,000 cfs in critical and dry years, 2,000 cfs in below- and above-normal years, and 3,000 cfs in wet years from October 1 through June 30.

Objective: Increase survival of smolts migrating down the mainstem rivers, decrease the number of smolts diverted into the central Delta, increase the survival of smolts diverted into the central Delta, and provide attraction flows for San Joaquin Basin adults (October-December).

Location: Flows are presently calculated for QWEST. Measured flows would be preferable.

Narrative description: Upon reaching the mouth of the Mokelumne River on the lower San Joaquin River, juvenile salmon diverted into the central Delta are often exposed to upstream flow (reverse flows) that moves the net flow easterly in the San Joaquin River and toward the south via Old and Middle rivers. These reversals of flow are exacerbated during periods of high pumping. Susceptibility to diversion into Clifton Court Forebay or entrainment at the CVP and SWP pumping plants is also more likely for fish migrating through the central and southern Delta than for those migrating down the mainstem Sacramento River, presumably because of these reverse flows. Reverse flows also make it less likely that smolts originating in the San Joaquin Basin will successfully reach the ocean.

Fall-run CWT fish released in the lower San Joaquin River at Jersey Point between 1989 and 1991 showed that after corrections for temperature at release, reverse flows in the San Joaquin River at Jersey Point appeared to decrease the survival of smolts migrating through the lower San Joaquin River ($r=0.76$, $p<0.10$) (USFWS 1992b).

Also, reverse flows in the western San Joaquin River and diversion into the central Delta through Threemile Slough may be the reason for survival being less for fall-run CWT fish released at Ryde between 1984 and 1992, when flow at Jersey Point (QWEST) was negative. The relationship between smolt survival and flow at Jersey Point (QWEST) is apparent when QWEST flows are between -3,000 to +2,000 cfs ($r = 0.75$, $p<0.01$) (P.Brandes, USFWS, pers. comm.).

Related actions that may impede or augment the action: Export limits and DCC gate closure would result in a survival increase greater than the increase resulting from the improvement of reverse flows alone.

Agency and organization roles and responsibilities: USBR and DWR would be largely responsible for a change in QWEST because it is related to exports and Delta inflow. Water users on the San Joaquin and Sacramento rivers may also be partially responsible for contributing to Delta inflow.

Potential obstacles to implementation: This action may inhibit exports and may require additional flow from the San Joaquin River.

Predicted benefits: Since 1978, only a few CWT smolts released at Ryde have been observed at the CVP and SWP salvage facilities, although up to several hundred from central Delta releases have been observed (USFWS 1987). This suggests that, even though smolts remaining in the Sacramento River are exposed to net reverse flows in the western San Joaquin River through their potential movement through Threemile Slough or around the tip of Sherman Island, they appear to be affected to a much lesser degree than are those smolts diverted into the central Delta via the DCC and Georgiana Slough.

We believe that increasing QWEST flows up to a minimum of 3,000 cfs in wet years will allow the benefits from the other recommended actions to be maximized. All races and stocks of juvenile salmon and steelhead using the Delta for rearing and as a migration corridor could benefit from this action.

Action 4: Increase mean monthly flow at Vernalis to 4,500 cfs, 6,000 cfs, 8,000 cfs, 12,000 cfs, and 21,000 cfs in critical, dry, below-normal, above-normal, and wet year types (60-20-20), respectively, during the smolt migration period.

Objective: Increase the survival of smolts migrating through the Delta that originate in the San Joaquin Basin.

Location: Vernalis.

Narrative description: Survival of CWT hatchery smolts released at Dos Reis between 1982, 1985-1987, and 1988-1991 has shown a strong relationship to flows at Vernalis ($r = 0.89$, $p < 0.01$ with data in 1985 excluded) (USFWS 1992a). Additionally, indices of adult production show a strong relationship to Vernalis flows and exports between 1967 and 1984 ($r = 89$, $p < 0.01$, with data from 1979 not included) (USFWS 1992a). The fact that two independent models essentially respond in the same way lends credibility to our conclusions.

Related actions that may impede or augment the action: Export limits and a barrier at the head of upper Old River would increase survival over that resulting from increasing flows at Vernalis alone.

Agency and organization roles and responsibilities: Various water right holders and USBR.

Potential obstacles to implementation: Water originating in the San Joaquin Basin is in high demand for agricultural and municipal use. Water users are unlikely to contribute water without considerable political necessity.

Predicted benefits: Smolt survival is projected to double over that observed during the baseline period as indexed by the San Joaquin smolt survival model (Brandes 1994), if these Vernalis flows are adopted and total exports are limited to 1,200 cfs, for the entire period of San Joaquin smolt migration through the Delta.

Action 5: Install the head of Old River barrier in September-December.

Objective: Increase dissolved oxygen at Stockton to ensure San Joaquin adult salmon passage through the Delta.

Location: Upper Old River confluence with the San Joaquin River.

Narrative description: Low dissolved oxygen resulting from the high biological oxygen demand (BOD) and high temperatures at Stockton are exacerbated with low flows entering the Delta from the San Joaquin River. These environmental conditions have been shown to delay or block migration of San Joaquin River fall-run adults (Hallock 1970). Increased flows from the San Joaquin River would also serve to increase the oxygen levels at Stockton.

Related actions that may impede or augment the action: Increased flows from the San Joaquin River during September-December would serve to attract adults. Export limits may also augment the action.

Agency and organization roles and responsibilities: DWR has been responsible for the construction of the barrier in past years.

Potential obstacles to implementation: The barrier placement under high exports may increase drafting from central Delta channels and may have an impact on juvenile winter run, spring run, and other central Delta fishes.

Other actions considered but not recommended: Reduction of water temperatures was not selected as an action item because it is uncertain whether water temperature can be significantly reduced using "controllable factors" (SWRCB 1991). However, evaluation of ways to reduce temperature in the Delta should continue because temperature reduction has the potential to significantly increase fall-run survival in the Delta.

The team looked at the impact of in-Delta agricultural diversions on juvenile salmon and steelhead (estimated to be less than a few hundred thousand for each species) (Hayes pers. comm.). The team decided, based on this limited information, that screening appeared to have a relatively small impact on these populations in relation to other limiting factors and that restricting these species from the central Delta or curtailing agricultural diversions during critical time periods would be more effective in minimizing losses. We have chosen to recommend keeping smolts out of the central Delta.

The team also did not recommend any specific action items to deal with "other factors" such as competition, poaching, and exotic species. We believed that if populations are kept healthy through implementation of the recommended actions, the impact of these factors would decline as well. However, the team believes that when positive actions are possible to lessen mortality of fish populations, such actions should be taken.

Additionally, actions were not recommended in Montezuma Slough or in the Bay. Impacts from Montezuma Slough do occur, but changes in operations at that site would have small population benefits toward the doubling goal. This conclusion is based on evidence that only a small fraction of fall-run smolts migrating out of the Delta enter Montezuma Slough. Also, the recovery in the ocean fishery of adults that had been released at Port Chicago and the Golden Gate in 1984, 1985, and 1986 as paired CWT smolts indicated that survival through the Bay was generally high (ranged between 0.78 to 0.85) and did not appear to vary much between years measured (Table 3-Xe-8).

Table 3-Xe-8. Survival indices of smolts migrating through the Bay from Port Chicago to the Golden Gate Bridge.

Year	Port Chicago recovery rate	Golden Gate recovery rate	Survival index
1986	.0282	.0360	.78
1985	.0096	.0113	.85
1984	.0211	.0272	.78

Note: Survival was estimated by dividing the recovery rate in the ocean fishery of the fish released at Port Chicago by the recovery rate of those released at the Golden Gate Bridge (USFWS 1987).

Tables 3-Xe-9 through 3-Xe-13 have been included to show model output for the various races of juvenile salmon with the integration of recommended actions and their effects on the doubling goals. The tables are provided to show comparisons between survival associated with the recommended actions, baseline historical (1965-1989) smolt survival (referred to as DAYFLOW in the tables), and present smolt survival (referred to as OP STUDY in the tables). It is important to view the differences in the indices of survival between alternatives qualitatively, rather than viewing the differences as absolute.

Table 3-Xe-9. Sacramento River fall run (April-June)

Water-year type	Dayflow	Op study	Options				Doubling goal
			A	B	C	D	
W	.45	.42	.53	.54	.57	.45	.90
AN	.33	.29	.40	.41	.44	.37	.66
BN	.25	.23	.37	.38	.41	.32	.50
D	.19	.17	.29	.31	.32	.27	.38

C	.24	.22	.34	.36	.38	.30	.48
Average for years from 1965-1989	.34	.31	.43	.44	.47	.37	.68

Option A: DCC closed (April-June), 1,200-cfs exports (April-June)

Option B: DCC closed (April-June), 0 exports (April-June).

Option C: DCC closed (April-June) Georgiana Slough closed (April-June).

Option D: Isolated Delta facility with 15% loss at screens.

Model Assumptions:

1. Migrational distributions = 17% April, 65% May, 18% June.

2. Temperatures based on mean monthly temperatures at Freeport from USGS.

3. Sacramento River fall-run smolt model used to estimate survival.

Table 3-Xe-10. Sacramento River late fall-run and spring-run yearlings (November-January).

Water-year type	Dayflow	Op study	Options				Doubling goal
			A	B	C	D	
	.82	.71	.89	.91	.98	.83	W
AN	.73	.60	.89	.91	.98	.83	1.00
BN	.76	.58	.89	.91	.98	.83	1.00
D	.62	.55	.88	.90	.98	.83	1.00
C	.64	.53	.88	.90	.98	.83	1.00
Average for years from 1965-1989	.75	.63	.88	.90	.98	.83	1.00

Option A: Cross Channel gates closed (Nov-Jan), 1200 exports (Nov-Jan).

Option B: Cross channel gates closed (Nov-Jan), 0 exports (Nov-Jan).

Option C: Cross-channel closed (Nov-Jan), Georgiana Slough closed (Nov-Jan).

Option D: Isolated Delta facility with 15% loss at screens.

Model Assumptions:

1. Temperatures = 53°F November, 47° F December and January.

2. Migrational Distribution = 25% November, 50% December, 25% January.

3. Sacramento Smolt model modified to reflect greater 25 mortality due to exports in reach 2 (coefficient changed from 0.0000434 to 0.000054, based on December 1993 late fall mark/recovery data).

Table 3-Xe-11. Sacramento winter-run salmon (February-April)

Water-year type	Dayflow	Op study	Options				Doubling goal
			A	B	C	D	
W	.73	.69	.79	.81	.87	.74	1.00
AN	.72	.67	.78	.80	.85	.72	1.00
BN	.64	.61	.76	.78	.84	.71	1.00
D	.51	.48	.71	.72	.78	.66	1.00
C	.42	.42	.72	.74	.81	.68	0.84
Average for years from 1965-1989	.64	.61	.76	.78	.84	.71	1.00

Option A: Cross channel closed (Feb-April), 1200 exports (Feb-April)

Option B: Cross channel closed (Feb-April), 0 exports (Feb-April).

Option C: Cross channel closed (Feb-April), Georgiana Slough closed (Feb-April).

Option D: Isolated Delta facility with 15% loss at screens.

Model Assumptions:

1. Temperatures: February = 50°F, March = 55°F, April temperatures (X) monthly from USGS.

2. Migrational distributions: Feb = 13%, March = 57% and April = 30%, based on 1993 recoveries at Sacramento.

3. Sacramento fall fun smolt model modified to reflect greater mortality due to exports in reach 2 (coefficient changed from 0.0000434 to 0.000054, based on December 1993 late fall mark/recovery data).

Table 3-Xe-12. San Joaquin fall-run salmon (April-May)

Water-year type	Dayflow	Op study	Options				Doubling goal
			A	B	C	D	
W	.34	.22	.68	.50	.57	.80	.68
AN	.08	.06	.16	.30	.46	.65	.16
BN	.04	.05	.08	.20	.35	.50	.08
D	.04	.04	.08	.16	.24	.36	.08
C	.04	.03	.08	.14	.15	.24	.08
Average for years from 1965-1989	.16	.12	.32	.32	.40	.57	.32

Option A: No **UOR barrier, 1200 exports (April-May), increased flows (4/1 - 5/31) to (W) 29000, (AN) 5500, (BN) 2000, (D) 2000, (C) 2000.

Option B: No UOR barrier, 1200 exports (April-May), (4/1 - 5/31) flows increased to (W) 21000, (AN) 12000, (BN) 8000, (D) 6000, (C) 4500.

Option C: No UOR barrier, 0 exports (April-May), 2000-10,000 cfs at Stockton (April-May) (may be similar to isolated Delta facility if similar flows were provided).

Option D: UOR barrier (April-May), 0 exports (April-May) 2000-10,000 cfs at Stockton (April-May).

Model Assumptions:

1. Migrational Distribution 45% April, 55% May.

2. Temperature at Jersey point estimated from Neomysis studies.

3. San Joaquin smolt model used to estimate survival.

Table 3-Xe-13. Mokelumne River fall-run salmon (April-June)

Water-year type	Dayflow	Op study	Options		Doubling goal
			A	B	
W	.29	.22	.42	.49	.58
AN	.23	.19	.37	.44	.46
BN	.20	.18	.36	.43	.40
D	.14	.15	.33	.39	.28
C	.22	.23	.35	.42	.44
Average for years from 1965-1989	.24	.20	.38	.45	.48

Option A: Reduce exports 1200 (4/1 - 6/30).

Option B: No exports (A-J), or isolated Delta facility.

Model Assumptions:

1. Temperatures are mean monthly from USGS. The same as those used in Sacramento fall run simulations.

2. Migrational distributions: Apr = 17%, May = 65% and Jun = 18%, same as those used in Sacramento fall run simulations.

3. Only reach two from the Sacramento fall fun smolt model was used to estimate survival.

The doubling goal for winter-run and fall-run for all water-year types was truncated at 1.0. This assumes that these indices of survival reflect actual survival and that increases to values of over 1.0 are biologically impossible. Because we could not double the survival index or reach a survival index of 1.0, determining the exact doubling goal for these two races was immaterial.

Although our recommended suite of actions does double average survival of smolts migrating through the Delta that originate in the San Joaquin Basin, it did not match specific water-year-type goals. We believed it was necessary to increase survival to more than doubling in the dry years and decrease it to less than doubling in the wet years. The great discrepancies in survival between wet and all other water-year types made it unlikely that matching such goals would double San Joaquin Basin adult production in the long term.

APPENDIX A

Estimation of Natural Production of Chinook Salmon

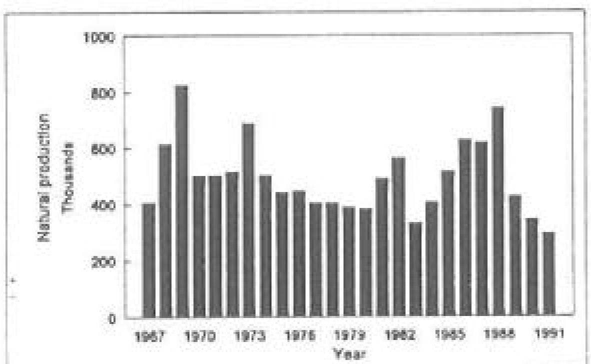
This appendix contains output from a three-dimensional spreadsheet used to estimate production of all races of chinook salmon in each of the streams for which escapement data were available. Sources of data considered and specific assumptions made for each stream are noted on the bottom of each worksheet.

Chinook salmon production summaries for all races and streams.

		Harvest		Production		
	Escapement	Instream	Ocean	Total	Natural	Goal
All races combined	274757	53163	411617	739536	495051	990102
Fall run	223579	40677	342227	606483	372757	745514
Late-fall run	15079	5456	24255	39301	34031	68062
Winter run	23109	4622	26305	54036	54036	108071
Spring run	12990	2408	18829	34227	34227	68454
Sacramento River						
Fall run	76701	7670	107080	191451	114871	229742
Late-fall run	14159	2832	19807	36798	33781	67561
Winter run	23109	23819	26305	54036	54036	108071
Spring run	11089	2218	15983	29290	29290	58580
Clear Creek	1584	158	2708	4451	3561	7121
Cow Creek	1373	137	1384	2895	2316	4632
Cottonwood Creek	1647	165	1872	3684	2947	5895
Battle Creek						
Fall run	17616	1762	30547	49924	4992	9985
Late-fall run	1000	200	1521	2721	272	544
Paynes Creek	90	9	107	206	165	330
Antelope Creek	192	19	241	452	361	723
Mill Creek						
Fall run	1104	110	1423	2638	2110	4220
Spring run	824	82	1285	2191	2191	4382
Deer Creek						
Fall run	406	41	506	952	762	1523
Spring run	1317	132	1812	3260	3260	6520
Misc. creeks	304	30	348	683	546	1092
Butte Creek						
Fall run	418	42	491	951	760	1521
Spring run	360	36	617	1012	1012	2025
Big Chico Creek	242	24	233	499	399	798
Feather River	48512	9702	79711	137926	85726	171452
Yuba River	12868	1287	18975	33130	33130	66261
Bear River	100	10	114	224	224	449
American River	41040	18468	74741	134249	80549	161098
Mokelumne River	3340	334	4098	7772	4663	9326
Cosumnes River	764	76	805	1645	1645	3291
Calaveras River	413	361	588	1083	1083	2167
Stanislaus River	4807	240	5773	10820	10820	21640
Toulumne River	8923	446	9504	18872	18872	37745
Merced River	4512	226	5133	9870	8976	17952

Central Valley: Production totals for all races combined.

Year	E(c,n,cv)	E(c,h,cv)	E(c,t,cv)	H(c,i,cv)	P(c,i,cv)	PFMC H(c,o,sf,c)	PFMC H(c,o,m,c)	PFMC H(c,o,sf,r)	PFMC H(c,o,m,r)	H(c,o,cv)	P(c,t,cv)	P(c,n,cv)
1967	283943	14839	298782	50028	348810	69533	17549	58503	7650	153235	502045	405909
1968	326119	18702	344821	67537	412358	167963	58255	123807	25095	375110	787468	614672
1969	490735	13175	503910	93424	597334	176749	103613	113517	14737	408616	1005950	827233
1970	281525	22643	304168	57764	361932	163097	63732	97300	13838	337967	699899	500121
1971	294244	20419	314663	66346	381009	125755	24944	145879	20448	317026	698035	502194
1972	216274	15176	231450	48057	279507	189558	40238	176503	11089	417388	696895	513856
1973	302990	26943	329933	80199	410132	242412	180283	167017	13886	603598	1013730	688949
1974	252129	20005	272134	62192	334326	222785	59895	130242	11348	424270	758596	503022
1975	242247	19277	261524	52559	314083	160434	73927	84977	7717	327055	641138	441900
1976	258541	14955	273496	53058	326554	138231	99626	63760	4807	306424	632978	446087
1977	203986	22165	226151	50424	276575	185164	78675	72595	4006	340440	617015	404957
1978	183523	17442	200965	37254	238219	158158	132842	64085	1809	356894	595113	405351
1979	217696	24783	242479	47221	289700	180087	54060	102547	5929	342623	632323	388509
1980	163275	30521	193796	42956	236752	211778	62524	73093	4020	371415	608167	382954
1981	259543	47482	307025	62319	369344	199910	89995	70084	3743	363732	733076	490594
1982	218339	44883	263222	52527	315749	281761	136678	116910	5586	540935	856684	562753
1983	193258	34393	227651	39971	267622	75019	103215	49717	3243	231194	498816	333455
1984	228946	48219	277165	47717	324882	167668	53992	73233	5437	300330	625212	405806
1985	353267	34678	387945	67673	455618	175681	36637	112475	9276	334069	789687	512381
1986	290091	31461	321552	61853	383406	302302	200154	86255	28558	617269	1000675	626776
1987	270234	36530	306764	51209	357973	355615	91231	119526	33320	599692	957665	616081
1988	270625	36559	307184	49405	356589	642693	187818	114455	15919	960885	1317474	740693
1989	162253	35426	197679	36323	234002	255817	107955	93659	37248	494679	728681	424390
1990	106603	27232	133835	23151	156986	199147	137072	77562	35053	448834	605820	344513
1991	107833	32792	140625	27908	168533	174831	79798	37274	24830	316733	485266	293116
Mean	247129	170867	274757	53163	327920	208886	91788	96999	13944	411617	739536	495051
											Restoration goal:	990102



Estimated natural production [P(c,n,cv)] for all races of chinook salmon in the Central Valley for each of the years in the baseline period.

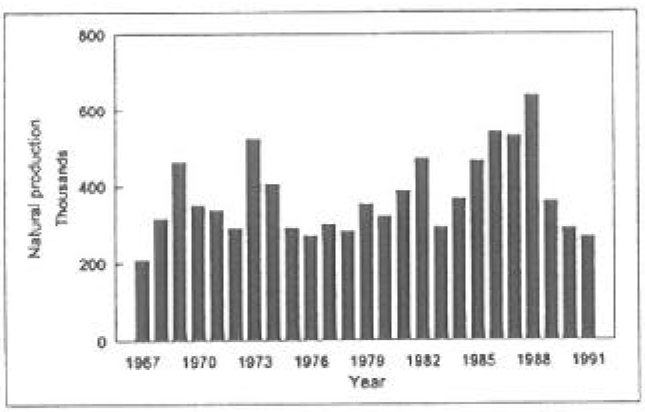
Description of variables named in worksheet:

E(c,n,cv)	Escapement (naturally spawning fish in the Central Valley)
E(c,h,cv)	Escapement (to hatcheries in the Central Valley)
E(c,t,cv)	Escapement naturally and to hatcheries in the Central Valley)
H(c,i,cv)	Harvest (instream harvest in the Central Valley)
P(c,i,cv)	Production (total escapement plus instream harvest)
H(c,o,sf,c)	Harvest (ocean, San Francisco, commercial)
H(c,o,m,c)	Harvest (ocean, Monterey, commercial)
H(c,o,sf,r)	Harvest (ocean, San Francisco, recreational)
H(c,o,m,r)	Harvest (ocean, Monterey, recreational)
H(c,o,cv)	Harvest (ocean harvest of chinook salmon assigned to the Central Valley)
P(c,t,cv)	Production (total Central Valley)
P(c,n,cv)	Production (natural production for the Central Valley)
PFMC	Data taken from Pacific Fishery Management Council reports.

Central Valley: Production totals for fall-run chinook salmon.

Year	E(f,n,cv)	E(f,h,cv)	E(f,t,cv)	H(f,i,cv)	P(f,i,cv)	P(f,t,cv)/ P(c,t,cv)	H(f,o,cv)	P(f,t,cv)	P(f,n,cv)
1967	165735	14839	180574	26405	206979	0.59	90927	297906	207040
1968	191828	18702	210530	33114	243644	0.59	221636	465279	313510
1969	308414	12388	320802	52436	373238	0.62	255319	628557	464926
1970	214489	19583	234072	41017	275089	0.76	256874	531963	348234
1971	218032	19210	237242	44738	281980	0.74	234627	516608	337503
1972	139192	14627	153819	28114	181933	0.65	271681	453614	291069
1973	244945	26540	271485	67479	338964	0.83	498859	837823	523054
1974	215704	19300	235004	51548	286552	0.86	363644	650197	406031
1975	178801	17779	196580	37658	234238	0.75	243912	478149	292048
1976	182092	14346	196438	35686	232124	0.71	217815	449939	271055
1977	163852	21409	185261	40109	225370	0.81	277411	502781	299330
1978	141625	15589	157214	26816	184030	0.77	275708	459738	281939
1979	203682	23954	227636	42531	270167	0.93	319521	589688	353465
1980	142557	29654	172211	38010	210221	0.89	329794	540015	321325
1981	216590	44877	261467	52631	314098	0.85	309326	623424	388039
1982	189784	42997	232781	43866	276647	0.88	473946	750593	470216
1983	173672	33435	207107	34610	241717	0.90	208815	450532	291970
1984	212015	47591	259606	42617	302223	0.93	279383	581606	367721
1985	330222	34290	364512	61554	426066	0.94	312401	738468	465793
1986	262021	30673	292694	53253	345947	0.90	556962	902910	540914
1987	242287	35727	278014	43261	321275	0.90	538214	859489	529988
1988	246195	36102	282297	42464	324761	0.91	875118	1199878	636753
1989	144657	34544	179201	31398	210599	0.90	445205	655804	361936
1990	93917	27040	120957	19354	140311	0.89	401158	541468	288846
1991	99470	32513	131983	26266	158249	0.94	297406	455655	266223
Mean	196871	26708	223579	40677	264257	0.82	342227	606483	372757

Restoration goal: 745514



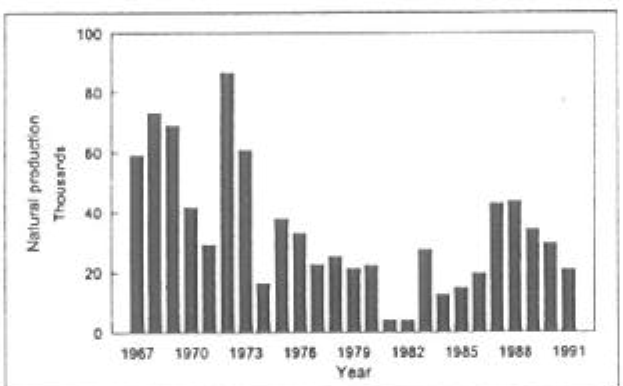
Estimated natural production [P(f,n,cv)] for fall-run in the Central Valley for each of the years in the baseline period.

Description of variables named in worksheet:

E(f,n,cv) Escapement (naturally spawning fall-run in the Central Valley)
E(f,h,cv) Escapement (hatchery spawning fall-run in the Central Valley)
E(f,t,cv) Escapement (naturally and hatchery spawning fall-run in the Central Valley)
H(f,i,cv) Harvest (instream harvest in the Central Valley)
P(f,i,cv) Production (total fall-run escapement plus instream harvest)
P(c,i,cv) Production (total escapement plus instream harvest)
H(f,o,cv) Harvest (ocean harvest of fall-run chinook salmon assigned to the Central Valley)
P(f,t,cv) Production (total fall-run in Central Valley)
P(f,n,cv) Production (natural production of fall-run for the Central Valley)

Central Valley: Production totals for late-fall-run chinook salmon.

Year	E(l,n,cv)	E(l,h,cv)	E(l,t,cv)	H(l,i,cv)	P(l,i,cv)	P(l,t,cv)/ P(c,i,cv)	H(l,o,cv)	P(l,t,cv)	P(l,n,cv)
1967	37208		37208	7442	44650	0.13	19615	64265	58995
1968	34733		34733	14540	49273	0.12	44822	79594	73068
1969	37178	787	37965	12043	50008	0.08	34209	76723	69130
1970	19190	3060	22250	7556	29806	0.08	27833	51632	41590
1971	14323	1209	15532	9527	25059	0.07	20851	34147	29173
1972	31553	549	32102	10942	43044	0.15	64277	96048	86828
1973	22204	403	22607	5951	28558	0.07	42030	67054	60578
1974	6445	705	7150	5062	12212	0.04	15498	19468	16302
1975	16663	1498	18161	6810	24971	0.08	26002	44486	37837
1976	15280	609	15889	5147	21036	0.06	19739	36958	32769
1977	9090	756	9846	4116	13962	0.05	17186	26359	22542
1978	8880	1853	10733	4060	14793	0.06	22163	32175	24993
1979	8740	829	9569	3637	13206	0.05	15618	25063	21232
1980	7747	867	8614	2563	11177	0.05	17535	26553	22190
1981	1597	2605	4202	1446	5648	0.02	5562	10008	4112
1982	1141	1886	3027	3452	6479	0.02	11099	9855	4024
1983	13274	958	14232	4153	18385	0.07	15883	31832	27469
1984	5907	628	6535	2917	9452	0.03	8737	15091	12668
1985	7660	388	8048	3109	11157	0.02	8181	16739	14706
1986	6710	788	7498	4549	12047	0.03	19395	23483	19539
1987	14443	803	15246	5277	20523	0.06	34381	48944	42822
1988	10683	457	11140	4379	15519	0.04	41819	49390	43683
1989	9875	882	10757	3574	14331	0.06	30296	40197	34205
1990	6921	192	7113	2785	9898	0.06	28298	32939	29511
1991	6531	279	6810	1362	8172	0.05	15358	23530	20812
Mean	14159	1000	15079	5456	20535	0.06	24255	39301	34031
							Restoration goal:		68062



Estimated natural production [P(l,n,cv)] for late-fall-run in the Central Valley for each of the years in the baseline period.

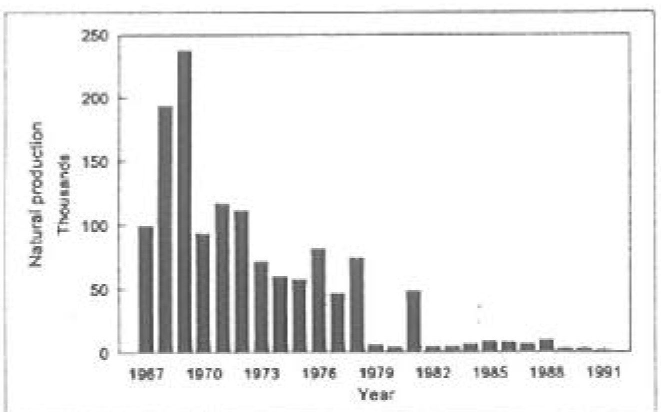
Description of variables named in worksheet:

E(l,n,cv)	Escapement (naturally spawning late-fall-run in the Central Valley)
E(l,h,cv)	Escapement (hatchery spawning late-fall-run in the Central Valley)
E(l,t,cv)	Escapement (naturally and hatchery spawning late-fall-run in the Central Valley)
H(l,i,cv)	Harvest (instream harvest in the Central Valley)
P(l,i,cv)	Production (total late-fall-run escapement plus instream harvest)
P(c,i,cv)	Production (total escapement plus instream harvest)
H(l,o,cv)	Harvest (ocean harvest of late-fall run assigned to the Central Valley)
P(l,t,cv)	Production (total late-fall-run in Central Valley)
P(l,n,cv)	Production (natural production of late-fall-run for the Central Valley)

Central Valley: Production totals for winter-run chinook salmon.

Year	E(w,n,cv)	E(w,h,cv)	E(w,t,cv)	H(w,i,cv)	P(w,i,cv)	P(w,t,cv)/ P(c,t,cv)	H(w,o,cv)	P(w,t,cv)	P(w,n,cv)
1967	57306	0	57306	11461	68767	0.20	30210	98977	98977
1968	84414	0	84414	16883	101297	0.25	92147	193444	193444
1969	117808	0	117808	23562	141370	0.24	96706	238076	238076
1970	40409	0	40409	8082	48491	0.13	45280	93771	93771
1971	53089	0	53089	10618	63707	0.17	53008	116715	116715
1972	37133	0	37133	7427	44560	0.16	66541	111101	111101
1973	24079	0	24079	4816	28895	0.07	42525	71420	71420
1974	21897	0	21897	4379	26276	0.08	33346	59622	59622
1975	23430	0	23430	4686	28116	0.09	29277	57393	57393
1976	35096	0	35096	7019	42115	0.13	39519	81634	81634
1977	17214	0	17214	3443	20657	0.07	25427	46084	46084
1978	24862	0	24862	4972	29834	0.13	44697	74532	74532
1979	2364	0	2364	473	2837	0.01	3355	6192	6192
1980	1156	0	1156	231	1387	0.01	2176	3563	3563
1981	20041	0	20041	4008	24049	0.07	23684	47733	47733
1982	1242	0	1242	248	1490	0.00	2553	4044	4044
1983	1831	0	1831	366	2197	0.01	1898	4095	4095
1984	2663	0	2663	533	3196	0.01	2954	6150	6150
1985	3962	0	3962	792	4754	0.01	3486	8240	8240
1986	2464	0	2464	493	2957	0.01	4760	7717	7717
1987	1997	0	1997	399	2396	0.01	4015	6411	6411
1988	2094	0	2094	419	2513	0.01	6771	9284	9284
1989	533	0	533	107	640	0.00	1352	1992	1992
1990	441	0	441	88	529	0.00	1513	2042	2042
1991	191	0	191	38	229	0.00	431	660	660
Mean	23109	0	23109	4622	27730	0.07	26305	54036	54036

Restoration goal: 108071



Estimated natural production [P(w,n,cv)] for winter-run in the Central Valley for each of the years in the baseline period.

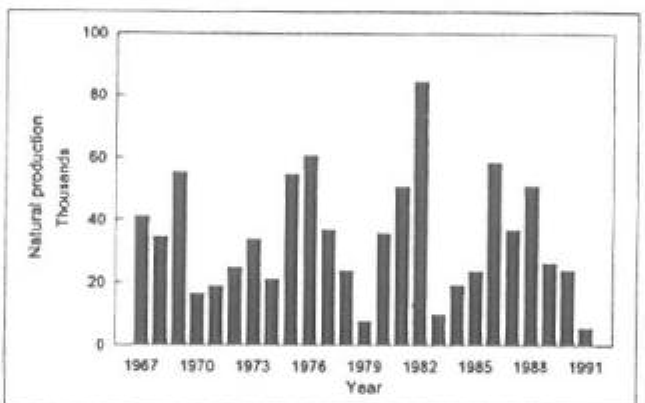
Description of variables named in worksheet:

E(w,n,cv)	Escapement (naturally spawning winter-run in the Central Valley)
E(w,h,cv)	Escapement (hatchery spawning winter-run in the Central Valley)
E(w,t,cv)	Escapement (naturally and hatchery spawning winter-run in the Central Valley)
H(w,i,cv)	Harvest (in the Central Valley)
P(w,i,cv)	Production (total winter-run escapement plus instream harvest)
P(c,i,cv)	Production (total escapement plus instream harvest)
H(w,o,cv)	Harvest (ocean harvest of winter-run chinook salmon assigned to the Central Valley)
P(w,t,cv)	Production (total winter-run in Central Valley)
P(w,n,cv)	Production (natural production of winter-run for the Central Valley)

Central Valley: Production totals for spring-run chinook salmon

Year	E(s,n,cv)	E(s,h,cv)	E(s,t,cv)	H(s,i,cv)	P(s,i,cv)	P(s,t,cv)/ P(c,t,cv)	H(s,o,cv)	P(s,t,cv)	P(s,n,cv)
1967	23694	0	23694	4721	28415	0.08	12483	40898	40898
1968	15144	0	15144	3001	18145	0.04	16506	34651	34651
1969	27335	0	27335	5384	32719	0.05	22382	55101	55101
1970	7437	0	7437	1109	8546	0.02	7980	16526	16526
1971	8800	0	8800	1463	10263	0.03	8540	18803	18803
1972	8396	0	8396	1574	9970	0.04	14889	24859	24859
1973	11762	0	11762	1952	13714	0.03	20184	33898	33898
1974	8083	0	8083	1202	9285	0.03	11782	21067	21067
1975	23353	0	23353	3406	26759	0.09	27864	54622	54622
1976	26073	0	26073	5206	31279	0.10	29350	60629	60629
1977	13830	0	13830	2756	16586	0.06	20416	37002	37002
1978	8156	0	8156	1406	9562	0.04	14325	23887	23887
1979	2910	0	2910	581	3491	0.01	4129	7620	7620
1980	11815	0	11815	2151	13966	0.06	21910	35876	35876
1981	21315	0	21315	4234	25549	0.07	25161	50710	50710
1982	26172	0	26172	4961	31133	0.10	53336	84469	84469
1983	4481	0	4481	841	5322	0.02	4598	9920	9920
1984	8361	0	8361	1651	10012	0.03	9255	19267	19267
1985	11423	0	11423	2217	13640	0.03	10001	23641	23641
1986	18896	0	18896	3559	22455	0.06	36151	58606	58606
1987	11507	0	11507	2271	13778	0.04	23082	36860	36860
1988	11653	0	11653	2143	13796	0.04	37177	50973	50973
1989	7188	0	7188	1244	8432	0.04	17826	26258	26258
1990	5324	0	5324	925	6249	0.04	17865	24114	24114
1991	1641	0	1641	241	1882	0.01	3538	5420	5420
Mean	12990	0	12990	2408	15398	0.05	18829	34227	34227

Restoration goal: 68454



Estimated natural production [P(s,n,cv)] for spring-run in the Central Valley for each of the years in the baseline period.

Notes:
Spring-run chinook salmon numbers presented here include spring-run spawning in the Sacramento River and in Mill, Deer, and Butte creeks.

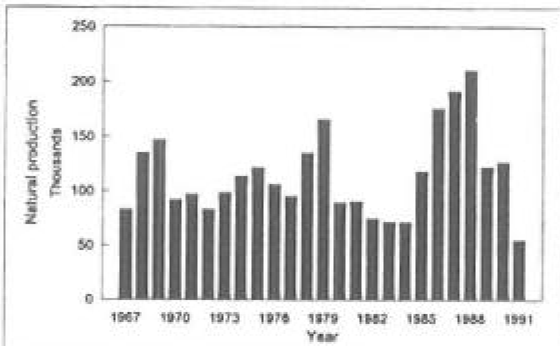
Description of variables named in worksheet:

- E(s,n,cv) Escapement (naturally spawning spring-run in the Central Valley)
- E(s,h,cv) Escapement (hatchery spawning spring-run in the Central Valley)
- E(s,t,cv) Escapement (naturally and hatchery spawning spring-run in the Central Valley)
- H(s,i,cv) Harvest (in the Central Valley)
- P(s,i,cv) Production (total spring-run escapement plus instream harvest)
- P(c,i,cv) Production (total escapement plus instream harvest)
- H(s,o,cv) Harvest (ocean harvest of spring-run chinook salmon assigned to the Central Valley)
- P(s,t,cv) Production (total spring-run in Central Valley)
- P(s,n,cv) Production (natural production of spring-run for the Central Valley)

Sacramento River: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,sa)	DFG E(f,h,sa)	E(f,t,sa)	Proportion harvested instream	H(f,i,sa)	P(f,i,sa)	P(f,i,sa)/ P(f,i,cv)	H(f,o,sa)	P(f,t,sa)	h	P(f,n,sa)
1967	87300	0	87300	0.1	8730	96030	0.46	42187	138217	0.4	82930
1968	107400	0	107400	0.1	10740	118140	0.48	107468	225608	0.4	135365
1969	132200	0	132200	0.1	13220	145420	0.39	99477	244897	0.4	146938
1970	71810	0	71810	0.1	7181	78991	0.29	73761	152752	0.4	91651
1971	80203	0	80203	0.1	8020	88223	0.31	73408	161631	0.4	96979
1972	50690	0	50690	0.1	5069	55759	0.31	83265	139024	0.4	83414
1973	60400	0	60400	0.1	6040	66440	0.20	97781	164221	0.4	98533
1974	75794	0	75794	0.1	7579	83373	0.29	105804	189177	0.4	113506
1975	90415	0	90415	0.1	9042	99457	0.42	103564	203021	0.4	121812
1976	83024	0	83024	0.1	8302	91326	0.39	85697	177023	0.4	106214
1977	64673	0	64673	0.1	6467	71140	0.32	87568	158708	0.4	95225
1978	82293	0	82293	0.1	8229	90522	0.49	135618	226140	0.4	135684
1979	115199	0	115199	0.1	11520	126719	0.47	149868	276587	0.4	165952
1980	52414	0	52414	0.1	5241	57655	0.27	90450	148105	0.4	88863
1981	68985	0	68985	0.1	6899	75884	0.24	74730	150614	0.4	90368
1982	41564	0	41564	0.1	4156	45720	0.17	78327	124048	0.4	74429
1983	58244	0	58244	0.1	5824	64068	0.27	55348	119416	0.4	71650
1984	56064	0	56064	0.1	5606	61670	0.20	57010	118680	0.4	71208
1985	103179	0	103179	0.1	10318	113497	0.27	83218	196715	0.4	118029
1986	102330	0	102330	0.1	10233	112563	0.33	181222	293785	0.4	176271
1987	108627	0	108627	0.1	10863	119490	0.37	200175	319664	0.4	191799
1988	86454	0	86454	0.1	8645	95099	0.29	256260	351360	0.4	210816
1989	59568	0	59568	0.1	5957	65525	0.31	138519	204044	0.4	122426
1990	49732	0	49732	0.1	4973	54705	0.39	156406	211111	0.4	126667
1991	28963	0	28963	0.1	2896	31859	0.20	59875	91734	0.4	55041
Mean	76701	0	76701	0.1	7670	84371	0.33	107080	191451	0.4	114871

Restoration goal: 229742



Estimated natural production [P(f,n,sa)] for fall-run in the Sacramento River for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

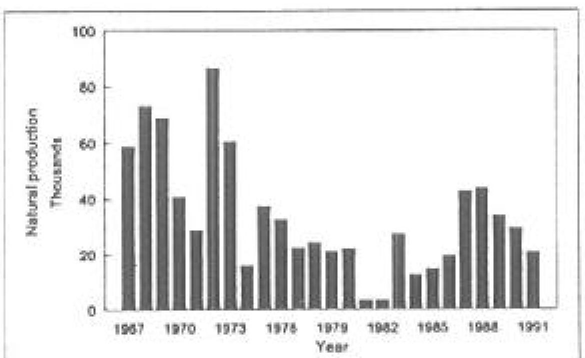
Estimate of h (proportion of production produced in a hatchery) based on data and discussions presented in Cramer (1990).

Description of variables named in worksheet:

E(f,n,sa)	Escapement (naturally spawning fish in the Sacramento River)
E(f,h,sa)	Escapement (to hatcheries in the Sacramento River)
E(f,t,sa)	Escapement naturally and to hatcheries in the Sacramento River)
H(f,i,sa)	Harvest (in the Sacramento River, estimated as E(f,t,sa)* prop. harvested instream)
P(f,i,sa)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,sa)	Harvest (ocean harvest of fall-run salmon assigned to the Sacramento River)
P(f,t,sa)	Production (total Sacramento River)
h	Proportion hatchery
P(f,n,sa)	Production (natural production for the Sacramento River)
DFG	Data taken from Mills and Fisher (1994).

Sacramento River: Production estimates for late-fall-run chinook salmon.

Year	DFG E(l,n,sa)	DFG E(l,h,sa)	E(l,t,sa)	Proportion harvested instream	H(l,i,sa)	P(l,i,sa)	P(l,i,sa)/ P(l,i,cv)	H(l,o,sa)	P(l,t,sa)	h	P(l,n,sa)
1967	37208	0	37208	0.2	7442	44650	1.00	19615	64265	0.082	58995
1968	34733	0	34733	0.2	6947	41680	0.85	37915	79594	0.082	73068
1969	37178	0	37178	0.2	7436	44614	0.89	30519	75132	0.082	68971
1970	19190	0	19190	0.2	3838	23028	0.77	21503	44531	0.082	40880
1971	14323	0	14323	0.2	2865	17188	0.69	14301	31489	0.082	28907
1972	31553	0	31553	0.2	6311	37864	0.88	56542	94405	0.082	86664
1973	22204	0	22204	0.2	4441	26645	0.93	39214	65858	0.082	60458
1974	6445	0	6445	0.2	1289	7734	0.63	9815	17549	0.082	16110
1975	16663	0	16663	0.2	3333	19996	0.80	20821	40817	0.082	37470
1976	15280	0	15280	0.2	3056	18336	0.87	17206	35542	0.082	32627
1977	9090	0	9090	0.2	1818	10908	0.78	13427	24335	0.082	22339
1978	8880	0	8880	0.2	1776	10656	0.72	15965	26621	0.082	24438
1979	8740	0	8740	0.2	1748	10488	0.79	12404	22892	0.082	21015
1980	7747	0	7747	0.2	1549	9296	0.83	14584	23881	0.082	21922
1981	1597	0	1597	0.2	319	1916	0.34	1887	3804	0.082	3492
1982	1141	0	1141	0.2	228	1369	0.21	2346	3715	0.082	3410
1983	13274	0	13274	0.2	2655	15929	0.87	13761	29689	0.082	27255
1984	5907	0	5907	0.2	1181	7088	0.75	6553	13641	0.082	12523
1985	7660	0	7660	0.2	1532	9192	0.82	6740	15932	0.082	14625
1986	6710	0	6710	0.2	1342	8052	0.67	12963	21015	0.082	19292
1987	14443	0	14443	0.2	2889	17332	0.84	29035	46366	0.082	42564
1988	10683	0	10683	0.2	2137	12820	0.83	34544	47364	0.082	43480
1989	9875	0	9875	0.2	1975	11850	0.83	25051	36901	0.082	33875
1990	6921	0	6921	0.2	1384	8305	0.84	23745	32050	0.082	29422
1991	6531	0	6531	0.2	1306	7837	0.96	14729	22566	0.082	20716
Mean	14159	0	14159	0.2	2832	16991	0.78	19807	36798	0.1	33781
										Restoration goal:	67561



Estimated natural production [P(l,n,sa)] for late-fall-run in the Sacramento River for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

Estimate of h (proportion of production produced in a hatchery) based on the assumption that the number of hatchery-produced late-fall-run chinook salmon that spawned naturally was equal, on average, to the number of late-fall-run chinook salmon that spawned at CNFH.

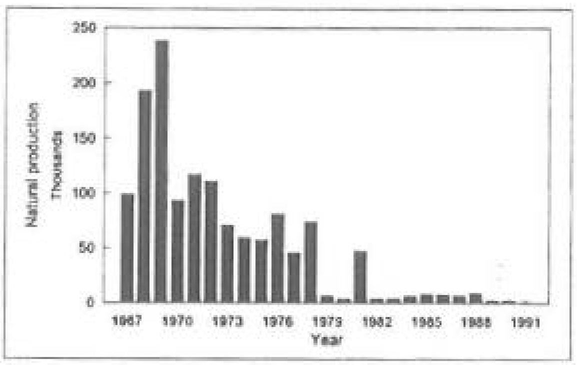
Description of variables named in worksheet:

E(l,n,sa)	Escapement (naturally spawning fish in the Sacramento River)
E(l,h,sa)	Escapement (to hatcheries in the Sacramento River)
E(l,t,sa)	Escapement naturally and to hatcheries in the Sacramento River)
H(l,i,sa)	Harvest (in the Sacramento River, estimated as E(l,t,sa)* prop. harvested instream)
P(l,i,sa)	Production (total escapement plus instream harvest)
P(l,i,cv)	Production (total Central Valley)
H(l,o,sa)	Harvest (ocean harvest of late-fall-run salmon assigned to the Sacramento River)
P(l,t,sa)	Production (total Sacramento River)
h	Proportion hatchery
P(l,n,sa)	Production (natural production for the Sacramento River)
DFG	Data taken from Mills and Fisher (1994).

Sacramento River: Production estimates for winter-run chinook salmon.

Year	DFG E(w,n,sa)	DFG E(w,h,sa)	E(w,t,sa)	Proportion harvested instream	H(w,i,sa)	P(w,i,sa)	P(w,i,sa)/ P(w,i,cv)	H(w,o,sa)	P(w,t,sa)	h	P(w,n,sa)
1967	57306	0	57306	0.2	11461	68767	1.00	30210	98977	0	98977
1968	84414	8	84414	0.2	16883	101297	1.00	92147	193444	0	193444
1969	117808	0	117808	0.2	23562	141370	1.00	96706	238076	0	238076
1970	40409	0	40409	0.2	8082	48491	1.00	45280	93771	0	93771
1971	53089	0	53089	0.2	10618	63707	1.00	53008	116715	0	116715
1972	37133	0	37133	0.2	7427	44560	1.00	66541	111101	0	111101
1973	24079	0	24079	0.2	4816	28895	1.00	42525	71420	0	71420
1974	21897	0	21897	0.2	4379	26276	1.00	33346	59622	0	59622
1975	23430	0	23430	0.2	4686	28116	1.00	29277	57393	0	57393
1976	35096	0	35096	0.2	7019	42115	1.00	39519	81634	0	81634
1977	17214	0	17214	0.2	3443	20657	1.00	25427	46084	0	46084
1978	24862	0	24862	0.2	4972	29834	1.00	44697	74532	0	74532
1979	2364	0	2364	0.2	473	2837	1.00	3355	6192	0	6192
1980	1156	0	1156	0.2	231	1387	1.00	2176	3563	0	3563
1981	20041	0	20041	0.2	4008	24049	1.00	23684	47733	0	47733
1982	1242	0	1242	0.2	248	1490	1.00	2553	4044	0	4044
1983	1831	0	1831	0.2	366	2197	1.00	1898	4095	0	4095
1984	2663	0	2663	0.2	533	3196	1.00	2954	6150	0	6150
1985	3962	0	3962	0.2	792	4754	1.00	3486	8240	0	8240
1986	2464	0	2464	0.2	493	2957	1.00	4760	7717	0	7717
1987	1997	0	1997	0.2	399	2396	1.00	4015	6411	0	6411
1988	2094	0	2094	0.2	419	2513	1.00	6771	9284	0	9284
1989	533	0	533	0.2	107	640	1.00	1352	1992	0	1992
1990	441	0	441	0.2	88	529	1.00	1513	2042	0	2042
1991	191	0	191	0.2	38	229	1.00	431	660	0	660
Mean	23109	0	23109	0.2	23819	27730	1.00	26305	54036	0.0	54036

Restoration goal: 108071



Estimated natural production [P(w,n,sa)] for winter-run in the Sacramento River for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

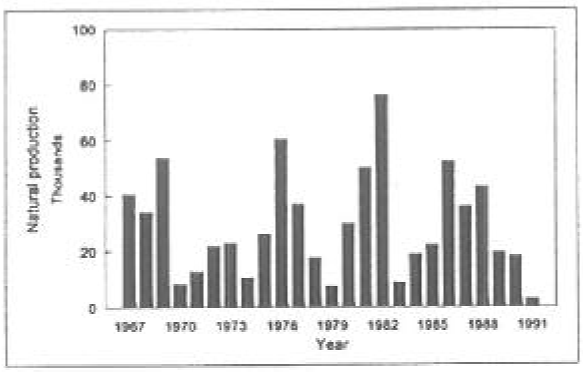
Estimate of h (proportion of production produced in a hatchery) based on absence of hatchery production of winter-run chinook salmon prior to 1991.

Description of variables named in worksheet:

E(w,n,sa)	Escapement (naturally spawning fish in the Sacramento River)
E(w,h,sa)	Escapement (to hatcheries in the Sacramento River)
E(w,t,sa)	Escapement naturally and to hatcheries in the Sacramento River)
H(w,i,sa)	Harvest (in the Sacramento River, estimated as E(w,t,sa)* prop. harvested instream)
P(w,i,sa)	Production (total escapement plus instream harvest)
P(w,i,cv)	Production (total Central Valley)
H(w,o,sa)	Harvest (ocean harvest of fall-run salmon assigned to the Sacramento River)
P(w,t,sa)	Production (total Sacramento River)
h	Proportion hatchery
P(w,n,sa)	Production (natural production for the Sacramento River)
DFG	Data taken from Mills and Fisher (1994).

Sacramento River: Production estimates for spring-run chinook salmon.

Year	DFG E(s,n,sa)	DFG E(s,h,sa)	E(s,t,sa)	Proportion harvested instream	H(s,i,sa)	P(s,i,sa)	P(s,i,sa)/ P(s,i,cv)	H(s,o,sa)	P(s,t,sa)	h	P(s,n,sa)
1967	23514	0	23514	0.2	4703	28217	0.99	12396	40613	0	40613
1968	14864	0	14864	0.2	2973	17837	0.98	16226	34062	0	34062
1969	26505	0	26505	0.2	5301	31806	0.97	21757	53563	0	53563
1970	3652	0	3652	0.2	730	4382	0.51	4092	8475	0	8475
1971	5830	0	5830	0.2	1166	6996	0.68	5821	12817	0	12817
1972	7346	0	7346	0.2	1469	8815	0.88	13164	21979	0	21979
1973	7762	0	7762	0.2	1552	9314	0.68	13708	23023	0	23023
1974	3933	0	3933	0.2	787	4720	0.51	5989	10709	0	10709
1975	10703	0	10703	0.2	2141	12844	0.48	13374	26218	0	26218
1976	25983	0	25983	0.2	5197	31180	1.00	29258	60437	0	60437
1977	13730	0	13730	0.2	2746	16476	0.99	20281	36757	0	36757
1978	5903	0	5903	0.2	1181	7084	0.74	10612	17696	0	17696
1979	2900	0	2900	0.2	580	3480	1.00	4116	7596	0	7596
1980	9696	0	9696	0.2	1939	11635	0.83	18253	29888	0	29888
1981	21025	0	21025	0.2	4205	25230	0.99	24847	50077	0	50077
1982	23438	0	23438	0.2	4688	28126	0.90	48184	76310	0	76310
1983	3931	0	3931	0.2	786	4717	0.89	4075	8792	0	8792
1984	8147	0	8147	0.2	1629	9776	0.98	9038	18814	0	18814
1985	10747	0	10747	0.2	2149	12896	0.95	9456	22352	0	22352
1986	16691	0	16691	0.2	3338	20029	0.89	32246	52275	0	52275
1987	11204	0	11204	0.2	2241	13445	0.98	22523	35968	0	35968
1988	9781	0	9781	0.2	1956	11737	0.85	31628	43365	0	43365
1989	5255	0	5255	0.2	1051	6306	0.75	13331	19637	0	19637
1990	3922	0	3922	0.2	784	4706	0.75	13456	18162	0	18162
1991	773	0	773	0.2	155	928	0.49	1743	2671	0	2671
Mean	11089	0	11089	0.2	2218	13307	0.83	15983	29290	0.0	29290
									Restoration goal:		58580



Estimated natural production [P(s,n,sa)] for spring-run in the Sacramento River for each of the years in the baseline period.

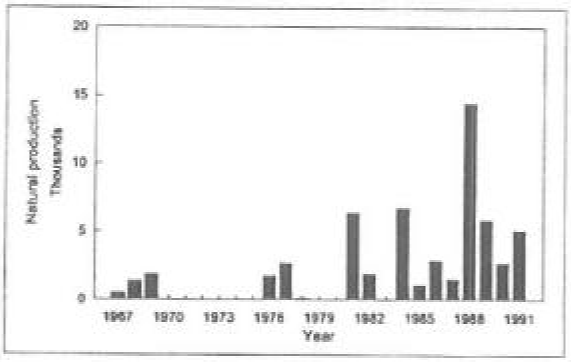
Notes:
Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

Description of variables named in worksheet:

E(s,n,sa)	Escapement (naturally spawning fish in the Sacramento River)
E(s,h,sa)	Escapement (to hatcheries in the Sacramento River)
E(s,t,sa)	Escapement naturally and to hatcheries in the Sacramento River)
H(s,i,sa)	Harvest (in the Sacramento River, estimated as E(s,t,sa)* prop. harvested instream)
P(s,i,sa)	Production (total escapement plus instream harvest)
P(s,i,cv)	Production (total Central Valley)
H(s,o,sa)	Harvest (ocean harvest of spring-run salmon assigned to the Sacramento River)
P(s,t,sa)	Production (total Sacramento River)
h	Proportion hatchery
P(s,n,sa)	Production (natural production for the Sacramento River)
DFG	Data taken from Mills and Fisher (1994).

Clear Creek: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,cl)	DFG E(f,h,cl)	E(f,t,cl)	Proportion harvested instream	H(f,i,cl)	P(f,i,cl)	P(f,i,cl)/ P(f,i,cv)	H(f,o,cl)	P(f,t,cl)	*h*	P(f,n,cl)
1967	370	0	370	0.1	37	407	0.00	179	586	0.2	469
1968	800	0	800	0.1	80	880	0.00	801	1681	0.2	1344
1969	1240	0	1240	0.1	124	1364	0.00	933	2297	0.2	1838
1970											
1971											
1972											
1973											
1974											
1975											
1976	1013	0	1013	0.1	101	1114	0.00	1046	2160	0.2	1728
1977	1362	0	1362	0.1	136	1498	0.01	1844	3342	0.2	2674
1978	60	0	60	0.1	6	66	0.00	99	165	0.2	132
1979											
1980											
1981	3672	0	3672	0.1	367	4039	0.01	3978	8017	0.2	6414
1982	785	0	785	0.1	79	864	0.00	1479	2343	0.2	1874
1983											
1984	4000	0	4000	0.1	400	4400	0.01	4067	8467	0.2	6774
1985	700	0	700	0.1	70	770	0.00	565	1335	0.2	1068
1986	1260	0	1260	0.1	126	1386	0.00	2231	3617	0.2	2894
1987	650	0	650	0.1	65	715	0.00	1198	1913	0.2	1530
1988	4453	0	4453	0.1	445	4898	0.02	13199	18098	0.2	14478
1989	2154	0	2154	0.1	215	2369	0.01	5009	7378	0.2	5903
1990	799	0	799	0.1	80	879	0.01	2513	3392	0.2	2713
1991	2027	0	2027	0.1	203	2230	0.01	4190	6420	0.2	5136
Mean	1584	0	1584	0.1	158	1742	0.01	2708	4451	0.2	3561
									Restoration goal:		7121



Estimated natural production [P(f,n,cl)] for fall-run in Clear Creek for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

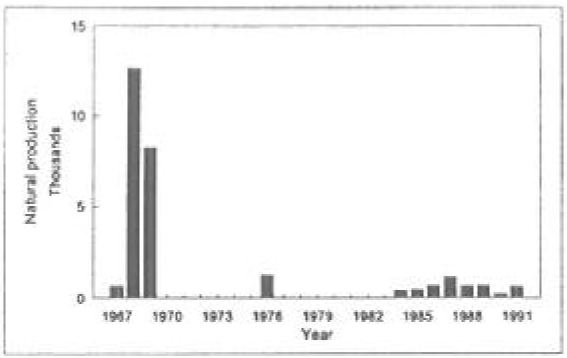
Estimate of h (proportion of production produced in a hatchery) based on data and discussions presented in Cramer (1990).

Description of variables named in worksheet:

E(f,n,cl)	Escapement (naturally spawning fish in Clear Creek)
E(f,h,cl)	Escapement (to hatcheries in Clear Creek)
E(f,t,cl)	Escapement naturally and to hatcheries in Clear Creek)
H(f,i,cl)	Harvest (in Clear Creek, estimated as E(f,t,cl)* prop. harvested instream)
P(f,i,cl)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,cl)	Harvest (ocean harvest of fall-run salmon assigned to Clear Creek)
P(f,t,cl)	Production (total Clear Creek)
h	Proportion hatchery
P(f,n,cl)	Production (natural production for Clear Creek)
DFG	Data taken from Mills and Fisher (1994).

Cow Creek: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,cw)	DFG E(f,h,cw)	E(f,t,cw)	Proportion harvested instream	H(f,i,cw)	P(f,i,cw)	P(f,i,cw)/ P(f,i,cv)	H(f,o,cw)	P(f,t,cw)	h	P(f,n,cw)
1967	520	0	520	0.1	52	572	0.00	251	823	0.2	659
1968	7540	0	7540	0.1	754	8294	0.03	7545	15839	0.2	12671
1969	5570	0	5570	0.1	557	6127	0.02	4191	10318	0.2	8255
1970											
1971											
1972											
1973											
1974											
1975											
1976	726	0	726	0.1	73	799	0.00	749	1548	0.2	1238
1977											
1978											
1979											
1980											
1981											
1982											
1983											
1984	250	0	250	0.1	25	275	0.00	254	529	0.2	423
1985	300	0	300	0.1	30	330	0.00	242	572	0.2	458
1986	300	0	300	0.1	30	330	0.00	531	861	0.2	689
1987	500	0	500	0.1	50	550	0.00	921	1471	0.2	1177
1988	200	0	200	0.1	20	220	0.00	593	813	0.2	650
1989	250	0	250	0.1	25	275	0.00	581	856	0.2	685
1990	75	0	75	0.1	8	83	0.00	236	318	0.2	255
1991	250	0	250	0.1	25	275	0.00	517	792	0.2	633
Mean	1373	0	1373	0.1	137	1511	0.01	1384	2895	0.2	2316
									Restoration goal:		4632



Estimated natural production [P(f,n,cw)] for fall-run in Cow Creek for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

Estimate of h (proportion of production produced in a hatchery) based on data and discussions presented in Cramer (1990).

CDFG spawner surveys have been primarily confined to mainstem Cow Creek, where most chinook spawning occurs. Some additional spawning takes place in Cow Creek's five tributary streams.

Cow Creek supports a small run of late-fall-run chinook salmon, but there are no abundance estimates due to typically high flows and turbidity during their spawning period.

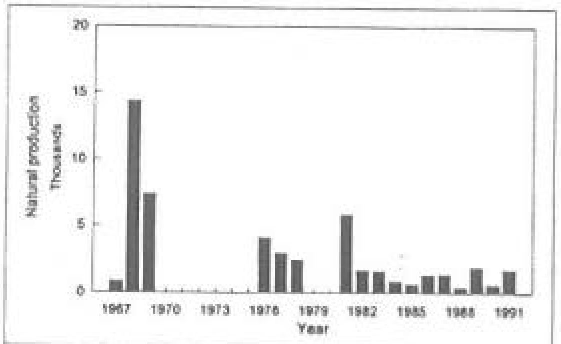
Description of variables named in worksheet:

E(f,n,cw)	Escapement (naturally spawning fish in Cow Creek)
E(f,h,cw)	Escapement (to hatcheries in Cow Creek)
E(f,t,cw)	Escapement naturally and to hatcheries in Cow Creek)
H(f,i,cw)	Harvest (in Cow Creek, estimated as E(f,t,co)* prop. harvested instream)
P(f,i,cw)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,cw)	Harvest (ocean harvest of fall-run salmon assigned to Cow Creek)
P(f,t,cw)	Production (total Cow Creek)
h	Proportion hatchery
P(f,n,cw)	Production (natural production for Cow Creek)
DFG	Data taken from Mills and Fisher (1994)

Cottonwood Creek: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,ct)	DFG E(f,h,ct)	E(f,t,ct)	Proportion harvested instream	H(f,i,ct)	P(f,i,ct)	P(f,i,ct)/ P(f,i,cv)	H(f,o,ct)	P(f,t,ct)	h	P(f,n,ct)
1967	600	0	600	0.1	60	660	0.00	290	950	0.2	760
1968	8540	0	8540	0.1	854	9394	0.04	8545	17939	0.2	14352
1969	4967	0	4967	0.1	497	5464	0.01	3738	9201	0.2	7361
1970											
1971											
1972											
1973											
1974											
1975											
1976	2427	0	2427	0.1	243	2670	0.01	2505	5175	0.2	4140
1977	1512	0	1512	0.1	151	1663	0.01	2047	3710	0.2	2968
1978	1120	0	1120	0.1	112	1232	0.01	1846	3078	0.2	2462
1979											
1980											
1981	3356	0	3356	0.1	336	3692	0.01	3636	7327	0.2	5862
1982	700	0	700	0.1	70	770	0.00	1319	2089	0.2	1671
1983	1000	0	1000	0.1	100	1100	0.00	950	2050	0.2	1640
1984	500	0	500	0.1	50	550	0.00	508	1058	0.2	847
1985	400	0	400	0.1	40	440	0.00	323	763	0.2	610
1986	600	0	600	0.1	60	660	0.00	1063	1723	0.2	1378
1987	600	0	600	0.1	60	660	0.00	1106	1766	0.2	1413
1988	120	0	120	0.1	12	132	0.00	356	488	0.2	390
1989	700	0	700	0.1	70	770	0.00	1628	2398	0.2	1918
1990	175	0	175	0.1	18	193	0.00	550	743	0.2	594
1991	687	0	687	0.1	69	756	0.00	1420	2176	0.2	1741
Mean	1647	0	1647	0.1	165	1812	0.01	1672	3684	0.2	2947

Restoration goal: 5895



Estimated natural production [P(f,n,ct)] for fall-run in Cottonwood Creek for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

Estimate of h (proportion of production produced in a hatchery) based on data and discussions presented in Cramer (1990).

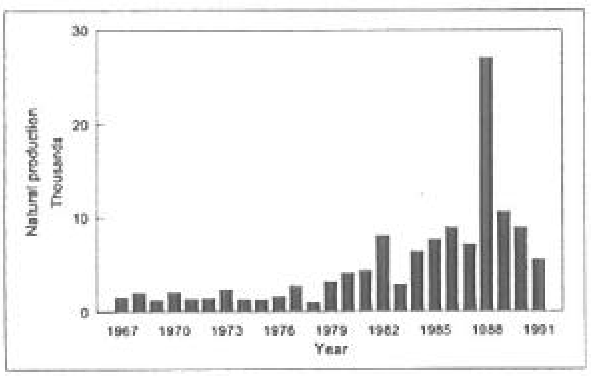
No consistent surveys have been conducted for late-fall and spring-runs of chinook salmon.

Description of variables named in worksheet:

E(f,n,ct)	Escapement (naturally spawning fish in Cottonwood Creek)
E(f,h,ct)	Escapement (to hatcheries in Cottonwood Creek)
E(f,t,ct)	Escapement naturally and to hatcheries in Cottonwood Creek)
H(f,i,ct)	Harvest (in Cottonwood Creek, estimated as E(f,t,ct)* prop. harvested instream)
P(f,i,ct)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,ct)	Harvest (ocean harvest of fall-run salmon assigned to Cottonwood Creek)
P(f,t,ct)	Production (total Cottonwood Creek)
h	Proportion hatchery
P(f,n,ct)	Production (natural production for Cottonwood Creek)
DFG	Data taken from Mills and Fisher (1994).

Battle Creek: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,ba)	DFG E(f,h,ba)	E(f,t,ba)	Proportion harvested instream	H(f,i,ba)	P(f,i,ba)	P(f,i,ba)/ P(f,i,cv)	H(f,o,ba)	P(f,t,ba)	h	P(f,n,ba)
1967	2160	7440	9600	0.1	960	10560	0.05	4639	15199	0.9	1520
1968	2950	6355	9305	0.1	931	10236	0.04	9311	19546	0.9	1955
1969	3200	3678	6878	0.1	688	7566	0.02	5176	12741	0.9	1274
1970	3320	6356	9676	0.1	968	10644	0.04	9939	20582	0.9	2058
1971	3285	3645	6930	0.1	693	7623	0.03	6343	13966	0.9	1397
1972	2030	3221	5251	0.1	525	5776	0.03	8625	14402	0.9	1440
1973	4300	4540	8840	0.1	884	9724	0.03	14311	24035	0.9	2403
1974	2294	3036	5330	0.1	533	5863	0.02	7440	13303	0.9	1330
1975	2426	3312	5738	0.1	574	6312	0.03	6572	12884	0.9	1288
1976	3147	4446	7593	0.1	759	8352	0.04	7837	16190	0.9	1619
1977	5604	5636	11240	0.1	1124	12364	0.05	15219	27583	0.9	2758
1978	1770	1882	3652	0.1	365	4017	0.02	6018	10036	0.9	1004
1979	4430	8729	13159	0.1	1316	14475	0.05	17119	31594	0.9	3159
1980	4940	9503	14443	0.1	1444	15887	0.08	24924	40811	0.9	4081
1981	6933	13223	20156	0.1	2016	22172	0.07	21835	44006	0.9	4401
1982	7270	19760	27030	0.1	2703	29733	0.11	50938	80671	0.9	8067
1983	5227	8756	13983	0.1	1398	15381	0.06	13288	28669	0.9	2867
1984	8312	21648	29960	0.1	2996	32956	0.11	30465	63421	0.9	6342
1985	23961	16320	40281	0.1	4028	44309	0.10	32488	76797	0.9	7680
1986	18753	12481	31234	0.1	3123	34357	0.10	55314	89672	0.9	8967
1987	7912	16321	24233	0.1	2423	26656	0.08	44656	71312	0.9	7131
1988	52852	13579	66431	0.1	6643	73074	0.23	196910	269984	0.9	26998
1989	19076	11986	31062	0.1	3106	34168	0.16	72231	106400	0.9	10640
1990	6453	14635	21088	0.1	2109	23197	0.17	66321	89518	0.9	8952
1991	6613	10683	17296	0.1	1730	19026	0.12	35756	54782	0.9	5478
Mean	8369	9247	17616	0.1	1762	19377	0.07	30547	49924	0.9	4992
									Restoration goal:		9985



Estimated natural production [P(f,n,ba)] for fall-run in Battle Creek for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

Estimate of h (proportion of production produced in a hatchery) based on the fact that Coleman National Fish Hatchery is located on Battle Creek.

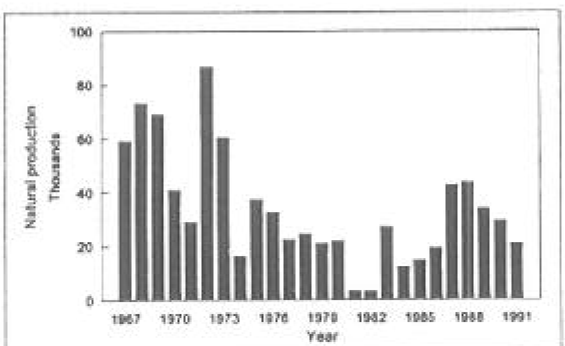
No abundance estimate is available for spring-run chinook in Battle Creek, while winter-run chinook are believed to have been extirpated.

Description of variables named in worksheet:

E(f,n,ba)	Escapement (naturally spawning fish in Battle Creek)
E(f,h,ba)	Escapement (to hatcheries in Battle Creek)
E(f,t,ba)	Escapement naturally and to hatcheries in Battle Creek)
H(f,i,ba)	Harvest (in Battle Creek, estimated as E(f,t,ba)* prop. harvested instream)
P(f,i,ba)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,ba)	Harvest (ocean harvest of fall-run salmon assigned to Battle Creek)
P(f,t,ba)	Production (total Battle Creek)
h	Proportion hatchery
P(f,n,ba)	Production (natural production for Battle Creek)
DFG	Data taken from Mills and Fisher (1994).

Battle Creek: Production estimates for late-fall-run chinook salmon.

Year	DFG E(l,n,ba)	DFG E(l,h,ba)	E(l,t,ba)	Proportion harvested instream	H(l,i,ba)	P(l,i,ba)	P(l,i,ba)/ P(l,i,cv)	H(l,o,ba)	P(l,t,ba)	h	P(l,n,ba)
1967											
1968											
1969		787	787	0.2	157	944	0.02	646	1590	0.9	159
1970		3060	3060	0.2	612	3672	0.12	3429	7101	0.9	710
1971		1209	1209	0.2	242	1451	0.06	1207	2658	0.9	266
1972		549	549	0.2	110	659	0.02	984	1643	0.9	164
1973		403	403	0.2	81	484	0.02	712	1195	0.9	120
1974		705	705	0.2	141	846	0.07	1074	1920	0.9	192
1975		1498	1498	0.2	300	1798	0.07	1872	3669	0.9	367
1976		609	609	0.2	122	731	0.03	686	1417	0.9	142
1977		756	756	0.2	151	907	0.06	1117	2024	0.9	202
1978		1853	1853	0.2	371	2224	0.15	3331	5555	0.9	555
1979		829	829	0.2	166	995	0.08	1177	2171	0.9	217
1980		867	867	0.2	173	1040	0.09	1632	2673	0.9	267
1981		2605	2605	0.2	521	3126	0.55	3078	6204	0.9	620
1982		1886	1886	0.2	377	2263	0.35	3877	6140	0.9	614
1983		958	958	0.2	192	1150	0.06	993	2143	0.9	214
1984		628	628	0.2	126	754	0.08	697	1450	0.9	145
1985		388	388	0.2	78	466	0.04	341	807	0.9	81
1986		788	788	0.2	158	946	0.08	1522	2468	0.9	247
1987		803	803	0.2	161	964	0.05	1614	2578	0.9	258
1988		457	457	0.2	91	548	0.04	1478	2026	0.9	203
1989		882	882	0.2	176	1058	0.07	2237	3296	0.9	330
1990		192	192	0.2	38	230	0.02	659	889	0.9	89
1991		279	279	0.2	56	335	0.04	629	964	0.9	96
Mean		1000	1000	0.2	200	1200	0.09	1521	2721	0.9	272
									Restoration goal:		544



Estimated natural production [P(l,n,ba)] for late-fall-run in the Battle Creek for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

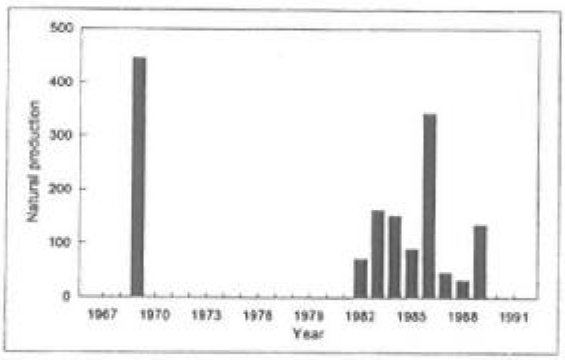
Estimate of h (proportion of production produced in a hatchery) based on the fact that Coleman National Fish Hatchery is located on Battle Creek and that late-fall-run chinook salmon spawn on Battle Creek.

Description of variables named in worksheet:

E(l,n,ba)	Escapement (naturally spawning fish in Battle Creek)
E(l,h,ba)	Escapement (to hatcheries in Battle Creek)
E(l,t,ba)	Escapement naturally and to hatcheries in Battle Creek)
H(l,i,ba)	Harvest (in Battle Creek, estimated as E(f,t,ba)* prop. harvested instream)
P(l,i,ba)	Production (total escapement plus instream harvest)
P(l,i,cv)	Production (total Central Valley)
H(l,o,ba)	Harvest (ocean harvest of late-fall-run salmon assigned to Battle Creek)
P(l,t,ba)	Production (total Battle Creek)
h	Proportion hatchery
P(l,n,ba)	Production (natural production for Battle Creek)
DFG	Data taken from Mills and Fisher (1994).

Paynes Creek: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,pa)	DFG E(f,h,pa)	E(f,t,pa)	Proportion harvested instream	H(f,i,pa)	P(f,i,pa)	P(f,i,pa)/ P(f,i,cv)	H(f,o,pa)	P(f,t,pa)	h	P(f,n,pa)
1967											
1968											
1969	300	0	300	0.1	30	330	0.00	226	556	0.2	445
1970											
1971											
1972											
1973											
1974											
1975											
1976											
1977											
1978											
1979											
1980											
1981											
1982	30	0	30	0.1	3	33	0.00	57	90	0.2	72
1983	100	0	100	0.1	10	110	0.00	95	205	0.2	164
1984	90	0	90	0.1	9	99	0.00	92	191	0.2	152
1985	60	0	60	0.1	6	66	0.00	48	114	0.2	92
1986	150	0	150	0.1	15	165	0.00	266	431	0.2	345
1987	20	0	20	0.1	2	22	0.00	37	59	0.2	47
1988	10	0	10	0.1	1	11	0.00	30	41	0.2	33
1989	50	0	50	0.1	5	55	0.00	116	171	0.2	137
1990											
1991											
Mean	90	0	90	0.1	9	99	0.00	107	206	0.2	165
									Restoration goal:		330



Estimated natural production [P(f,n,pa)] for fall-run in Paynes Creek for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

Estimate of h (proportion of production produced in a hatchery) based on data and discussions presented in Cramer (1990).

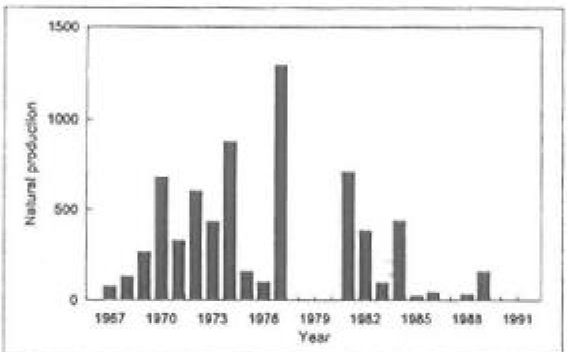
Abundance estimates for other runs of chinook salmon are not available, although these other runs may opportunistically utilize the stream.

Description of variables named in worksheet:

E(f,n,pa)	Escapement (naturally spawning fish in Paynes Creek)
E(f,h,pa)	Escapement (to hatcheries in Paynes Creek)
E(f,t,pa)	Escapement naturally and to hatcheries in Paynes Creek)
H(f,i,pa)	Harvest (in Paynes Creek, estimated as E(f,t,pa)* prop. harvested instream)
P(f,i,pa)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,pa)	Harvest (ocean harvest of fall-run salmon assigned to Paynes Creek)
P(f,t,pa)	Production (total Paynes Creek)
h	Proportion hatchery
P(f,n,pa)	Production (natural production for Paynes Creek)
DFG	Data taken from Mills and Fisher (1994).

Antelope Creek: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,an)	DFG E(f,h,an)	E(f,t,an)	Proportion harvested instream	H(f,i,an)	P(f,i,an)	P(f,i,an)/ P(f,i,cv)	H(f,o,an)	P(f,t,an)	*h*	P(f,n,an)
1967	60	0	60	0.1	6	66	0.00	29	95	0.2	76
1968	80	0	80	0.1	8	88	0.00	80	168	0.2	134
1969	180	0	180	0.1	18	198	0.00	135	333	0.2	267
1970	400	0	400	0.1	40	440	0.00	411	851	0.2	681
1971	205	0	205	0.1	21	226	0.00	188	413	0.2	331
1972	275	0	275	0.1	28	303	0.00	452	754	0.2	603
1973	200	0	200	0.1	20	220	0.00	324	544	0.2	435
1974	440	0	440	0.1	44	484	0.00	614	1098	0.2	879
1975	90	0	90	0.1	9	99	0.00	103	202	0.2	162
1976	60	0	60	0.1	6	66	0.00	62	128	0.2	102
1977	660	0	660	0.1	66	726	0.00	894	1620	0.2	1296
1978											
1979											
1980											
1981	407	0	407	0.1	41	448	0.00	441	889	0.2	711
1982	162	0	162	0.1	16	178	0.00	305	483	0.2	387
1983	60	0	60	0.1	6	66	0.00	57	123	0.2	98
1984	260	0	260	0.1	26	286	0.00	264	550	0.2	440
1985	15	0	15	0.1	2	17	0.00	12	29	0.2	23
1986	20	0	20	0.1	2	22	0.00	35	57	0.2	46
1987											
1988	10	0	10	0.1	1	11	0.00	30	41	0.2	33
1989	60	0	60	0.1	6	66	0.00	140	206	0.2	164
1990											
1991											
Mean	192	0	192	0.1	19	211	0.00	241	452	0.2	361
									Restoration goal:		723



Estimated natural production [P(f,n,an)] for fall-run in Antelope Creek for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

Estimate of h (proportion of production produced in a hatchery) based on data and discussions presented in Cramer (1990).

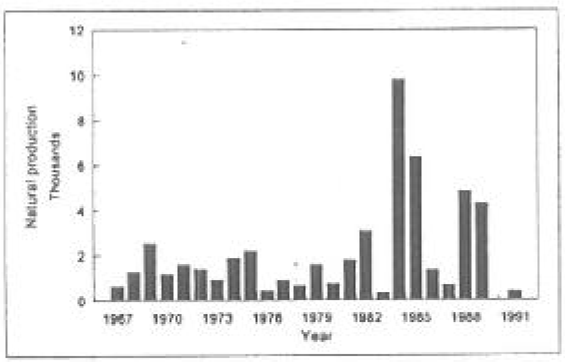
Insufficient information is available to provide abundance estimates for late-fall and spring-run chinook salmon in Antelope Creek.

Description of variables named in worksheet:

E(f,n,an)	Escapement (naturally spawning fish in Antelope Creek)
E(f,h,an)	Escapement (to hatcheries in Antelope Creek)
E(f,t,an)	Escapement naturally and to hatcheries in Antelope Creek)
H(f,i,an)	Harvest (in Antelope Creek, estimated as E(f,t,an)* prop. harvested instream)
P(f,i,an)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,an)	Harvest (ocean harvest of fall-run salmon assigned to Antelope Creek)
P(f,t,an)	Production (total Antelope Creek)
h	Proportion hatchery
P(f,n,an)	Production (natural production for Antelope Creek)
DFG	Data taken from Mills and Fisher (1994).

Mill Creek: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,mi)	DFG E(f,h,mi)	E(f,t,mi)	Proportion harvested instream	H(f,i,mi)	P(f,i,mi)	P(f,i,mi)/ P(f,i,cv)	H(f,o,mi)	P(f,t,mi)	*h*	P(f,n,mi)
1967	500	0	500	0.1	50	550	0.00	242	792	0.2	633
1968	750	0	750	0.1	75	825	0.00	750	1575	0.2	1260
1969	1700	0	1700	0.1	170	1870	0.01	1279	3149	0.2	2519
1970	690	0	690	0.1	69	759	0.00	709	1468	0.2	1174
1971	980	0	980	0.1	98	1078	0.00	897	1975	0.2	1580
1972	631	0	631	0.1	63	694	0.00	1037	1731	0.2	1384
1973	420	0	420	0.1	42	462	0.00	680	1142	0.2	914
1974	944	0	944	0.1	94	1038	0.00	1318	2356	0.2	1885
1975	1208	0	1208	0.1	121	1329	0.01	1384	2712	0.2	2170
1976	245	0	245	0.1	25	270	0.00	253	522	0.2	418
1977	456	0	456	0.1	46	502	0.00	617	1119	0.2	895
1978	300	0	300	0.1	30	330	0.00	494	824	0.2	660
1979	810	0	810	0.1	81	891	0.00	1054	1945	0.2	1556
1980	320	0	320	0.1	32	352	0.00	552	904	0.2	723
1981	1020	0	1020	0.1	102	1122	0.00	1105	2227	0.2	1782
1982	1290	0	1290	0.1	129	1419	0.01	2431	3850	0.2	3080
1983	200	0	200	0.1	20	220	0.00	190	410	0.2	328
1984	5800	0	5800	0.1	580	6380	0.02	5898	12278	0.2	9822
1985	4180	0	4180	0.1	418	4598	0.01	3371	7969	0.2	6375
1986	574	0	574	0.1	57	631	0.00	1017	1648	0.2	1318
1987	282	0	282	0.1	28	310	0.00	520	830	0.2	664
1988	1487	0	1487	0.1	149	1636	0.01	4408	6043	0.2	4835
1989	1564	0	1564	0.1	156	1720	0.01	3637	5357	0.2	4286
1990											
1991	150	0	150	0.1	15	165	0.00	310	475	0.2	380
Mean	1104	0	1104	0.1	110	1215	0.00	1423	2638	0.2	2110
									Restoration goal:		4220



Estimated natural production [P(f,n,mi)] for fall-run in Mill Creek for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

Estimate of h (proportion of production produced in a hatchery) based on data and discussions presented in Cramer (1990).

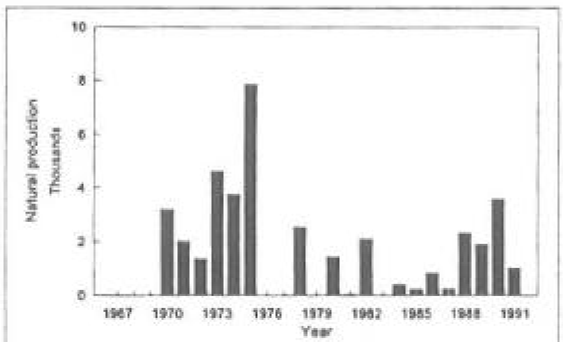
There are no estimates of late-fall-run chinook salmon abundance in Mill Creek during the baseline period.

Description of variables named in worksheet:

E(f,n,mi)	Escapement (naturally spawning fish in Mill Creek)
E(f,h,mi)	Escapement (to hatcheries in Mill Creek)
E(f,t,mi)	Escapement naturally and to hatcheries in Mill Creek)
H(f,i,mi)	Harvest (in Mill Creek, estimated as E(f,t,mi)* prop. harvested instream)
P(f,i,mi)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,mi)	Harvest (ocean harvest of fall-run salmon assigned to Mill Creek)
P(f,t,mi)	Production (total Mill Creek)
h	Proportion hatchery
P(f,n,mi)	Production (natural production for Mill Creek)
DFG	Data taken from Mills and Fisher (1994).

Mill Creek: Production estimates for spring-run chinook salmon.

Year	DFG E(s,n,mi)	DFG E(s,h,mi)	E(s,t,mi)	Proportion harvested instream	H(s,i,mi)	P(s,i,mi)	P(s,i,mi)/ P(s,i,cv)	H(s,o,mi)	P(s,t,mi)	h	P(s,n,mi)
1967											
1968											
1969											
1970	1500	0	1500	0.1	150	1650	0.19	1541	3191	0	3191
1971	1000	0	1000	0.1	100	1100	0.11	915	2015	0	2015
1972	500	0	500	0.1	50	550	0.06	821	1371	0	1371
1973	1700	0	1700	0.1	170	1870	0.14	2752	4622	0	4622
1974	1500	0	1500	0.1	150	1650	0.18	2094	3744	0	3744
1975	3500	0	3500	0.1	350	3850	0.14	4009	7859	0	7859
1976											
1977											
1978	925	0	925	0.1	93	1018	0.11	1524	2542	0	2542
1979											
1980	500	0	500	0.1	50	550	0.04	863	1413	0	1413
1981	15	0	15	0.1	2	17	0.00	16	33	0	33
1982	700	0	700	0.1	70	770	0.02	1319	2089	0	2089
1983											
1984	191	0	191	0.1	19	210	0.02	194	404	0	404
1985	121	0	121	0.1	12	133	0.01	98	231	0	231
1986	291	0	291	0.1	29	320	0.01	515	835	0	835
1987	89	0	89	0.1	9	98	0.01	164	262	0	262
1988	572	0	572	0.1	57	629	0.05	1695	2325	0	2325
1989	556	0	556	0.1	56	612	0.07	1293	1905	0	1905
1990	844	0	844	0.1	84	928	0.15	2654	3583	0	3583
1991	319	0	319	0.1	32	351	0.19	659	1010	0	1010
Mean	824	0	824	0.1	82	906	0.08	1285	2191	0.0	2191
									Restoration goal:		4382



Estimated natural production [P(s,n,mi)] for spring-run in Mill Creek for each of the years in the baseline period.

Notes:
Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

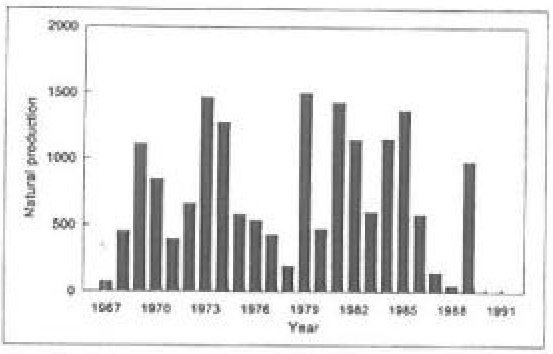
Description of variables named in worksheet:

E(s,n,mi)	Escapement (naturally spawning fish in Mill Creek)
E(s,h,mi)	Escapement (to hatcheries in Mill Creek)
E(s,t,mi)	Escapement naturally and to hatcheries in Mill Creek)
H(s,i,mi)	Harvest (in Mill Creek, estimated as E(s,t,mi)* prop. harvested instream)
P(s,i,mi)	Production (total escapement plus instream harvest)
P(s,i,cv)	Production (total Central Valley)
H(s,o,mi)	Harvest (ocean harvest of spring-run salmon assigned to Mill Creek)
P(s,t,mi)	Production (total Mill Creek)
h	Proportion hatchery
P(s,n,mi)	Production (natural production for Mill Creek)
DFG	Data taken from Mills and Fisher (1994).

Deer Creek: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,de)	DFG E(f,h,de)	E(f,t,de)	Proportion harvested instream	H(f,i,de)	P(f,i,de)	P(f,i,de)/ P(f,i,cv)	H(f,o,de)	P(f,t,de)	h	P(f,n,de)
1967	60	0	60	0.1	6	66	0.00	29	95	0.2	76
1968	270	0	270	0.1	27	297	0.00	270	567	0.2	454
1969	750	0	750	0.1	75	825	0.00	564	1389	0.2	1111
1970	500	0	500	0.1	50	550	0.00	514	1064	0.2	851
1971	248	0	248	0.1	25	273	0.00	227	500	0.2	400
1972	304	0	304	0.1	30	334	0.00	499	834	0.2	667
1973	676	0	676	0.1	68	744	0.00	1094	1838	0.2	1470
1974	640	0	640	0.1	64	704	0.00	893	1597	0.2	1278
1975	328	0	328	0.1	33	361	0.00	376	737	0.2	589
1976	315	0	315	0.1	32	347	0.00	325	672	0.2	537
1977	220	0	220	0.1	22	242	0.00	298	540	0.2	432
1978	90	0	90	0.1	9	99	0.00	148	247	0.2	198
1979	780	0	780	0.1	78	858	0.00	1015	1873	0.2	1498
1980	210	0	210	0.1	21	231	0.00	362	593	0.2	475
1981	820	0	820	0.1	82	902	0.00	888	1790	0.2	1432
1982	480	0	480	0.1	48	528	0.00	905	1433	0.2	1146
1983	370	0	370	0.1	37	407	0.00	352	759	0.2	607
1984	680	0	680	0.1	68	748	0.00	691	1439	0.2	1152
1985	900	0	900	0.1	90	990	0.00	726	1716	0.2	1373
1986	256	0	256	0.1	26	282	0.00	453	735	0.2	588
1987	64	0	64	0.1	6	70	0.00	118	188	0.2	151
1988	16	0	16	0.1	2	18	0.00	47	65	0.2	52
1989	358	0	358	0.1	36	394	0.00	832	1226	0.2	981
1990											
1991											
Mean	406	0	406	0.1	41	446	0.00	506	952	0.2	762

Restoration goal: 1523



Estimated natural production [P(f,n,de)] for fall-run in Deer Creek for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

Estimate of h (proportion of production produced in a hatchery) based on data and discussions presented in Cramer (1990).

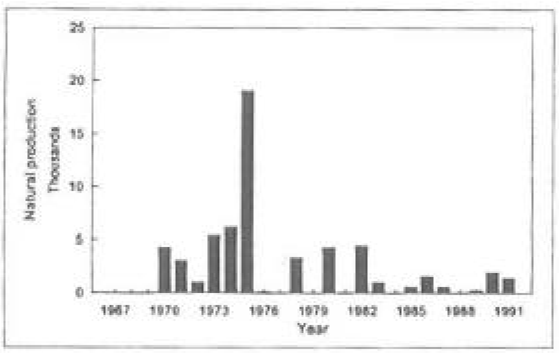
An unknown number of late-fall-run chinook salmon spawn in Deer Creek, but they are probably strays, and may not be a self-sustaining population.

Description of variables named in worksheet:

E(f,n,de) Escapement (naturally spawning fish in Deer Creek)
E(f,h,de) Escapement (to hatcheries in Deer Creek)
E(f,t,de) Escapement naturally and to hatcheries in Deer Creek)
H(f,i,de) Harvest (in Deer Creek, estimated as E(f,t,de)* prop. harvested instream)
P(f,i,de) Production (total escapement plus instream harvest)
P(f,i,cv) Production (total Central Valley)
H(f,o,de) Harvest (ocean harvest of fall-run salmon assigned to Deer Creek)
P(f,t,de) Production (total Deer Creek)
h Proportion hatchery
P(f,n,de) Production (natural production for Deer Creek)
DFG Data taken from Mills and Fisher (1994).

Deer Creek: Production estimates for spring-run chinook salmon.

Year	DFG E(s,n,de)	DFG E(s,h,de)	E(s,t,de)	Proportion harvested instream	H(s,i,de)	P(s,i,de)	P(s,i,de)/ P(s,i,cv)	H(s,o,de)	P(s,t,de)	h	P(s,n,de)
1967											
1968											
1969											
1970	2000	0	2000	0.1	200	2200	0.26	2054	4254	0	4254
1971	1500	0	1500	0.1	150	1650	0.16	1373	3023	0	3023
1972	400	0	400	0.1	40	440	0.04	657	1097	0	1097
1973	2000	0	2000	0.1	200	2200	0.16	3238	5438	0	5438
1974	2500	0	2500	0.1	250	2750	0.30	3490	6240	0	6240
1975	8500	0	8500	0.1	850	9350	0.35	9736	19086	0	19086
1976	44	0	44	0.1	4	48	0.00	45	94	0	94
1977											
1978	1200	0	1200	0.1	120	1320	0.14	1978	3298	0	3298
1979											
1980	1500	0	1500	0.1	150	1650	0.12	2589	4239	0	4239
1981	25	0	25	0.1	3	28	0.00	27	55	0	55
1982	1500	0	1500	0.1	150	1650	0.05	2827	4477	0	4477
1983	500	0	500	0.1	50	550	0.10	475	1025	0	1025
1984											
1985	301	0	301	0.1	30	331	0.02	243	574	0	574
1986	543	0	543	0.1	54	597	0.03	962	1559	0	1559
1987	200	0	200	0.1	20	220	0.02	369	589	0	589
1988											
1989	77	0	77	0.1	8	85	0.01	179	264	0	264
1990	458	0	458	0.1	46	504	0.08	1440	1944	0	1944
1991	449	0	449	0.1	45	494	0.26	928	1422	0	1422
Mean	1317	0	1317	0.1	132	1448	0.12	1812	3260	0.0	3260
									Restoration goal:		6520



Estimated natural production [P(s,n,de)] for spring-run in Deer Creek for each of the years in the baseline period.

Notes:
Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

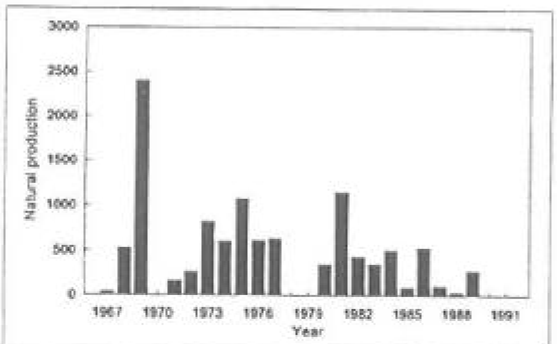
Description of variables named in worksheet:

E(s,n,de)	Escapement (naturally spawning fish in Deer Creek)
E(s,h,de)	Escapement (to hatcheries in Deer Creek)
E(s,t,de)	Escapement naturally and to hatcheries in Deer Creek)
H(s,i,de)	Harvest (in Deer Creek, estimated as E(s,t,de)* prop. harvested instream)
P(s,i,de)	Production (total escapement plus instream harvest)
P(s,i,cv)	Production (total Central Valley)
H(s,o,de)	Harvest (ocean harvest of spring-run salmon assigned to Deer Creek)
P(s,t,de)	Production (total Deer Creek)
h	Proportion hatchery
P(s,n,de)	Production (natural production for Deer Creek)
DFG	Data taken from Mills and Fisher (1994).

Miscellaneous creeks: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,ms)	DFG E(f,h,ms)	E(f,t,ms)	Proportion harvested instream	H(f,i,ms)	P(f,i,ms)	P(f,i,ms)/ P(f,i,cv)	H(f,o,ms)	P(f,t,ms)	h	P(f,n,ms)
1967	30	0	30	0.1	3	33	0.00	14	47	0.2	38
1968	310	0	310	0.1	31	341	0.00	310	651	0.2	521
1969	1620	0	1620	0.1	162	1782	0.00	1219	3001	0.2	2401
1970											
1971	100	0	100	0.1	10	110	0.00	92	202	0.2	161
1972	120	0	120	0.1	12	132	0.00	197	329	0.2	263
1973	376	0	376	0.1	38	414	0.00	609	1022	0.2	818
1974	300	0	300	0.1	30	330	0.00	419	749	0.2	599
1975	600	0	600	0.1	60	660	0.00	687	1347	0.2	1078
1976	356	0	356	0.1	36	392	0.00	367	759	0.2	607
1977	320	0	320	0.1	32	352	0.00	433	785	0.2	628
1978											
1979											
1980	151	0	151	0.1	15	166	0.00	261	427	0.2	341
1981	660	0	660	0.1	66	726	0.00	715	1441	0.2	1153
1982	180	0	180	0.1	18	198	0.00	339	537	0.2	430
1983	210	0	210	0.1	21	231	0.00	200	431	0.2	344
1984	300	0	300	0.1	30	330	0.00	305	635	0.2	508
1985	60	0	60	0.1	6	66	0.00	48	114	0.2	92
1986	230	0	230	0.1	23	253	0.00	407	660	0.2	528
1987	45	0	45	0.1	5	50	0.00	83	132	0.2	106
1988	10	0	10	0.1	1	11	0.00	30	41	0.2	33
1989	100	0	100	0.1	10	110	0.00	233	343	0.2	274
1990											
1991											
Mean	304	0	304	0.1	30	334	0.00	348	683	0.2	546

Restoration goal: 1092



Estimated natural production [P(f,n,ms)] for fall-run in miscellaneous creeks for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

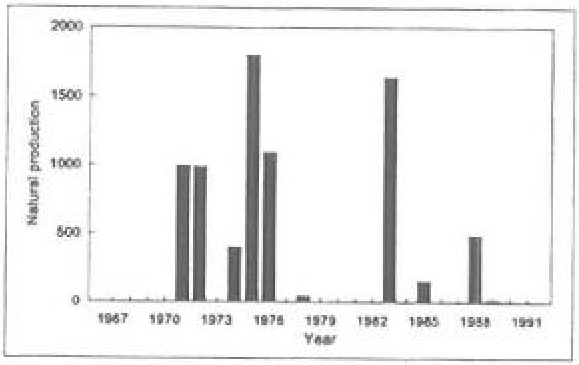
Estimate of h (proportion of production produced in a hatchery) based on data and discussions presented in Cramer (1990).

Description of variables named in worksheet:

E(f,n,ms)	Escapement (naturally spawning fish in miscellaneous creeks)
E(f,h,ms)	Escapement (to hatcheries in miscellaneous creeks)
E(f,t,ms)	Escapement naturally and to hatcheries in miscellaneous creeks)
H(f,i,ms)	Harvest (in miscellaneous creeks, estimated as E(f,t,ms)* prop. harvested instream)
P(f,i,ms)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,ms)	Harvest (ocean harvest of fall-run salmon assigned to miscellaneous creeks)
P(f,t,ms)	Production (total Miscellaneous Creeks)
h	Proportion hatchery
P(f,n,ms)	Production (natural production for miscellaneous creeks)
DFG	Data taken from Mills and Fisher (1994).

Butte Creek: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,bu)	DFG E(f,h,bu)	E(f,t,bu)	Proportion harvested instream	H(f,i,bu)	P(f,i,bu)	P(f,i,bu)/ P(f,i,cv)	H(f,o,bu)	P(f,t,bu)	h	P(f,n,bu)
1967											
1968											
1969											
1970											
1971	615	0	615	0.1	62	677	0.00	563	1239	0.2	992
1972	450	0	450	0.1	45	495	0.00	739	1234	0.2	987
1973											
1974	200	0	200	0.1	20	220	0.00	279	499	0.2	399
1975	1000	0	1000	0.1	100	1100	0.00	1145	2245	0.2	1796
1976	640	0	640	0.1	64	704	0.00	661	1365	0.2	1092
1977											
1978	20	0	20	0.1	2	22	0.00	33	55	0.2	44
1979											
1980											
1981											
1982											
1983	1000	0	1000	0.1	100	1100	0.00	950	2050	0.2	1640
1984											
1985	100	0	100	0.1	10	110	0.00	81	191	0.2	153
1986											
1987											
1988	150	0	150	0.1	15	165	0.00	445	610	0.2	488
1989	5	0	5	0.1	1	6	0.00	12	17	0.2	14
1990											
1991											
Mean	418	0	418	0.1	42	460	0.00	491	951	0.2	760
									Restoration goal:		1521



Estimated natural production [P(f,n,bu)] for fall-run in Butte Creek for each of the years in the baseline period.

Notes:
Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.
Estimate of h (proportion of production produced in a hatchery) based on data and discussions presented in Cramer (1990).
Late-fall-run chinook salmon have been reported in Butte Creek, however, no systemic counts have been made to verify numbers.

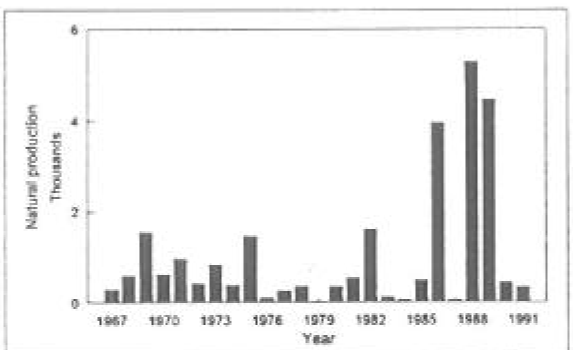
Description of variables named in worksheet:

E(f,n,bu)	Escapement (naturally spawning fish in Butte Creek)
E(f,h,bu)	Escapement (to hatcheries in Butte Creek)
E(f,t,bu)	Escapement naturally and to hatcheries in Butte Creek)
H(f,i,bu)	Harvest (in Butte Creek, estimated as E(f,t,bu)* prop. harvested instream)
P(f,i,bu)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,bu)	Harvest (ocean harvest of fall-run salmon assigned to Butte Creek)
P(f,t,bu)	Production (total Butte Creek)
h	Proportion hatchery
P(f,n,bu)	Production (natural production for Butte Creek)
DFG	Data taken from Mills and Fisher (1994).

Butte Creek: Production estimates for spring-run chinook salmon.

Year	DFG E(s,n,bu)	DFG E(s,h,bu)	E(s,t,bu)	Proportion harvested instream	H(s,i,bu)	P(s,i,bu)	P(s,i,bu)/ P(s,i,cv)	H(s,o,bu)	P(s,t,bu)	h	P(s,n,bu)
1967	180	0	180	0.1	18	198	0.01	87	285	0	285
1968	280	0	280	0.1	28	308	0.02	280	588	0	588
1969	830	0	830	0.1	83	913	0.03	625	1538	0	1538
1970	285	0	285	0.1	29	314	0.04	293	606	0	606
1971	470	0	470	0.1	47	517	0.05	430	947	0	947
1972	150	0	150	0.1	15	165	0.02	246	411	0	411
1973	300	0	300	0.1	30	330	0.02	486	816	0	816
1974	150	0	150	0.1	15	165	0.02	209	374	0	374
1975	650	0	650	0.1	65	715	0.03	745	1460	0	1460
1976	46	0	46	0.1	5	51	0.00	47	98	0	98
1977	100	0	100	0.1	10	110	0.01	135	245	0	245
1978	128	0	128	0.1	13	141	0.01	211	352	0	352
1979	10	0	10	0.1	1	11	0.00	13	24	0	24
1980	119	0	119	0.1	12	131	0.01	205	336	0	336
1981	250	0	250	0.1	25	275	0.01	271	546	0	546
1982	534	0	534	0.1	53	587	0.02	1006	1594	0	1594
1983	50	0	50	0.1	5	55	0.01	48	103	0	103
1984	23	0	23	0.1	2	25	0.00	23	49	0	49
1985	254	0	254	0.1	25	279	0.02	205	484	0	484
1986	1371	0	1371	0.1	137	1508	0.07	2428	3936	0	3936
1987	14	0	14	0.1	1	15	0.00	26	41	0	41
1988	1300	0	1300	0.1	130	1430	0.10	3853	5283	0	5283
1989	1300	0	1300	0.1	130	1430	0.17	3023	4453	0	4453
1990	100	0	100	0.1	10	110	0.02	314	424	0	424
1991	100	0	100	0.1	10	110	0.06	207	317	0	317
Mean	360	0	360	0.1	36	396	0.03	617	1012	0.0	1012

Restoration goal: 2025



Estimated natural production [P(s,n,bu)] for spring-run in Butte Creek for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

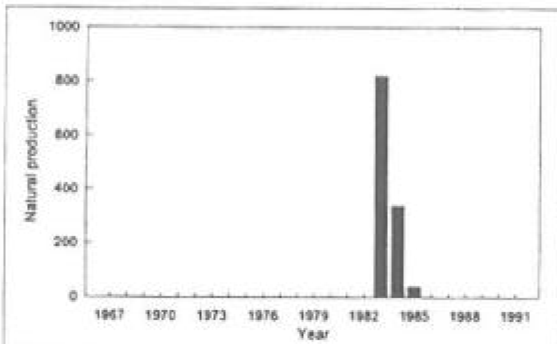
Snorkel surveys conducted by PG&E indicate that CDFG spring-run estimates may be low by about 20%.

Description of variables named in worksheet:

E(s,n,bu)	Escapement (naturally spawning fish in Butte Creek)
E(s,h,bu)	Escapement (to hatcheries in Butte Creek)
E(s,t,bu)	Escapement naturally and to hatcheries in Butte Creek)
H(s,i,bu)	Harvest (in Butte Creek, estimated as E(s,t,bu)* prop. harvested instream)
P(s,i,bu)	Production (total escapement plus instream harvest)
P(s,i,cv)	Production (total Central Valley)
H(s,o,bu)	Harvest (ocean harvest of spring-run salmon assigned to Butte Creek)
P(s,t,bu)	Production (total Butte Creek)
h	Proportion hatchery
P(s,n,bu)	Production (natural production for Butte Creek)
DFG	Data taken from Mills and Fisher (1994).

Big Chico Creek: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,bc)	DFG E(f,h,bc)	E(f,t,bc)	Proportion harvested instream	H(f,i,bc)	P(f,i,bc)	P(f,i,bc)/ P(f,i,cv)	H(f,o,bc)	P(f,t,bc)	*h*	P(f,n,bc)
1967											
1968											
1969											
1970											
1971											
1972											
1973											
1974											
1975											
1976											
1977											
1978											
1979											
1980											
1981											
1982											
1983	500	0	500	0.1	50	550	0.00	475	1025	0.2	820
1984	200	0	200	0.1	20	220	0.00	203	423	0.2	339
1985	25	0	25	0.1	3	28	0.00	20	48	0.2	38
1986											
1987											
1988											
1989											
1990											
1991											
Mean	242	0	242	0.1	24	266	0.00	233	499	0.2	399
									Restoration goal:		798



Estimated natural production [P(f,n,bc)] for fall-run in Big Chico Creek for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

Estimate of h (proportion of production produced in a hatchery) based on data and discussions presented in Cramer (1990).

In years without significant autumn rain, no fall-run of chinook salmon is possible in Big Chico Creek.

Late-fall-run chinook salmon have been reported in Big Chico Creek, but no abundance estimates are available due to scarcity of data.

Spring-run chinook salmon are thought to have been extirpated from Big Chico Creek, although fry were transplanted from the Feather River from 1987 to 1992, and spring-run fry were captured in a fyke net in the spring of 1994.

Fall- and Late-Fall-run chinook salmon have been reported to spawn in Mud and Rock Creeks, tributaries to Big Chico Creek, but there is no quantitative data to support abundance estimates.

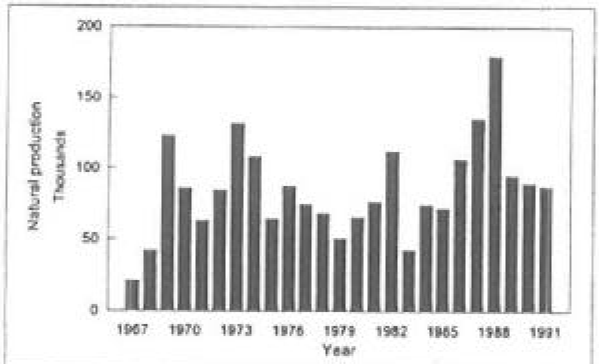
Description of variables named in worksheet:

E(f,n,bc)	Escapement (naturally spawning fish in Big Chico Creek)
E(f,h,bc)	Escapement (to hatcheries in Big Chico Creek)
E(f,t,bc)	Escapement naturally and to hatcheries in Big Chico Creek)
H(f,i,bc)	Harvest (in Big Chico Creek, estimated as E(f,t,bc)* prop. harvested instream)
P(f,i,bc)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,bc)	Harvest (ocean harvest of fall-run salmon assigned to Big Chico Creek)
P(f,t,bc)	Production (total Big Chico Creek)
h	Proportion hatchery
P(f,n,bc)	Production (natural production for Big Chico Creek)
DFG	Data taken from Mills and Fisher (1994).

Feather River: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,fe)	E(f,h,fe)	E(f,t,fe)	Proportion harvested instream	H(f,i,fe)	P(f,i,fe)	P(f,i,fe)/ P(f,i,cv)	H(f,o,fe)	P(f,t,fe)	h	P(f,n,fe)
1967	10100	2002	12102	0.2	2420	14522	0.07	6380	20902	0	20902
1968	12200	6160	18360	0.2	3672	22032	0.09	20042	42074	0	42074
1969	56200	4490	60690	0.2	12138	72828	0.20	49819	122647	0	122647
1970	58170	3590	61760	0.2	12352	74112	0.27	69205	143317	0.4	85990
1971	43500	4025	47525	0.2	9505	57030	0.20	47453	104483	0.4	62690
1972	43200	3891	47091	0.2	9418	56509	0.31	84385	140895	0.4	84537
1973	65100	8682	73782	0.2	14756	88538	0.26	130304	218842	0.4	131305
1974	59300	6844	66144	0.2	13229	79373	0.28	100727	180099	0.4	108060
1975	37735	5956	43691	0.2	8738	52429	0.22	54595	107024	0.4	64214
1976	58802	3911	62713	0.2	12543	75256	0.32	70617	145872	0.4	87523
1977	37668	8905	46573	0.2	9315	55888	0.25	68793	124681	0.4	74808
1978	33000	4961	37961	0.2	7592	45553	0.25	68247	113800	0.4	68280
1979	28415	4140	32555	0.2	6511	39066	0.14	46203	85269	0.4	51161
1980	31605	3812	35417	0.2	7083	42500	0.20	66674	109175	0.4	65505
1981	44738	8751	53489	0.2	10698	64187	0.20	63211	127398	0.4	76439
1982	47956	9473	57429	0.2	11486	68915	0.25	118063	186978	0.4	112187
1983	22823	9411	32234	0.2	6447	38681	0.16	33416	72097	0.4	43258
1984	42671	10850	53521	0.2	10704	64225	0.21	59372	123597	0.4	74158
1985	50192	7443	57635	0.2	11527	69162	0.16	50711	119873	0.4	71924
1986	46844	9934	56778	0.2	11356	68134	0.20	109693	177826	0.4	106696
1987	58974	11321	70295	0.2	14059	84354	0.26	141314	225668	0.4	135401
1988	54216	13313	67529	0.2	13506	81035	0.25	218361	299396	0.4	179637
1989	29986	12656	42642	0.2	8528	51170	0.24	108174	159344	0.4	95607
1990	25000	7431	32431	0.2	6486	38917	0.28	111267	150184	0.4	90111
1991	27802	14661	42463	0.2	8493	50956	0.32	95764	146719	0.4	88032
Mean	41048	7465	48512	0.2	9702	58215	0.22	79711	137926	0.4	85726

Restoration goal: 171452



Estimated natural production [P(f,n,fe)] for fall-run in the Feather River for each of the years in the baseline period.

Notes:

Estimate of hatchery-spawned fish is the total number of chinook salmon identified as fall and spring run at Feather River hatchery. Fall- and spring-run chinook salmon were combined because hatchery produced spring-run are believed to be distinct from naturally produced spring run in other rivers and because returns of coded-wire tagged spring run adults suggest that they are not behaviorally distinct from fall run.

Estimate of "Proportion harvested instream" based on data in draft summaries of 1991-1993 angler surveys.

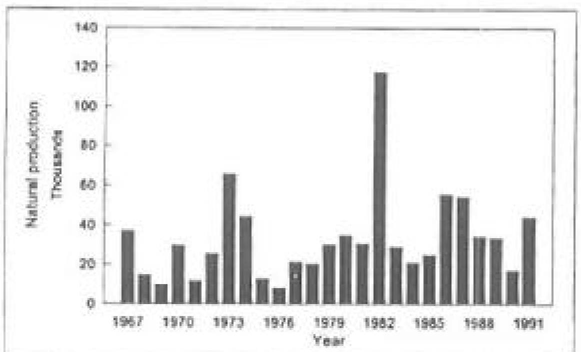
Estimate of h (proportion of production produced in a hatchery) based on data and discussions presented in Cramer (1990) and in Dettman and Kelley (1987). Proportion of production produced in a hatchery assumed to be 0 prior to first expected returns of progeny produced at the Feather River Hatchery.

Description of variables named in worksheet:

E(f,n,fe)	Escapement (naturally spawning fish in the Feather River)
E(f,h,fe)	Escapement (to hatcheries in the Feather River)
E(f,t,fe)	Escapement naturally and to hatcheries in the Feather River)
H(f,i,fe)	Harvest (in the Feather River, estimated as E(f,t,fe)* prop. harvested instream)
P(f,i,fe)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,fe)	Harvest (ocean harvest of fall-run salmon assigned to the Feather River)
P(f,t,fe)	Production (total Feather River)
h	Proportion hatchery
P(f,n,fe)	Production (natural production for the Feather River)
DFG	Data taken from Mills and Fisher (1994).

Yuba River: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,yu)	DFG E(f,h,yu)	E(f,t,yu)	Proportion harvested instream	H(f,i,yu)	P(f,i,yu)	P(f,i,yu)/ P(f,i,cv)	H(f,o,yu)	P(f,t,yu)	h	P(f,n,yu)
1967	23500	0	23500	0.1	2350	25850	0.12	11356	37206	0	37206
1968	7000	0	7000	0.1	700	7700	0.03	7004	14704	0	14704
1969	5230	0	5230	0.1	523	5753	0.02	3935	9688	0	9688
1970	13830	0	13830	0.1	1383	15213	0.06	14206	29419	0	29419
1971	5650	0	5650	0.1	565	6215	0.02	5171	11386	0	11386
1972	9258	0	9258	0.1	926	10184	0.06	15207	25391	0	25391
1973	24119	0	24119	0.1	2412	26531	0.08	39046	65577	0	65577
1974	17809	0	17809	0.1	1781	19590	0.07	24860	44450	0	44450
1975	5641	0	5641	0.1	564	6205	0.03	6461	12666	0	12666
1976	3779	0	3779	0.1	378	4157	0.02	3901	8058	0	8058
1977	8722	0	8722	0.1	872	9594	0.04	11810	21404	0	21404
1978	7416	0	7416	0.1	742	8158	0.04	12222	20379	0	20379
1979	12430	0	12430	0.1	1243	13673	0.05	16171	29844	0	29844
1980	12406	0	12406	0.1	1241	13647	0.06	21409	35055	0	35055
1981	14025	0	14025	0.1	1403	15428	0.05	15193	30621	0	30621
1982	39367	0	39367	0.1	3937	43304	0.16	74187	117491	0	117491
1983	14256	0	14256	0.1	1426	15682	0.06	13547	29229	0	29229
1984	9965	0	9965	0.1	997	10962	0.04	10133	21095	0	21095
1985	13066	0	13066	0.1	1307	14373	0.03	10538	24911	0	24911
1986	19406	0	19406	0.1	1941	21347	0.06	34367	55714	0	55714
1987	18510	0	18510	0.1	1851	20361	0.06	34110	54471	0	54471
1988	8501	0	8501	0.1	850	9351	0.03	25198	34549	0	34549
1989	9837	0	9837	0.1	984	10821	0.05	22875	33696	0	33696
1990	4000	0	4000	0.1	400	4400	0.03	12580	16980	0	16980
1991	13979	0	13979	0.1	1398	15377	0.10	28899	44276	0	44276
Mean	12868	0	12868	0.1	1287	14155	0.05	18975	33130	0.0	33130
									Restoration goal:		66261



Estimated natural production [P(f,n,yu)] for fall-run in the Yuba River for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

Estimate of h (proportion of production produced in a hatchery) based on data and discussions presented in Cramer (1990).

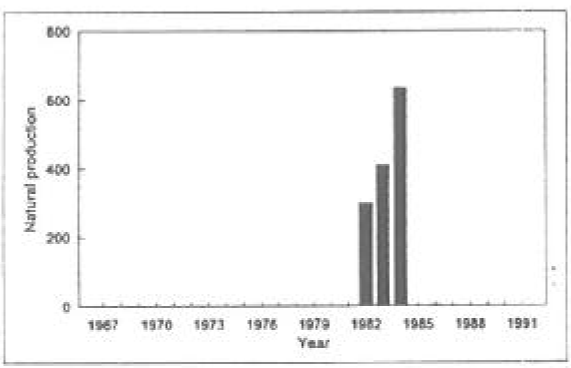
Description of variables named in worksheet:

E(f,n,yu)	Escapement (naturally spawning fish in the Yuba River)
E(f,h,yu)	Escapement (to hatcheries in the Yuba River)
E(f,t,yu)	Escapement naturally and to hatcheries in the Yuba River)
H(f,i,yu)	Harvest (in the Yuba River, estimated as E(f,t,yu)* prop. harvested instream)
P(f,i,yu)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,yu)	Harvest (ocean harvest of fall-run salmon assigned to the Yuba River)
P(f,t,yu)	Production (total Yuba River)
h	Proportion hatchery
P(f,n,yu)	Production (natural production for the Yuba River)
DFG	Data taken from Mills and Fisher (1994).

Bear River: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,be)	DFG E(f,h,be)	E(f,t,be)	Proportion harvested instream	H(f,i,be)	P(f,i,be)	P(f,i,be)/ P(f,i,cv)	H(f,o,be)	P(f,t,be)	h	P(f,n,be)
1967											
1968											
1969											
1970											
1971											
1972											
1973											
1974											
1975											
1976											
1977											
1978	0	0	0	0.1	0	0	0.00	0	0	0	0
1979											
1980	0	0	0	0.1	0	0	0.00	0	0	0	0
1981											
1982	100	0	100	0.1	10	110	0.00	188	298	0	298
1983	200	0	200	0.1	20	220	0.00	190	410	0	410
1984	300	0	300	0.1	30	330	0.00	305	635	0	635
1985											
1986	1	0	1	0.1	0	1	0.00	2	3	0	3
1987											
1988											
1989											
1990											
1991											
Mean	100	0	100	0	10	110	0	114	224	0	224

Restoration goal: 449



Estimated natural production [P(f,n,be)] for fall-run in the Bear River for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

Estimate of h (proportion of production produced in a hatchery) based on data and discussions presented in Cramer (1990).

Due to inadequate flow releases below the South Sutter Water District's diversion dam, there are no self-sustaining runs of chinook salmon in the Bear River.

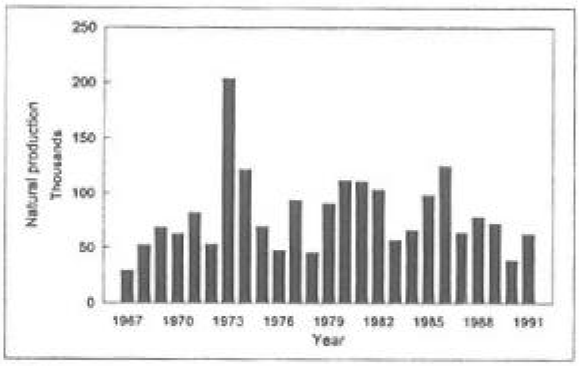
Description of variables named in worksheet:

E(f,n,be)	Escapement (naturally spawning fish in the Bear River)
E(f,h,be)	Escapement (to hatcheries in the Bear River)
E(f,t,be)	Escapement naturally and to hatcheries in the Bear River)
H(f,i,be)	Harvest (in the Bear River, estimated as E(f,t,be)* prop. harvested instream)
P(f,i,be)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,be)	Harvest (ocean harvest of fall-run salmon assigned to the Bear River)
P(f,t,be)	Production (total Bear River)
h	Proportion hatchery
P(f,n,be)	Production (natural production for the Bear River)
DFG	Data taken from Mills and Fisher (1994).

American River: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,am)	DFG E(f,h,am)	E(f,t,am)	Proportion harvested instream	H(f,i,am)	P(f,i,am)	P(f,i,am)/ P(f,i,cv)	H(f,o,am)	P(f,t,am)	h	P(f,n,am)
1967	18000	5147	23147	0.45	10416	33563	0.16	14745	48308	0.4	28985
1968	26200	5233	31433	0.45	14145	45578	0.19	41461	87039	0.4	52223
1969	43660	3605	47265	0.45	21269	68534	0.18	46882	115416	0.4	69250
1970	28680	8629	37309	0.45	16789	54098	0.20	50516	104614	0.4	62768
1971	41680	10110	51790	0.45	23306	75096	0.27	62485	137580	0.4	82548
1972	17459	7042	24501	0.45	11025	35526	0.20	53052	88578	0.4	53147
1973	82242	12535	94777	0.45	42650	137427	0.41	202253	339680	0.4	203808
1974	53596	8200	61796	0.45	27808	89604	0.31	113711	203315	0.4	121989
1975	32132	7412	39544	0.45	17795	57339	0.24	59707	117046	0.4	70227
1976	23159	5215	28374	0.45	12768	41142	0.18	38606	79748	0.4	47849
1977	41605	6868	48473	0.45	21813	70286	0.31	86516	156802	0.4	94081
1978	12929	8162	21091	0.45	9491	30582	0.17	45817	76399	0.4	45839
1979	37315	10351	47666	0.45	21450	69116	0.26	81742	150858	0.4	90515
1980	34259	15543	49802	0.45	22411	72213	0.34	113287	185500	0.4	111300
1981	43462	20593	64055	0.45	28825	92880	0.30	91468	184348	0.4	110609
1982	33000	10898	43898	0.45	19754	63652	0.23	109048	172700	0.4	103620
1983	26400	8900	35300	0.45	15885	51185	0.21	44218	95403	0.4	57242
1984	27447	12249	39696	0.45	17863	57559	0.19	53209	110769	0.4	66461
1985	56120	9093	65213	0.45	29346	94559	0.22	69333	163891	0.4	98335
1986	49372	5695	55067	0.45	24780	79847	0.23	128551	208398	0.4	125039
1987	21145	6497	27642	0.45	12439	40081	0.12	67145	107226	0.4	64336
1988	15879	8625	24504	0.45	11027	35531	0.11	95743	131274	0.4	78764
1989	17078	9740	26818	0.45	12068	38886	0.18	82205	121091	0.4	72655
1990	6708	4857	11565	0.45	5204	16769	0.12	47944	64714	0.4	38828
1991	18145	7128	25273	0.45	11373	36646	0.23	68871	105517	0.4	63310
Mean	32307	8733	41040	0.45	18468	59508	0.22	74741	134249	0.4	80549

Restoration goal: 161098



Estimated natural production [P(f,n,am)] for fall-run in the American River for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data in draft summaries of 1991-1993 angler surveys.

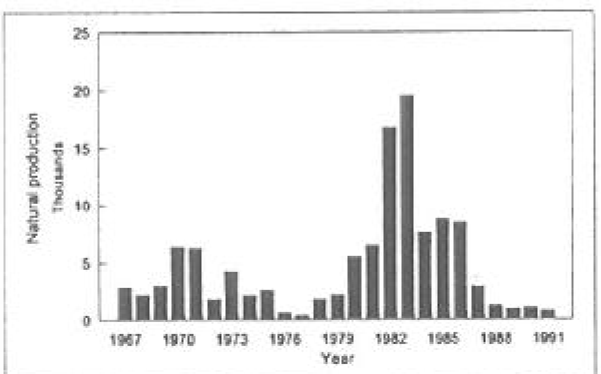
Estimate of h (proportion of production produced in a hatchery) based on data and discussions presented in Cramer (1990) and in Dettman and Kelley (1986, 1987).

Description of variables named in worksheet:

E(f,n,am)	Escapement (naturally spawning fish in the American River)
E(f,h,am)	Escapement (to hatcheries in the American River)
E(f,t,am)	Escapement naturally and to hatcheries in the American River)
H(f,i,am)	Harvest (in the American River, estimated as E(f,t,am)* prop. harvested instream)
P(f,i,am)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,am)	Harvest (ocean harvest of fall-run salmon assigned to the American River)
P(f,t,am)	Production (total American River)
h	Proportion hatchery
P(f,n,am)	Production (natural production for the American River)
DFG	Data taken from Mills and Fisher (1994).

Mokelumne River: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,mo)	DFG E(f,h,mo)	E(f,t,mo)	Proportion harvested instream	H(f,i,mo)	P(f,i,mo)	P(f,i,mo)/ P(f,i,cv)	H(f,o,mo)	P(f,t,mo)	h	P(f,n,mo)
1967	2750	250	3000	0.1	300	3300	0.02	1450	4750	0.4	2850
1968	753	954	1707	0.1	171	1878	0.01	1708	3586	0.4	2151
1969	2070	615	2685	0.1	269	2954	0.01	2020	4974	0.4	2984
1970	4092	908	5000	0.1	500	5500	0.02	5136	10636	0.4	6381
1971	3970	1230	5200	0.1	520	5720	0.02	4759	10479	0.4	6288
1972	749	353	1102	0.1	110	1212	0.01	1810	3022	0.4	1813
1973	2192	408	2600	0.1	260	2860	0.01	4209	7069	0.4	4241
1974	1202	220	1422	0.1	142	1564	0.01	1985	3549	0.4	2130
1975	1501	399	1900	0.1	190	2090	0.01	2176	4266	0.4	2560
1976	399	74	473	0.1	47	520	0.00	488	1009	0.4	605
1977	250	0	250	0.1	25	275	0.00	339	614	0.4	368
1978	602	484	1086	0.1	109	1195	0.01	1790	2984	0.4	1791
1979	1000	507	1507	0.1	151	1658	0.01	1961	3618	0.4	2171
1980	2592	639	3231	0.1	323	3554	0.02	5576	9130	0.4	5478
1981	3568	1386	4954	0.1	495	5449	0.02	5367	10816	0.4	6490
1982	6695	2677	9372	0.1	937	10309	0.04	17662	27971	0.4	16782
1983	11293	4573	15866	0.1	1587	17453	0.07	15077	32530	0.4	19518
1984	5075	959	6034	0.1	603	6637	0.02	6136	12773	0.4	7664
1985	7479	223	7702	0.1	770	8472	0.02	6212	14684	0.4	8811
1986	3006	1913	4919	0.1	492	5411	0.02	8711	14122	0.4	8473
1987	1020	630	1650	0.1	165	1815	0.01	3041	4856	0.4	2913
1988	384	128	512	0.1	51	563	0.00	1518	2081	0.4	1248
1989	400	80	480	0.1	48	528	0.00	1116	1644	0.4	987
1990	363	68	431	0.1	43	474	0.00	1355	1830	0.4	1098
1991	410		410	0.1	41	451	0.00	848	1299	0.4	779
Mean	2553	820	3340	0.1	334	3674	0.01	4098	7772	0.4	4663
									Restoration goal:		9326



Estimated natural production [P(f,n,mo)] for fall-run in the Mokelumne River for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

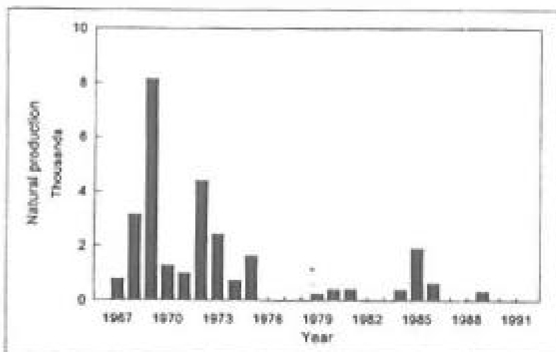
Estimate of h (proportion of production produced in a hatchery) based on data and discussions presented in Cramer (1990).

Description of variables named in worksheet:

E(f,n,mo)	Escapement (naturally spawning fish in the Mokelumne River)
E(f,h,mo)	Escapement (to hatcheries in the Mokelumne River)
E(f,t,mo)	Escapement naturally and to hatcheries in the Mokelumne River)
H(f,i,mo)	Harvest (in the Mokelumne River, estimated as E(f,t,mo)* prop. harvested instream)
P(f,i,mo)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,mo)	Harvest (ocean harvest of fall-run salmon assigned to the Mokelumne River)
P(f,t,mo)	Production (total Mokelumne River)
h	Proportion hatchery
P(f,n,mo)	Production (natural production for the Mokelumne River)
DFG	Data taken from Mills and Fisher (1994).

Cosumnes River: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,co)	DFG E(f,h,co)	E(f,t,co)	Proportion harvested instream	H(f,i,co)	P(f,i,co)	P(f,i,co)/ P(f,i,cv)	H(f,o,co)	P(f,t,co)	h	P(f,n,co)
1967	500	0	500	0.1	50	550	0.00	242	792	0	792
1968	1500	0	1500	0.1	150	1650	0.01	1501	3151	0	3151
1969	4400	0	4400	0.1	440	4840	0.01	3311	8151	0	8151
1970	600	0	600	0.1	60	660	0.00	616	1276	0	1276
1971	500	0	500	0.1	50	550	0.00	458	1008	0	1008
1972	1600	0	1600	0.1	160	1760	0.01	2628	4388	0	4388
1973	900	0	900	0.1	90	990	0.00	1457	2447	0	2447
1974	285	0	285	0.1	29	314	0.00	398	711	0	711
1975	725	0	725	0.1	73	798	0.00	830	1628	0	1628
1976											
1977											
1978											
1979	100	0	100	0.1	10	110	0.00	130	240	0	240
1980	150	0	150	0.1	15	165	0.00	259	424	0	424
1981	200	0	200	0.1	20	220	0.00	217	437	0	437
1982	5	0	5	0.1	1	6	0.00	9	15	0	15
1983											
1984	200	0	200	0.1	20	220	0.00	203	423	0	423
1985	1000	0	1000	0.1	100	1100	0.00	807	1907	0	1907
1986	220	0	220	0.1	22	242	0.00	390	632	0	632
1987											
1988											
1989	100	0	100	0.1	10	110	0.00	233	343	0	343
1990											
1991											
Mean	764	0	764	0.1	76	840	0.00	805	1645	0.0	1645
									Restoration goal:		3291



Estimated natural production [P(f,n,co)] for fall-run in the Cosumnes River for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

Estimate of h (proportion of production produced in a hatchery) based on data and discussions presented in Cramer (1990).

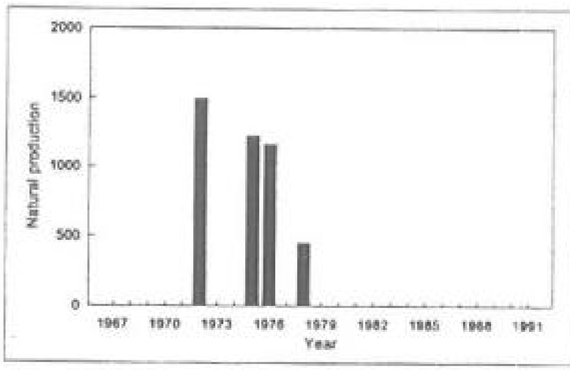
Abundance estimates for runs of chinook salmon other than fall-run have have not been made.

Description of variables named in worksheet:

E(f,n,co)	Escapement (naturally spawning fish in the Cosumnes River)
E(f,h,co)	Escapement (to hatcheries in the Cosumnes River)
E(f,t,co)	Escapement naturally and to hatcheries in the Cosumnes River)
H(f,i,co)	Harvest (in the Cosumnes River, estimated as E(f,t,co)* prop. harvested instream)
P(f,i,co)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,co)	Harvest (ocean harvest of fall-run salmon assigned to the Cosumnes River)
P(f,t,co)	Production (total Cosumnes River)
h	Proportion hatchery
P(f,n,co)	Production (natural production for the Cosumnes River)
DFG	Data taken from Mills and Fisher (1994).

Calaveras River: Production estimates for winter-run chinook salmon.

Year	DFG E(w.n.ca)	DFG E(w.h.ca)	E(w.t.ca)	Proportion harvested instream	H(w.i.ca)	P(w.i.ca)	P(w,i,ca)/ P(w.i.cv)	H(w.o.ca)	P(w.t.ca)	h	P(w.n.ca)
1967											
1968											
1969											
1970											
1971											
1972	500	0	500	0.2	100	600	0.01	896	1496	0	1496
1973											
1974											
1975	500	0	500	0.2	100	600	0.02	625	1225	0	1225
1976	500	0	500	0.2	100	600	0.01	563	1163	0	1163
1977											
1978	150	0	150	0.2	30	180	0.01	270	450	0	450
1979											
1980											
1981											
1982											
1983											
1984											
1985											
1986											
1987											
1988											
1989											
1990											
1991											
Mean	413	0	413	0.2	361	495	0.01	588	1083	0.0	1083
									Restoration goal:		2167



Estimated natural production [P(w,n,ca)] for winter-run in the Calaveras River for each of the years in the baseline period.

Notes:

Estimate of "Proportion harvested instream" based on data presented in Mills and Fisher (1994) and on draft summaries of 1991-1993 angler surveys.

Estimate of h (proportion of production produced in a hatchery) based on absence of hatchery production of winter-run chinook salmon prior to 1991.

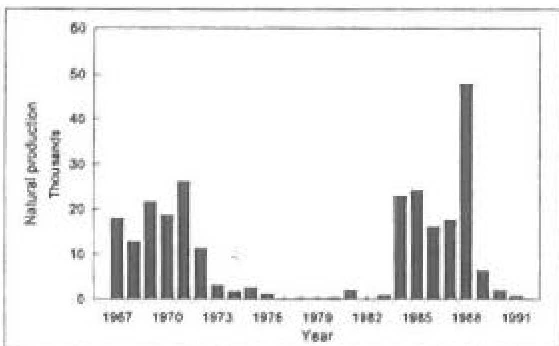
Description of variables named in worksheet:

E(w,n,ca) Escapement (naturally spawning fish in the Calaveras River)
E(w,h,ca) Escapement (to hatcheries in the Calaveras River)
E(w,t,ca) Escapement naturally and to hatcheries in the Calaveras River)
H(w,i,ca) Harvest (in the Calaveras River, estimated as E(w,t,ca)* prop. harvested instream)
P(w,i,ca) Production (total escapement plus instream harvest)
P(w,i,cv) Production (total Central Valley)
H(w,o,ca) Harvest (ocean harvest of fall-run salmon assigned to the Calaveras River)
P(w,t,ca) Production (total Calaveras River)
h Proportion hatchery
P(w,n,ca) Production (natural production for the Calaveras River)
DFG Data taken from Mills and Fisher (1994).

Stanislaus River: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,st)	DFG E(f,h,st)	E(f,t,st)	Proportion harvested instream	H(f,i,st)	P(f,i,st)	P(f,i,st)/ P(f,i,cv)	H(f,o,st)	P(f,t,st)	h	P(f,n,st)
1967	11885	0	11885	0.05	594	12479	0.06	5482	17961	0	17961
1968	6385	0	6385	0.05	319	6704	0.03	6099	12803	0	12803
1969	12327	0	12327	0.05	616	12943	0.03	8854	21797	0	21797
1970	9297	0	9297	0.05	465	9762	0.04	9115	18877	0	18877
1971	13621	0	13621	0.05	681	14302	0.05	11900	26202	0	26202
1972	4298	0	4298	0.05	215	4513	0.02	6739	11252	0	11252
1973	1234	0	1234	0.05	62	1296	0.00	1907	3203	0	3203
1974	750	0	750	0.05	38	788	0.00	999	1787	0	1787
1975	1200	0	1200	0.05	60	1260	0.01	1312	2572	0	2572
1976	600	0	600	0.05	30	630	0.00	591	1221	0	1221
1977	0	0	0	0.05	0	0	0.00	0	0	0	0
1978	50	0	50	0.05	3	53	0.00	79	131	0	131
1979	100	0	100	0.05	5	105	0.00	124	229	0	229
1980	100	0	100	0.05	5	105	0.00	165	270	0	270
1981	1000	0	1000	0.05	50	1050	0.00	1034	2084	0	2084
1982											
1983	500	0	500	0.05	25	525	0.00	454	979	0	979
1984	11439	0	11439	0.05	572	12011	0.04	11103	23114	0	23114
1985	13322	0	13322	0.05	666	13988	0.03	10256	24244	0	24244
1986	5888	0	5888	0.05	294	6182	0.02	9953	16136	0	16136
1987	6292	0	6292	0.05	315	6607	0.02	11068	17674	0	17674
1988	12344	0	12344	0.05	617	12961	0.04	34926	47887	0	47887
1989	1968	0	1968	0.05	98	2066	0.01	4368	6435	0	6435
1990	492	0	492	0.05	25	517	0.00	1477	1994	0	1994
1991	272	0	272	0.05	14	286	0.00	537	822	0	822
Mean	4807	0	4807	0.05	240	5047	0.02	5773	10820	0	10820

Restoration goal: 21640



Estimated natural production [P(f,n,st)] for fall-run in the Stanislaus River for each of the years in the baseline period.

Notes:

"Proportion harvested instream" was assumed to be equal to five percent of escapement (Bill Loudermilk, CDFG, personal communication) surveys.

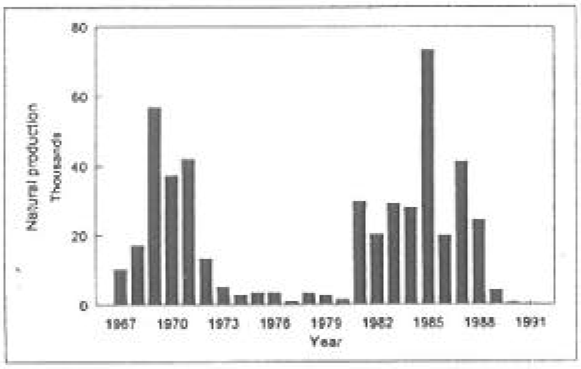
Estimate of h (proportion of production produced in a hatchery) based on lack of a hatchery on the Stanislaus River.

Description of variables named in worksheet:

E(f,n,st)	Escapement (naturally spawning fish in the Stanislaus River)
E(f,h,st)	Escapement (to hatcheries in the Stanislaus River)
E(f,t,st)	Escapement naturally and to hatcheries in the Stanislaus River)
H(f,i,st)	Harvest (in the Stanislaus River, estimated as E(f,t,st)* prop. harvested instream)
P(f,i,st)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,st)	Harvest (ocean harvest of fall-run salmon assigned to the Stanislaus River)
P(f,t,st)	Production (total Stanislaus River)
h	Proportion hatchery
P(f,n,st)	Production (natural production for the Stanislaus River)
DFG	Data taken from Mills and Fisher (1994).

Toulumne River: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,to)	DFG E(f,h,to)	E(f,t,to)	Proportion harvested instream	H(f,i,to)	P(f,i,to)	P(f,i,to)/ P(f,i,cv)	H(f,o,to)	P(f,t,to)	*h*	P(f,n,to)
1967	6800	0	6800	0.05	340	7140	0.03	3137	10277	0	10277
1968	8600	0	8600	0.05	430	9030	0.04	8214	17244	0	17244
1969	32200	0	32200	0.05	1610	33810	0.09	23128	56938	0	56938
1970	18400	0	18400	0.05	920	19320	0.07	18041	37361	0	37361
1971	21885	0	21885	0.05	1094	22979	0.08	19120	42100	0	42100
1972	5100	0	5100	0.05	255	5355	0.03	7997	13352	0	13352
1973	1989	0	1989	0.05	99	2088	0.01	3074	5162	0	5162
1974	1150	0	1150	0.05	58	1208	0.00	1532	2740	0	2740
1975	1600	0	1600	0.05	80	1680	0.01	1749	3429	0	3429
1976	1700	0	1700	0.05	85	1785	0.01	1675	3460	0	3460
1977	450	0	450	0.05	23	473	0.00	582	1054	0	1054
1978	1300	0	1300	0.05	65	1365	0.01	2045	3410	0	3410
1979	1183	0	1183	0.05	59	1242	0.00	1469	2711	0	2711
1980	559	0	559	0.05	28	587	0.00	921	1508	0	1508
1981	14253	0	14253	0.05	713	14966	0.05	14738	29704	0	29704
1982	7126	0	7126	0.05	356	7482	0.03	12819	20301	0	20301
1983	14836	0	14836	0.05	742	15578	0.06	13457	29035	0	29035
1984	13802	0	13802	0.05	690	14492	0.05	13397	27889	0	27889
1985	40322	0	40322	0.05	2016	42338	0.10	31043	73381	0	73381
1986	7288	0	7288	0.05	364	7652	0.02	12320	19972	0	19972
1987	14751	0	14751	0.05	738	15489	0.05	25947	41436	0	41436
1988	6349	0	6349	0.05	317	6666	0.02	17964	24630	0	24630
1989	1274	0	1274	0.05	64	1338	0.01	2828	4166	0	4166
1990	96	0	96	0.05	5	101	0.00	288	389	0	389
1991	53	0	53	0.05	3	56	0.00	105	160	0	160
Mean	8923	0	8923	0.05	446	9369	0.03	9504	18872	0	18872
									Restoration goal:		37745



Estimated natural production [P(f,n,to)] for fall-run in the Toulumne River for each of the years in the baseline period.

Notes:

"Proportion harvested instream" was assumed to be equal to five percent of escapement (Bill Loudermilk, CDFG, personal communication) surveys.

Estimate of h (proportion of production produced in a hatchery) based on lack of a hatchery on the Toulumne River.

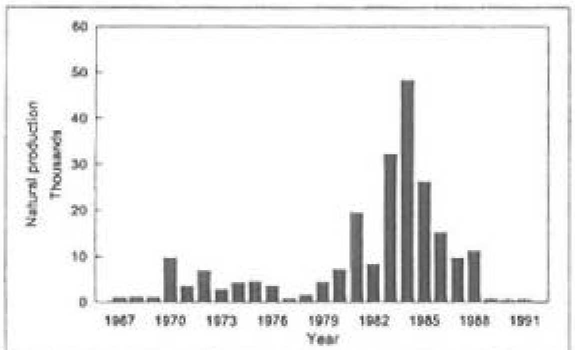
Description of variables named in worksheet:

E(f,n,to)	Escapement (naturally spawning fish in the Toulumne River)
E(f,h,to)	Escapement (to hatcheries in the Toulumne River)
E(f,t,to)	Escapement naturally and to hatcheries in the Toulumne River)
H(f,i,to)	Harvest (in the Toulumne River, estimated as E(f,t,to)* prop. harvested instream)
P(f,i,to)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,to)	Harvest (ocean harvest of fall-run salmon assigned to the Toulumne River)
P(f,t,to)	Production (total Toulumne River)
h	Proportion hatchery
P(f,n,to)	Production (natural production for the Toulumne River)
DFG	Data taken from Mills and Fisher (1994).

Merced River: Production estimates for fall-run chinook salmon.

Year	DFG E(f,n,me)	DFG E(f,h,me)	E(f,t,me)	Proportion harvested instream	H(f,i,me)	P(f,i,me)	P(f,i,me)/ P(f,i,cv)	H(f,o,me)	P(f,t,me)	h	P(f,n,me)
1967	600	0	600	0.05	30	630	0.00	277	907	0	907
1968	550	0	550	0.05	28	578	0.00	525	1103	0	1103
1969	600	0	600	0.05	30	630	0.00	431	1061	0	1061
1970	4700	100	4800	0.05	240	5040	0.02	4706	9746	0	9746
1971	1590	200	1790	0.05	90	1880	0.01	1564	3443	0	3443
1972	2528	120	2648	0.05	132	2780	0.02	4152	6932	0	6932
1973	797	375	1172	0.05	59	1231	0.00	1811	3042	0.1	2738
1974	1000	1000	2000	0.05	100	2100	0.01	2665	4765	0.1	4288
1975	1700	700	2400	0.05	120	2520	0.01	2624	5144	0.1	4630
1976	1200	700	1900	0.05	95	1995	0.01	1872	3867	0.1	3480
1977	350	0	350	0.05	18	368	0.00	452	820	0.1	738
1978	525	100	625	0.05	31	656	0.00	983	1639	0.1	1475
1979	1920	227	2147	0.05	107	2254	0.01	2666	4921	0.1	4428
1980	2851	157	3008	0.05	150	3158	0.02	4955	8113	0.1	7302
1981	9491	924	10415	0.05	521	10936	0.03	10770	21705	0.1	19535
1982	3074	189	3263	0.05	163	3426	0.01	5870	9296	0.1	8366
1983	16453	1795	18248	0.05	912	19160	0.08	16552	35713	0.1	32141
1984	24660	1885	26545	0.05	1327	27872	0.09	25766	53638	0.1	48274
1985	14841	1211	16052	0.05	803	16855	0.04	12358	29213	0.1	26291
1986	5523	650	6173	0.05	309	6482	0.02	10435	16917	0.1	15225
1987	2895	958	3853	0.05	193	4046	0.01	6777	10823	0.1	9741
1988	2760	457	3217	0.05	161	3378	0.01	9102	12480	0.1	11232
1989	129	82	211	0.05	11	222	0.00	468	690	0.1	621
1990	24	49	73	0.05	4	77	0.00	219	296	0.1	266
1991	119	41	160	0.05	8	168	0.00	316	484	0.1	435
Mean	4035	477	4512	0.05	226	4738	0.02	5133	9870	0.1	8976

Restoration goal: 17952



Estimated natural production [P(f,n,me)] for fall-run in the Merced River for each of the years in the baseline period.

Notes:

"Proportion harvested instream" was assumed to be equal to five percent of escapement (Bill Loudermilk, CDFG, personal communication) surveys.

Estimate of h (proportion of production produced in a hatchery) based on the following considerations: 1) There are not existing estimates; 2) The first returns of Merced River Fish Facility produced chinook salmon were expected in 1973; 3) The Merced River Fish Facility is small in relation to chinook salmon production facilities elsewhere in the Central Valley for which existing estimates of h were less than 0.4.

Description of variables named in worksheet:

E(f,n,me)	Escapement (naturally spawning fish in the Merced River)
E(f,h,me)	Escapement (to hatcheries in the Merced River)
E(f,t,me)	Escapement naturally and to hatcheries in the Merced River)
H(f,i,me)	Harvest (in the Merced River, estimated as E(f,t,me)* prop. harvested instream)
P(f,i,me)	Production (total escapement plus instream harvest)
P(f,i,cv)	Production (total Central Valley)
H(f,o,me)	Harvest (ocean harvest of fall-run salmon assigned to the Merced River)
P(f,t,me)	Production (total Merced River)
h	Proportion hatchery
P(f,n,me)	Production (natural production for the Merced River)
DFG	Data taken from Mills and Fisher (1994).

APPENDIX B

Estimation of Natural Production of Steelhead Upstream of RBDD

To estimate the restoration goal for steelhead spawning in the Sacramento River upstream of RBDD during the baseline period, it was assumed that no naturally produced fish spawned in the hatchery and that the proportion of hatchery-produced fish that spawned naturally was 0.29% of the total of inland harvest and natural escapement (Table B-1).

Table B-1. Inland harvest, escapement, and natural production for steelhead during the baseline period in the mainstem Sacramento River upstream of RBDD (Mills and Fisher 1994).

Year	Inland harvest	Natural escapement	Natural production
1967	5,819	15,312	15,003
1968	7,454	19,615	19,219
1969	5,784	15,222	14,915
1970	5,031	13,240	12,973
1971	4,517	1,187	11,647
1972	2,296	6,041	5,919
1973	3,390	8,921	8,714
1974	2,717	7,150	7,006
1975	2,120	5,579	5,466
1976	3,383	8,902	8,722
1977	2,318	6,099	5,976
1978	960	2,527	2,476
1979	1,330	3,499	3,428
1980	4,517	11,887	11,647
1981	1,278	3,363	3,295
1982	1,048	2,757	2,701
1983	1,325	3,486	3,416
1984	774	2,036	1,995
1985	1,706	4,489	4,398

Year	Inland harvest	Natural escapement	Natural production
1986	1,432	3,769	3,693
1987	863	2,272	2,226
1988	179	1,872	1,834
1989	711	470	461
1990	863	2,272	2,226
1991	377	991	971
Mean	2,488	6,546	6,414
SD	1,946	5,120	5,017
Goal			>=12,828

F. STRIPED BASS

Baseline Natural Production and Goals

Baseline period abundance of adult striped bass (fish 15 inches FL before 1982 and fish 16.5 inches FL since 1982) was estimated from mark-recapture studies conducted since 1969. A modified Petersen estimator was used:

$$N = M(C+1)/(R+1)$$

Where N = bass abundance
M = number of tagged fish released
C = number of fish subsequently examined for tags
R = number of tagged fish in the recapture sample

Gill nets and fyke traps are used to capture bass during their spring spawning migration to the Delta and Sacramento River. The fish are tagged with individually numbered disc-dangler tags and released. The population is sampled during a census of angler catches that is conducted during subsequent spring tagging.

From 3,100 to 18,400 tags have been applied annually. Creel census clerks, sampling at four to six fishing ports from Wednesday to Sunday each week, have observed from 1,500 to 38,700 bass and from 16 to 891 tags annually. Since 1969, the tagged:untagged ratio has varied from 1:37 (1973) to 1:108 (1985). The abundance estimation procedures are complicated by sex- and age-sampling biases; therefore, all tagging and recapture samples are stratified by sex and age.

Table 3-Xf-1. Estimated abundance of adult striped bass
in the Central Valley, 1967-1991.

Year	Adult striped bass abundance	Year	Adult striped bass abundance
1967	1,948,000	1980	1,115,999
1968	1,944,000	1981	911,300
1969	1,646,026	1982	825,126
1970	1,727,394	1983	1,009,748
1971	1,599,715	1984	1,042,668
1972	1,882,907	1985	1,024,188

Year	Adult striped bass abundance	Year	Adult striped bass abundance
1973	1,637,159	1986	1,037,127
1974	1,477,213	1987	998,349
1975	1,849,770	1988	892,413
1976	1,581,076	1989	724,580
1977	924,301	1990	574,364
1978	1,151,642	1991	625,702
1979	1,155,701	Mean	1,252,259

Goals - Production goals are double the estimated abundance shown in Table 3-Xf-1, about 2.5 million adult striped bass.

Outflow, export, and stocking considerations - The model developed for the technical team by Dr. Loo Botsford of the University of California, Davis, (Botsford and Brittnacher 1994) related abundance of adult striped bass to Delta outflow, total exports, and stocking of yearling striped bass. Exports include water pumped at the State Water Project (SWP), Central Valley Project (CVP), Contra Costa Canal (CCC), and North Bay Aqueduct from August through March and at all of these and Delta agricultural diversions from April through July. Because most of the spawning and rearing habitat for striped bass is located in the delta and the lower reaches of the Sacramento and San Joaquin rivers, the team has not included recommendations for the specific contributions of individual tributaries to total outflow. If the recommendations were implemented, flow should be allocated between the Sacramento and San Joaquin rivers, and between individual tributaries, to reflect requirements of the other anadromous fish species.

The Striped Bass Technical Team has noted that because the export and outflow levels required to double the striped bass population will be viewed as unreasonable by water user groups, they are unlikely to be implemented. In addition, the standards established by the December 15, 1994 Delta Accord are viewed by many parties as a constraint on further adjustments to outflow and exports for a period of at least 3 years. With this in mind, the team evaluated projected outflow and exports levels with the model developed by Botsford and Brittnacher.

Delta Accord based outflow and exports, as predicted by DWRSIM (Tables 3-Xf-2 and 3-Xf-3), appear to be inadequate to restore the striped bass population. The Botsford-Brittnacher model predicts that conditions resulting from the Delta Accord would maintain 697,000 adult striped bass systemwide; the California Department of Fish and Game=s model predicts 425,000 adults. If the actual number falls between these predicted values, the resulting adult population would be similar to the current low level of 550,000.

Table 3-Xf-2. Monthly Average Delta Outflow (cfs) required to meet 15 December 1994 Delta Accord X2 salinity standards as projected by DWRSIM.

Month	Wet	Above normal	Below normal	Dry	Critical
October	11,344	6,315	7,443	6,071	4,507
November	18,766	13,931	8,260	8,323	5,196
December	50,715	16,631	13,446	8,124	6,002
January	78,116	42,363	19,623	9,778	7,383
February	94,325	61,425	35,884	18,015	11,207
March	75,981	59,919	22,220	17,847	10,415
April	53,118	27,423	15,493	11,829	8,667
May	34,189	18,048	12,799	8,785	5,645
June	19,357	10,281	8,640	6,936	6,120
July	9,528	8,985	7,532	6,995	4,979
August	5,933	6,176	5,622	5,256	3,418
September	8,021	4,239	3,838	3,711	3,008
Total	27,675	16,599	9,672	6,733	4,616

Note: Data are preliminary and subject to change.

Table 3-Xf-3. Combined CVP/SWP exports (cfs) under the 15 December 1995 Delta Accord X2 as projected by DWRSIM.

Month	Wet	Above normal	Below normal	Dry	Critical
October	10,472	9,648	8,981	7,871	5,487
November	9,819	10,292	9,286	7,618	5,105

December	8,962	10,484	10,783	9,322	8,632
January	9,964	11,434	10,184	9,583	9,62
February	9,263	9,582	8,576	9,031	6,993
March	7,802	8,286	8,573	7,740	5,433
April	7,591	6,913	6,002	4,464	3,269
May	7,080	6,795	5,641	4,064	2,978
June	8,734	7,030	6,678	5,583	4,947
July	8,001	8,553	10,638	10,640	5,869
August	6,160	7,521	8,413	8,443	2,836
September	9,546	7,216	6,767	6,254	3,684
Total (taf)	6,295	6,279	6,090	5,488	3,926

Note: Data are preliminary and subject to change.

Based on these projections, several SBTT members feel that reestablishing a stocking program is essential to the restoration of the striped bass population and the recreational fishery that it supports. The team previously considered the potential of stocking as an initial measure to increase spawning stock and enable the population to sustain itself at a higher level. The Botsford-Brittnacher model suggests that, in absence of any meaningful changes in outflow and exports, the concept of stocking as an initial, temporary measure is not valid; after stocking is terminated, the population will return to levels dictated by outflow and exports. Stocking would increase the total number of adult striped bass over the period for which it is maintained. For example, based on the Botsford-Brittnacher model, stocking 3,000,000 yearling striped bass annually would increase adult numbers to about 900,000. While this would benefit the fishery, it would not contribute to achieving AFRP goals, which, based on Section 3403(h) of Title 34, must be measured as the number of Afish produced to adulthood without direct human intervention in the spawning, rearing or migration processes@.

The technical team notes that in the absence of a substantial improvement in the standards established by the Delta Accord, and/or a renewed stocking program, the striped bass fishery is likely to remain in its current, poor condition, or to decline further. Because the focus of the Anadromous Fish Restoration Program is limited to Anatural production@ it is inappropriate for the SBTT to recommend stocking as a restoration measure; however, the team does recommend that stocking and other measures to restore the striped bass fishery be considered under Section 3406(b)(18), which requires the federal government to Aif requested by the State of California, assist in developing and implementing management measures to restore the striped bass fishery of the Bay-Delta estuary@.

Sacramento-San Joaquin Delta -

Table 3-Xf-4. Limiting factors and potential solutions for striped bass.

Limiting factors	Potential solutions
1. Reduced Delta outflow	1. Increase Delta outflow requirements 2. Reduce export/diversion levels
2. Egg, larvae, and juvenile entrainment and losses at the SWP and CVP Delta pumping plants	1. Reduce export/diversion levels when eggs and larvae and/or juvenile bass appear in great abundance 2. Improve SWP and CVP salvage and transport effectiveness 3. Close the DCC and Georgiana Slough while bass eggs and larvae are passing down the Sacramento River 4. Provide Delta the outflow necessary to move eggs and larvae toward the western Delta and Suisun Bay 5. Install fish screens to prevent entrainment of predator fish into Clifton Court Forebay (CCF) 6. Remove and transplant predators from CCF in winter and early spring
3. Egg, larvae, and juvenile loss and entrainment at the Contra Costa Canal (CCC) diversion	1. Reduce export/diversion levels when eggs and larvae and/or juvenile bass appear in great abundance 2. Develop and implement a salvage- transport program
4. Egg, larvae, and juvenile mortality and entrainment at the PG&E power generating plants	1. Reduce pumping levels when bass egg and/or larvae abundance is high at the intakes 2. If feasible, place a barrier outside of the intakes to keep fish from entering
5. Egg, larvae, and juvenile	1. Consolidate and/or relocate diversions to areas with

Limiting factors	Potential solutions
mortality and entrainment at Sherman and Twitchell Island diversions	low bass egg/larvae concentrations 2. Convert islands to a wildlife management area and modify or eliminate diversions
6. Egg, larvae, and juvenile loss and entrainment at private agricultural diversions	1. Consolidate and/or relocate diversions to areas with low bass egg/larvae concentrations 2. Screen all larger diversions on a priority basis to keep out bass longer than 1.5 inches 3. Improve water distribution and use schemes throughout the Delta to minimize bass losses while meeting water demands
7. San Joaquin River water quality barrier to migration of adult striped bass	1. Increase Delta inflow, especially in the San Joaquin River at Vernalis 2. Implement more stringent salinity standards for the lower San Joaquin River 3. Improve the quality of agricultural return water
8. High toxic chemical and trace metal concentrations in Delta water	1. Regulate agricultural pesticides in Delta return drains to ensure proper fishery safeguards 2. Support SWRCB and RWQCB programs to control point and nonpoint sources of water pollution 3. Continue aggressive program to detect violations of water pollution laws, improve pollution investigations, and improve incident response capabilities
9. High toxic chemical and trace metal concentrations in dredge spoils, and spoil disposal turbidity	1. Discontinue current in-bay dredge and spoil disposal practices, and dispose of spoils in a deep ocean site instead 2. Deny approval of on-land disposal sites where there is potential for adverse impacts on wetlands or other fish or wildlife habitats

Limiting factors	Potential solutions
	3. Allow only spoils free of toxicity and/or contaminants to be discharged to estuary or ocean waters
10. Reduction of habitat, especially for juveniles, resulting from the filling of Bay and Delta tidelands	1. Identify fill projects that should be opposed because of impacts on striped bass and their habitat 2. Prohibit all but public water- dependent fill projects 3. Require from the projects that are approved mitigation in the form of wetlands and/or tidal waters to compensate for unavoidably filled habitat
11. Illegal take and poaching	1. Encourage public and angler use of the Cal-Tip program 2. Increase law enforcement efforts 3. Inform the involved courts and judges of concerns about the striped bass resource so that maximum penalties are imposed on violators
12. Competition of introduced exotic species with bass and/or their food supplies	1. Develop federal legislation controlling ballast water management within the Sacramento-San Joaquin Estuary 2. Support the Federal Aquatic Nuisance Species Task Force

Restoration Actions

Action 1: Implement a recommended Delta outflow schedule.

Objective: Provide conditions necessary to sustain a population of 2 million adult striped bass.

Location: Sacramento-San Joaquin Delta.

Narrative Description: The striped bass population of the Delta and its major tributaries has declined from a historical level of 3.0 million adults during the late 1950s and early 1960s to approximately 0.6 million adults today. Delta and upstream diversions and storage by irrigation districts, water agencies, the SWP, and the CVP have collectively resulted in a reduction in Delta outflows. Reduced Delta outflow has resulted in lower San Joaquin River salinity increasing above levels desirable for bass spawning during dry years.

Flows recommended by the Striped Bass Technical Team are based on a model developed by Loo Botsford of the University of California, Davis (Botsford and Brittnacher 1994). The Botsford/Brittnacher model builds on an earlier DFG model, with modifications to provide a better mechanistic representation for the purpose of increasing confidence for projections outside the range of conditions that were extant when the data were collected (Botsford and Brittnacher 1994). Model output consisted of average outflows and exports for April-July and August-March required to sustain a specified number of adult striped bass.

The model results indicate that flows required to double the baseline-period population of adult striped bass exceeded mean unimpaired runoff over the period of record (1922-1990). To limit recommendations to the range of conditions that are likely to occur in the future, flows were reduced to reflect mean unimpaired runoff. The Botsford-Brittnacher model predicts that these flows, in conjunction with a year-round export ceiling of 1,200 cfs, would sustain an adult striped bass population of 2.0 million. Average flows for the two periods were allocated to reflect the month-to-month pattern exhibited by the unimpaired hydrograph (Table 3-Xf-3).

Table 3-Xf-5. Required Delta outflow (cfs) at Chipps Island to sustain a 2.0 million population of striped bass.

Month	Year type				
	Wet	Above normal	Below normal	Dry	Critical
October	11,500	7,500	6,500	7,500	7,000
November	29,500	24,000	13,000	13,500	8,000
December	80,500	36,000	24,500	19,500	12,500
January	100,500	85,500	36,500	20,000	18,000
February	103,000	85,500	57,500	40,000	18,000
March	101,000	89,500	51,000	50,500	24,500
April	96,500	73,000	68,000	49,500	25,500
May	99,500	77,500	65,500	46,500	27,000
June	67,500	44,500	36,000	24,000	16,500
July	27,000	16,000	12,000	8,500	6,000
August	11,000	7,000	6,000	5,000	3,500

Month	Year type				
	Wet	Above normal	Below normal	Dry	Critical
September	8,000	6,500	5,500	4,500	3,500
Total (taf)	43,940	32,952	22,690	17,162	10,067

Related actions that may impede or augment the action: AFRP and other upstream flow recommendations could either limit or be limited by outflow recommendations for striped bass.

Agency and organization roles and responsibilities: If this measure is implemented, CVP, SWP, and other reservoir managers upstream of the Delta would be responsible for providing releases needed to meet the recommended flow schedule. DWR and USGS would need to provide information from their gaging stations so that flow levels can be evaluated and adjusted.

Potential obstacles to implementation: Flow recommendations are likely to be considered unreasonable by water users. Operations of many of the Central Valley reservoirs that do not fall under the jurisdiction of the CVP would have to be modified to meet the proposed flow schedule. Cooperation from the entities that operate these impoundments would be needed to meet instream flow goals. Flow simulation modeling for the CVPIA PEIS indicates that in some years striped bass flow recommendations may exceed unimpaired runoff. Management of water to meet striped bass restoration goals would probably limit availability for other anadromous fish species and other water users.

Projected benefits: Increased outflow will benefit striped bass by facilitating downstream dispersal of juveniles into the western estuary, especially Suisun Bay and San Pablo Bay. Reduced salinity and increased export of nutrients from upstream reaches would be expected to increase food production and habitat quality for juvenile striped bass. Implementation of the recommended flow schedule, in concert with export restrictions, will reduce losses resulting from direct and indirect effects of entrainment and result in doubling of the adult striped bass population.

Action 2: Reduce exports at the SWP and CVP pumping plants; establish a moratorium on net increases in Delta diversions and withdrawals at the CCC.

Objective: Reduce direct and indirect losses of striped bass resulting from the operation of the pumps and diversions.

Location: Sacramento-San Joaquin Delta.

Narrative description: Exporting water at the SWP and CVP pumping facilities often results in reverse flows in the San Joaquin River east of Antioch, entraining striped bass eggs and juveniles and disrupting the migrations of young and adult bass throughout the Delta. The CCC diversion contributes to reverse flows as well. A percentage of the bass eggs, larvae, and juveniles that drift and migrate down the Sacramento River are diverted into the DCC at Locke and are carried 30 miles through the central Delta to the CVP and SWP pumping plants. Bass eggs, larvae, and fry are lost through fish screens into the California Aqueduct and Delta-Mendota Canal. Plankton, an important source of food for juvenile bass in the western Delta and Suisun Bay, have been depleted by entrainment into Delta diversions and by rapid water transport through most major Delta channels.

The DCC and Georgiana Slough should be closed when eggs and larvae are passing down the Sacramento River, to reduce numbers of striped bass entrained by the pumps. In addition to following Delta outflow recommendations, the following export schedule should be implemented to attain/maintain a naturally reproducing population of 2 million adult striped bass.

The Striped Bass Technical Team recommends establishing a ceiling of 1,200 cfs for combined CVP/SWP exports throughout the year and in all water-year types. Although the available data suggest that eliminating exports completely would result in optimum conditions for successful striped bass reproduction and recruitment, the technical team has modified its recommendations based on the understanding that exports of 1,200 cfs are required to meet public health and safety standards. In addition to the prescribed reductions in CVP/SWP exports, the team recommends that Delta agricultural diversions and CCC withdrawals not exceed the current maximum rates of 3,100 cfs and 300 cfs, respectively.

Related actions that may impede or augment the action: Flow recommendations for rivers upstream of the Delta could either increase or reduce the vulnerability of striped bass to the south Delta pumping operations.

Agency and organization roles and responsibilities: If this measure were implemented, CVP and SWP managers would be responsible for operating within the provided guidelines.

Potential obstacles to implementation: Establishing a 1,200-cfs export ceiling would severely affect water users south of the Delta.

Projected benefits: This action will increase recruitment by reducing direct impacts of Delta exports and diversions. The Striped Bass Technical Team believes that implementation of these export restrictions, in concert with the recommended flow schedule, will result in increasing the adult striped bass population to 2 million fish.

Action 3: Reduce predation at and near the SWP and CVP fish salvage facilities.

Objective: Improve survival of striped bass eggs, larvae, and juveniles entrained by the SWP and CVP pumps.

Location: Sacramento-San Joaquin Delta, CVP pumping plant, and especially CCF at SWP pumping plant.

Narrative description: Predation on juvenile striped bass by larger bass and other predators occurs in CCF and near the CVP intake.

Entrances to CCF should be screened to prevent larger bass and other predatory fish from being entrained. If this proves infeasible, predators should be removed and transplanted during winter and early spring. Covering the "secondary fish screen" at the Skinner (SWP) fish screen facility, thereby darkening it, may also help reduce predation losses.

Related actions that may impede or augment the action: Implementation of outflow and export standards would reduce the number of fish exposed to predation at and near the fish salvage facilities. Predation is only one factor contributing to losses of entrained eggs and fish; the value of reducing predation depends on relative effects of losses in Delta channels and during salvage.

Agency and organization roles and responsibilities: Measures to reduce predation losses would be implemented by DFG in cooperation with DWR and USBR.

Potential obstacles to implementation: Effectively screening CCF in a manner that would permit continued exports may be infeasible or prohibitively expensive. Removal of predators from CCF may not be feasible.

Projected benefits: Losses of striped bass eggs, larvae, and juveniles to predation in CCF may be greatly reduced.

Action 4: Improve CVP and SWP salvage operations.

Objective: Improve survival of the bass eggs, larvae, and juveniles collected at CVP and SWP fish salvage facilities.

Location: Sacramento-San Joaquin Delta, Skinner and Banks pumping plants.

Narrative description: Striped bass salvaged at both SWP and CVP facilities are subject to high mortality during collection, handling, and trucking to Delta release sites. Further, fish that have been salvaged and trucked are generally stressed, disoriented, and vulnerable to predation by larger striped bass and other fish that congregate at the release sites.

Suggested methods for improving the salvage and transport are: 1) reducing the number of fish held in "fish collection buckets", 2) limiting holding time to 5 minutes, 3) adding salt (0.4% NaCl concentration) to the fish truck water when directed to do so by DFG biologists, 4) using compressed oxygen (4 psi) to maintain proper DOC in the fish truck, and 5) not using water venturi aerators in the fish truck tanks. Salvaged fish could be reared in pens to increase survival. Varying the sites and/or times of release may reduce the predation occurring when salvaged bass are put back into the Delta.

Related actions that may impede or augment the action: Delta outflow recommendations and export restrictions may or may not reduce striped bass vulnerability to the pumps, depending on the magnitude of the outflow, thus reducing the need to improve salvage operations. Section 3406(b)(4) develops and implements a program to mitigate fishery impacts associated with operations of the Tracy pumping plant.

Agency and organization roles and responsibilities: Salvage and transport operations are conducted by DFG.

Potential obstacles to implementation: Costs of making modifications that will result in significant increases in survival of salvaged fish are probably high. Because salvaged fish represent a small percentage of total losses to entrainment, potential benefits may not be sufficient to justify this action.

Projected benefits: Survival of bass subjected to the salvage/transport process may increase.

Action 5: Minimize loss and/or entrainment of bass eggs, larvae, and juveniles at the CCC diversion.

Objective: Improve survival of bass eggs, larvae, and juveniles as they move into historical nursery areas.

Location: CCC diversion, south Sacramento-San Joaquin Delta.

Narrative description: Bass eggs, larvae, and juveniles are entrained by the unscreened CCC diversion. This diversion, which has a capacity of 350 cfs, also contributes to reverse flows in the Delta east of Antioch, increasing the number of bass eggs and young entrained at the south Delta pumps and disrupting the migrations of young and adult bass throughout the Delta.

DFG and Contra Costa County Water Agency (CCCWA) should enter into an agreement similar to the one between DWR and DFG for direct and indirect fish losses at the Banks pumping plant. Alternatives for reducing bass losses at the CCC are: 1) installing a fish screen at the intake, 2) relocating the intake to an offstream storage reservoir, and 3) relocating the intake to CCF. Diversion rate should be reduced when bass eggs and/or larvae appear in great abundance at the CCC intake. A salvage and transport program could be developed and implemented.

Related actions that may impede or augment the action: Delta outflow and export recommendations, as well as DCC and Georgiana Slough closures, to a large degree determine the numbers of striped bass eggs, larvae, and juveniles at risk of entrainment at the CCC. Reducing exports at SWP and CVP facilities would substantially reduce the number of juveniles and eggs that are vulnerable to entrainment at the CCC. Section 3406(b)(5), develop and implement a program to mitigate fishery impacts resulting from operations of CCC Pumping Plant Number 1.

Agency and organization roles and responsibilities: CCCWA manages the CCC diversion. CCCWA, DWR, and DFG would cooperatively investigate and implement the salvage/transport project and look at alternatives to improve survival.

Potential obstacles to implementation: Relocating the CCC intake would take years to implement and would be costly. Screening would present some major technical difficulties. CCCWA will likely resist any major changes in its water delivery practices and costs involved in starting a salvage/transport program.

Projected benefits: Reduced losses of bass eggs, larvae, and juveniles into the CCC should result in increased overall bass survival and recruitment.

Action 6: Minimize loss and/or entrainment of bass eggs, larvae, and juveniles at the PG&E power generating plants.

Objective: Improve survival of striped bass eggs, larvae, and juveniles as they move into historical nursery areas.

Location: PG&E power generating plants at Antioch and Pittsburg.

Narrative description: The Antioch and Pittsburg power plants draw water for cooling purposes, then return it to the estuary. Their combined capacity is roughly 3,100 cfs. Problems for striped bass include entrainment and mortality resulting from factors ranging from abrasion and thermal shock for juveniles and eggs to impingement on the screens for adults. The power plant also entrains plankton that would otherwise have been available as food for juvenile striped bass.

PG&E should continue to reduce pumping rates when bass egg and larvae abundance is high at the intakes, and the situation should be monitored for potential feasible improvements. The possibility of placing a barrier outside the intakes to further reduce entrainment should be evaluated and implemented if feasible.

Related actions that may impede or augment the action: Increased outflow would probably reduce vulnerability of striped bass eggs and juveniles to entrainment and reduce the need to modify plant operations.

Agency and organization roles and responsibilities: PG&E should continue to monitor bass abundance at the power plant intakes and manage pumping levels accordingly. DFG may help in providing methods to determine the timing and levels of bass abundance near the intakes.

Potential obstacles to implementation: The detection of bass eggs and larvae may present difficulties. Feasibility of constructing and installing an effective barrier has not been evaluated.

Projected benefits: Bass mortality associated with the PG&E power plants would be reduced, and bass food supplies (plankton) may increase.

Action 7: Eliminate, relocate, or reduce Sherman and Twitchell Island diversions.

Objective: Improve survival of bass eggs, larvae, and juveniles as they move into historical nursery areas.

Location: Sherman and Twitchell Islands, west Sacramento-San Joaquin Delta.

Narrative description: Bass eggs, larvae, and juveniles in transit down the lower Sacramento River pass in close proximity to Sherman and Twitchell Islands, where agricultural diversions are located. The impacts of these diversions on striped bass are unknown but are potentially significant.

Sherman and/or Twitchell Island could be converted to wildlife management areas. Should these islands continue as agricultural producers, some diversions could be consolidated and/or relocated to areas with low bass egg and larval concentrations.

Related actions that may impede or augment the action: Export levels at the south Delta pumping plants, as well as DCC and Georgiana Slough closures, may determine the abundance of bass vulnerable to the island diversions.

Agency and organization roles and responsibilities: DFG and/or USFWS would be involved in the purchase of land to develop a wildlife management area. Private land owner cooperation would be necessary for land purchase or modification or relocation of agricultural diversions.

Potential obstacles to implementation: Private land owners would likely resist any elimination of the islands as agricultural producers and any major changes in their water use practices. Funds to purchase land and establish the wildlife management area(s) may not be available.

Projected benefits: Striped bass egg, larvae, and juvenile losses resulting from entrainment at Sherman and Twitchell Island diversions would be reduced or eliminated.

Action 8: Minimize loss and/or entrainment of bass eggs, larvae, and juveniles at private agricultural diversions.

Objective: Improve survival of bass eggs, larvae, and juveniles as they move into historical nursery areas.

Location: Sacramento-San Joaquin Delta.

Narrative description: Up to 1,800 private unscreened agricultural diversions have operated in the Delta for decades. Approximately 2,500-4,800 cfs are diverted from May through August, with lesser amounts diverted during other times of the year. Striped bass eggs, larvae, and juveniles are entrained and killed in unscreened pumps and siphons. Abundance of plankton, which are a component of the diet of young bass in the western Delta and Suisun Bay, has also been reduced by entrainment in Delta agricultural diversions.

Whenever feasible, agricultural diversions should be consolidated and relocated to areas with low bass egg and larval concentrations. All the larger existing agricultural water diversions should be screened on a priority basis to exclude bass longer than 1.5 inches, and existing screened diversions should be examined for identification of desirable improvements. The "area-wide" rescheduling of water diversions should be considered by all parties in select locations when bass eggs and larvae are at peak abundance during spring and early summer. DFG, Delta agriculture interests, and other appropriate agencies should cooperatively establish and negotiate future screening needs and irrigation schemes to protect young bass.

Related actions that may impede or augment the action: Delta outflow and export levels, as well as DCC and Georgiana Slough closures, may determine the numbers of bass vulnerable to the various private diversions.

Agency and organization roles and responsibilities: DFG and USFWS would need to cooperate with private land owners to implement any of the above actions. DFG would play a major role in determining screening needs and overseeing screen monitoring and installations. Funding should be available under Section 3406(b)(21) of Title 34. Area water interests and public agencies would need to work together to implement any plans of action.

Potential obstacles to implementation: Agricultural diverters might resist major changes in their water use operations and the costs associated with screening. Screens may reduce efficiency of diversions and increase the need for maintenance. Available funds may be insufficient to adequately do the job.

Projected benefits: Striped bass egg, larvae, and juvenile mortality associated with private agricultural diversions would be reduced. Reduced or relocated diversions could result in an increase of bass food supplies.

Action 9: Support measures to prevent the development of a water quality barrier to adult striped bass migration in the San Joaquin River near Stockton.

Objective: Ensure access to spawning areas in the San Joaquin River upstream of Stockton.

Location: San Joaquin River near Stockton.

Narrative description: Low flows in the San Joaquin River near Stockton often combine with agricultural drain water to create an effective dissolved solids (and dissolved oxygen) barrier to upstream migration and spawning by striped bass. This problem is caused by upstream water diversions and agricultural wastewater high in total dissolved solids (TDS).

Salinity standards, particularly in the lower San Joaquin River downstream of Stockton, should be upgraded to levels at which striped bass can use the river upstream of the Delta for spawning. This problem would be solved with implementation of AFRP flow recommendations for San Joaquin River chinook salmon and flow and export restrictions recommended in Actions 1 and 2. DFG and collective San Joaquin Valley and south Delta agricultural interests should develop ways to provide better water quality in agricultural drain discharges into the San Joaquin River.

Related actions that may impede or augment the action: Water quality would be substantially improved with implementation of Striped Bass Technical Team flow and export recommendations and San Joaquin Basin Technical Team flow and export recommendations.

Agency and organization roles and responsibilities: EPA, DFG, and local authorities would set and enforce water quality standards necessary to eliminate the barrier to spawners. DWR, USBR, and the South Delta Water Agency need to continue to work together to improve and maintain water levels, circulation patterns, and quality in the south Delta through the South Delta Agreement.

Potential obstacles to implementation: Private land owners may resist changes necessary to improve the quality of agricultural drain discharges. Non-CVP water agencies may not provide flows needed to meet water quality objectives.

Projected benefits: Spawning habitat available to striped bass spawners in the lower San Joaquin River would increase.

Action 10: Reduce toxic chemical and trace-metal pollution.

Objective: Provide better water quality for all life stages of striped bass.

Location: Throughout the Sacramento-San Joaquin Delta.

Narrative description: Water pollutants, including toxic chemicals (petrochemicals, chlorinated hydrocarbons, pesticides, etc.) and trace metals (mercury, selenium, copper, cadmium, and zinc) are harmful in many ways to all striped bass life stages. Toxic chemicals and trace metals potentially stress, debilitate, or kill bass eggs, larvae, young, and adults and their food (and possibly affect primary productivity) throughout the Sacramento-San Joaquin Estuary. Studies on Atlantic Coast stocks of striped bass show that the combination of toxic chemicals and trace metals found in those waters significantly decreased survival of young bass. Chronic exposure to toxic chemicals appears universal, and continues today, in Bay-Delta bass. For example, 67% of 46 adult bass examined in 1987 contained unmetabolized DDT in the liver. State water quality control agencies project increases in the volume and complexity of municipal, industrial, and agricultural waste discharges into the Bay-Delta system. Each year billions of gallons of storm water runoff wash into the estuary, carrying toxic and other waste materials from streets, parking lots, and other areas that are often incidental dumping grounds for all kinds of urban waste, trash, and garbage. It is common for municipal operations to have upsets in their treatment systems, with the result that large amounts of highly toxic chlorine and other materials are discharged directly to the receiving waters. The incidence and severity of fish diseases and parasites are influenced by water quality.

SWRCB's routine field checking program for regulated waste discharges should be strengthened. Agricultural pesticides in Delta return drains should be regulated and monitored by appropriate agencies to ensure proper fishery safeguards. DFG should continue to support SWRCB and RWQCB programs to control point and nonpoint sources of water pollution. Efforts to detect violations of water pollution laws and improve pollution investigations and incident response capabilities should be maintained by appropriate agencies.

Related actions that may impede or augment the action: Flow into and out of the Delta may affect the concentrations of various pollutants and exposure time for fish. Actions restricting dredge and fill activities may reduce the suspension of toxic chemicals.

Agency and organization roles and responsibilities: DFG, EPA, SWRCB, RWQCB, and other water agencies should all be involved in Delta water quality issues. Private land owner cooperation will also be required.

Potential obstacles to implementation: Funding for studies related to water quality, a strengthened field checking program, and increased levels of enforcement activity may be limited or unavailable. Agricultural, municipal, and industrial interests will likely resist any actions to improve water quality if their operations are significantly affected.

Projected benefits: The overall health of the Sacramento-San Joaquin Estuary will likely be improved. Potential benefits for striped bass are not known.

Action 11: Eliminate or reduce dredging and dredge spoil contributions to water pollution.

Objective: Provide better water quality for all life stages of striped bass.

Location: Throughout the Sacramento-San Joaquin Delta.

Narrative description: Dredging and in-bay spoil disposal recirculate toxic chemicals and trace metals deposited previously in bottom muds, whereby they then become concentrated in striped bass, partly via the food web. In addition, concurrent turbidity abrades fish gills, reduces phytoplankton, and smothers bottom organisms. The practice of slurrying spoils before disposal instead of disposing of the more solidified material from clamshell dredging appears to have exacerbated problems by causing excessive turbidities and enhanced release of toxic materials to the water column.

A deep ocean spoil disposal site should be used in place of current in-bay dredge and spoil disposal practices. Disposal at on-land sites, where there is potential for adverse impacts on wetlands or other fish or wildlife habitats, should be prohibited. Only spoils free of toxicity and/or contaminants should be allowed to be discharged to estuary or ocean waters. Dredge spoils should not be slurried before release. A survey of bottom muds of the Sacramento-San Joaquin Estuary should be conducted to identify areas with high concentrations of toxic chemicals.

Related actions that may impede or augment the action: Dredging activities necessary to keep shipping channels operational may diminish the effectiveness of recommended actions.

Agency and organization roles and responsibilities: The Corps would be responsible for carrying out its dredging operations in a manner not detrimental to biological resources. EPA, as well as state and local authorities, would assist in assessing levels of contamination in dredge spoils and bottom muds to be dredged.

Potential obstacles to implementation: The Corps and other groups responsible for dredging channels may resist changes in their operations. The development and use of an ocean disposal site would be highly controversial. A bottom mud survey would be costly and may be beyond present Corps capabilities.

Projected benefits: The overall health of the Sacramento-San Joaquin Estuary will likely be improved. Potential benefits for striped bass are not known but may be substantial.

Action 12: Eliminate or reduce unnecessary landfill projects.

Objective: Reduce or eliminate habitat loss resulting from the filling of Bay and Delta tidelands.

Location: Throughout the Sacramento-San Joaquin Estuary.

Narrative description: The loss of open water areas by filling of Bay and Delta tidelands has reduced bass and bass-food habitats. Research reports by the San Francisco Bay Conservation and Development Commission (BCDC) reveal that such filling also reduces the estuary's total water volume and its ability to assimilate certain pollutants. State reports document that between 1860 and 1959, almost 50% of the potentially fillable marshlands and tidelands were filled or diked off. An example is the Mare Island Training Wall (Dike 12), a landfill project completed in 1908, which probably eliminated at least 10 square miles of open water habitat in San Pablo Bay.

Fill projects that DFG should oppose because they are overly detrimental to bass and their habitat should be identified. All but public water-dependent fill projects (i.e., port development) should be prohibited unless there is reason to believe that fish and wildlife would benefit. Projects involving landfills should be required to provide mitigation in the form of wetlands and/or tidal waters to compensate for unavoidably filled habitat.

Related actions that may impede or augment the action: None identified.

Agency and organization roles and responsibilities: Permitting agencies will need to adopt the recommended actions as policy or regulations. DFG and USFWS will need to oppose any landfill projects detrimental to striped bass. Cooperation between numerous agencies and organizations will be needed because most fill activities take place on private land adjacent to Delta and Bay waters.

Potential obstacles to implementation: Developers will certainly resist any regulation or policy changes concerning landfills that would affect them.

Projected benefits: Habitat loss resulting from landfill projects in the Bay-Delta will be eliminated. Habitat lost as a result of past landfill projects may be mitigated.

Action 13: Eliminate or reduce illegal take and poaching.

Objective: Reduced impacts of illegal fishing on striped bass populations.

Location: Throughout the Sacramento-San Joaquin Estuary.

Narrative description: Illegal take and poaching are frequent problems in Bay-Delta waters. DFG wardens have cited anglers for bass overlimits and undersized fish, and have arrested people using illegal nets and set lines for striped bass. "Stings" have uncovered marketing of illegally caught bass in the Bay-Delta area. Available levels of enforcement effort are insufficient to prevent all of the poaching.

The general public and anglers should be encouraged to routinely use the Cal-Tip program to advise DFG of poachers, illegal selling of striped bass, and violations of angling regulations. DFG should continue to augment night and overtime patrols and purchase special equipment to aid striped bass enforcement, such as night-vision scopes and specialized boats. Courts and prosecutors that judge violations of striped bass laws should be fully informed of the grave plight of the bass resource so that maximum legal penalties will be imposed to deter future violations.

Related actions that may impede or augment the action: None identified.

Agency and organization roles and responsibilities: DFG enforcement personnel will carry out most of the actions necessary to reduce illegal take and poaching. Environmental and angling groups will need to share responsibility for making people aware of the problem and what they can do about it.

Potential obstacles to implementation: Limited availability of funding may greatly hinder DFG's ability to increase enforcement presence and effectiveness.

Projected benefits: Striped bass mortality associated with illegal take and poaching will likely decrease. Overall benefits in terms of increases in the striped bass population are unknown.

Action 14: Eliminate or reduce the introduction of exotic aquatic organisms.

Objective: Reduce impacts of exotic species on striped bass and their food supplies.

Location: Throughout the Sacramento-San Joaquin Estuary.

Narrative description: For decades there have been continual, unauthorized introductions of worldwide exotic aquatic plants and animals into the Sacramento-San Joaquin Estuary through the discharge of ballast water from ships entering San Francisco Bay from foreign ports. Some introductions may have resulted in major detrimental impacts on populations of existing aquatic organisms, including striped bass and their food supplies. Several species of exotic aquatic organisms originally from China and Japan have become extremely abundant. These include the yellowfin goby (*Acanthogobius flavimanus*), and zooplankton *Sinocalanun doerii*, *Pseudodiaptomus marinus*, and *P. forbesi*.

Discharges of ship ballast water within the Sacramento-San Joaquin Estuary should be restricted through federal legislation and regulations. DFG should participate on the Federal Aquatic Nuisance Species Task Force. Methods of eliminating or reducing populations of exotic organisms already established in the estuary should be investigated.

Related actions that may impede or augment the action: Largely undocumented impacts of exotic species may limit effectiveness of all other restorations actions.

Agency and organization roles and responsibilities: DFG would carry out any studies involving the detection and elimination of undesirable exotic aquatic species. Legislative bodies would need to take action to change present laws. The U.S. Coast Guard and other regulatory agencies would be needed to carry out enforcement and monitoring activities.

Potential obstacles to implementation: Shipping companies and vessel operators will likely resist any changes in their operational procedures. Exotic species already present in the Bay-Delta may be impossible to control or eliminate.

Projected benefits: The natural integrity of the Sacramento-San Joaquin Estuary ecosystem will not be further degraded and may even be improved.

G. AMERICAN SHAD

Baseline Period Production and Production Goals

Because there are no data to estimate the adult component of the American shad population for any years except 1976 and 1977, juvenile abundance in the California Department of Fish and Game fall midwater trawl (MWT) was used as an index of production. The MWT survey is conducted at about 90 sampling sites from the Delta downstream through San Pablo Bay from September to December. To reflect the fact that the juvenile index is related to abundance of spawning adults 3-5 years later, it would have been ideal to consider the index for 1962-1988. However, because the MWT survey was not begun until 1967, it was necessary to estimate the baseline period average and to establish the restoration goal on the basis of data collected from 1967 through 1988.

Additional deficiencies in MWT data occur because sampling does not include the entire period that juvenile shad are present in the system and because a portion of the system that is known to be utilized by juvenile shad is not sampled at all. Sampling does occur during October and November when the greatest numbers of juvenile shad are migrating to the ocean and, consequently, abundance of juveniles in the Delta is highest.

Table 3-Xg-1. Young-of-the year and adult American shad abundance estimates in the Sacramento-San Joaquin River system.

Year	Young-of-the-year MWT index	Adults abundance[a]
1964	1,531	
1965	4,064	
1966	1,991	
1967	3,501	
1968	773	
1969	4,055	
1970	871	
1971	1,543	
1972	335	
1973	1,084	

Year	Young-of-the-year MWT index	Adults abundance[a]
1974	5,275	
1975	2,486	
1976	354	3,040,000
1977	646	2,790,000
1978	2,461	
1979	1,953	
1980	3,903	
1981	1,434	
1982	5,386	
1983	2,928	
1984	846	
1985	1,596	
1986	1,860	
1987	899	
1988	1,459	
Mean	2,129	291,500

[a] Abundance derived from mark-recapture population estimates.

Goal - Based on mean juvenile shad abundance from 1967 through 1988, the AFRP goal for MWT index is 4,258.

Basis for flow recommendations - Because of the limited quantity of adult shad data, the degree of uncertainty associated with predicting population response to flow is probably greater for American shad than for other species. A regression relationship between Delta inflow and juvenile shad abundance in the MWT has been recognized for several years (Painter et al. 1979, Stevens and Miller 1983, Stevens et al. 1987). In general, the years with the highest Delta inflow have been the years when the abundance of juvenile shad was highest. More recently, this relationship deteriorated, reflecting several years (1990, 1991, 1992) when juvenile abundance was high despite relatively low inflow.

April through June is the most important period for providing flow for the purpose of increasing production of shad (Painter et al. 1979). The regression equation incorporating all the available data indicates that April-June Delta inflow would have to exceed unimpaired levels to meet the restoration goal established for the MWT index. To avoid this problem, flows needed for doubling were estimated by averaging the flows that occurred during years that the MWT index actually equaled or exceeded the established restoration goal of 4,258 (1974 and 1982). The flow generated by this method was in the range of mean unimpaired flow and was considered to be the average required across all year types.

Recommendations for individual year types were generated by identifying the proportion of total unimpaired inflow that would have occurred, on average, during each year type for the period of record (1922-1990). Within year types, flows were allocated to individual rivers known to be important for shad spawning to reflect historical (1922-1990) percent contribution to unimpaired runoff.

Sacramento River Basin - Upper Mainstem Sacramento River

Limiting factors and potential solutions -

Table 3-Xg-2. Limiting factors and potential solutions for American shad in the upper Sacramento River (Colusa to Red Bluff).

Limiting factors	Potential solutions
1. Inadequate flows for spawning, incubation, and rearing	Increase Sacramento River and tributary flows to levels specified in the proposed restoration program
2. Water temperatures higher than optimum range during May and June (temperatures exceed 68°F)	1. Manage Sacramento River and tributary flows to levels specified in the proposed restoration program 2. Manage Shasta Dam releases to maintain water temperatures between 61°F and 65°F in the Sacramento River
3. Entrainment of juveniles at diversions from Colusa to Red Bluff on the Sacramento River	1. Increase Sacramento River and tributary flows to levels specified in the proposed restoration program

Limiting factors	Potential solutions
	2. Provide proper spawning temperatures (≥61 °F) beginning May 1 to stimulate spawning so eggs and larvae can be transported past GCID and other diversions prior to peak irrigation season

Restoration actions -

Action 1: Provide adequate flows for shad spawning and survival of eggs and larvae as presented in the following table.

Table 3-Xg-3. Instream flow regime believed necessary to double natural production of American shad in the Sacramento River for five water year types.

Month	Wet	Above normal	Below normal	Dry	Critical
April	25,800	19,100	16,600	11,900	7,400
May	16,500	12,200	10,700	8,500	7,100
June	10,300	7,200	7,000	6,200	5,600

Objective: Improve shad spawning success, and increase survival of eggs and larvae.

Location: Sacramento River at Grimes (RM 125).

Narrative description: Delta inflow was assumed to be an index of flow needs in tributaries known to support spawning runs of American shad. Flow for each tributary was generated by multiplying the percent contribution of that tributary to total unimpaired runoff (1922-1992) by Delta inflow needed to achieve the restoration goal for the MWT index. Separate flow recommendations were generated for each of the five Sacramento or San Joaquin water year types.

Related actions that may impede or augment the action: Temperature standards for American Shad. Flow and temperature recommendations for other anadromous fish species.

Agency and organization roles and responsibilities: Meeting flow standard would be the responsibility of USBR. Monitoring success and making recommendations to improve conditions would be the responsibility of USFWS and/or DFG.

Potential obstacles to implementation: Flows are generally higher than those recommended for other species of anadromous fish. In many years, use of water to meet American shad needs would reduce availability for other species and for waters users.

Projected benefits: Providing the recommended flows would result in improved conditions for spawning and increased survival of eggs and larvae in the upper mainstem Sacramento River.

Action 2: Maintain mean daily water temperatures between 61 ^{o}F and 65 ^{o}F for 1 month between April 1 and June 30.

Objective: Improve shad spawning success, egg survival, and larvae survival of shad in the upper Sacramento River.

Location: Upper Sacramento River.

Narrative description: Maintaining mean daily water temperatures between 61 ^{o}F and 65 ^{o}F for 1 month between April 1 and June 30 will provide conditions needed for successful spawning and incubation. No additional water beyond that defined above for instream requirements needs to be released to meet these temperature recommendations, but management of the Shasta Reservoir temperature curtain should be used. A secondary goal is to provide appropriate spawning temperatures as early in spring as possible to minimize overlap between spawning and the peak of the irrigation season. It is anticipated that early spawning would result in transport of eggs and larvae past GCID and other diversions before the peak irrigation season.

Related actions that may impede or augment the action: Flow and temperature requirements are also recommended by the upper Sacramento River chinook salmon and sturgeon technical teams.

Agency and organization roles and responsibilities: USBR would be responsible for implementation, but USFWS and/or DFG would be responsible for monitoring success and making recommendations to modify the action.

Potential obstacles to implementation: Increased Shasta Dam releases are likely to decrease power generation prior to completion of the temperature control structure.

Projected benefits: Maintaining water temperatures within the specified range should increase survival of American shad eggs and larvae in the upper Sacramento River.

Lower Sacramento River and Delta Tributaries

Limiting factors and potential solutions -

Table 3-Xg-4. Limiting factors and potential solutions for American shad in the lower Sacramento River (Hood to Colusa).

Limiting factors	Potential solutions
1. Inadequate Sacramento River flows for spawning, incubation, and early life stage rearing	Increase Sacramento River and tributary flows to levels specified in the proposed restoration program
2. Temperatures outside the optimum range during May and June (temperatures exceed 68°F)	1. Increase Sacramento River and tributary flows to levels specified in the proposed restoration program 2. Maintain water temperatures between 65°F and 68°F by releasing water from lower outlets of upstream reservoirs with temperature control facilities
3. Water quality in the lower Sacramento River	Increase Sacramento River and tributary flows to levels specified in the proposed restoration program
4. Fish entrained at diversions located between Hood and Colusa on the Sacramento River	Increase Sacramento River and tributary flows to levels specified in the proposed restoration program
5. Reduced quality and quantity of suitable rearing habitat in the lower Sacramento River	Increase Sacramento River and tributary flows to levels specified in the proposed restoration program

Restoration actions -

Action 1: Maintain mean daily water temperatures between 65°F and 68°F for 1 month between April 1 and June 30 by managing releases from dams with water temperature control facilities.

<u>Objective</u>: Improve spawning success and survival of eggs and larvae in the lower Sacramento River.

<u>Location</u>: Sacramento River from Hood to Colusa.

Narrative description: Maintaining mean daily water temperatures between 61 °F and 65 °F for 1 month between April 1 and June 30 will provide conditions needed for successful spawning and incubation. No additional water beyond that defined above for instream requirements needs to be released to meet these temperature recommendations, but management of multilevel outlet structures should be used if available.

Related actions that may impede or augment the action: Flow and temperature requirements are also recommended by the upper Sacramento River and sturgeon technical teams.

Agency and organization roles and responsibilities: USBR would be responsible for implementing this action in association with other dam operators with the ability to control water temperatures with releases. USFWS and/or DFG will be responsible for monitoring success and making recommendations to provide optimum benefits.

Potential obstacles to implementation: Increased Shasta Dam releases are likely to decrease power generation.

Projected benefits: Maintaining temperatures within the specified range should increase survival of eggs and larvae in the lower Sacramento River.

Feather River

Limiting factors and potential solutions -

Table 3-Xg-5. Limiting factors and potential solutions for American shad in the Feather River.

Limiting factors	Potential solutions
1. Flows are frequently inadequate for attraction, spawning, incubation, and rearing	Increase Feather and Yuba River flows to levels specified in the proposed restoration program
2. Water temperatures outside the optimum range for spawning, incubation, and early rearing	1. If higher than optimum mean daily water temperatures, increase flows to levels specified in the proposed restoration program 2. Manage pumpback operations at Thermalito Reservoir to keep mean daily temperatures at Nicolaus between 61 °F and 68 °F

Limiting factors	Potential solutions
3. Fish entrainment at diversions in the Feather River below the Yuba River confluence	Increase Feather and Yuba River flows to levels specified in the proposed restoration program

Restoration actions -

Action 1: Provide adequate flows as presented in the following table.

Table 3-Xg-6. Instream flow regime believed necessary to double natural production of American shad in the Feather River for five water year types.

Month	Wet	Above normal	Below normal	Dry	Critical
April	17,500	13,400	12,600	9,000	4,200
May	17,100	12,100	10,100	6,600	3,600
June	9,800	5,700	4,900	3,300	2,500

Objective: Improve conditions for spawning, and increase survival of eggs and larvae.

Location: Feather River at Nicolaus.

Narrative description: Delta inflow was assumed to be an index of flow needs in tributaries known to support spawning runs of American shad. Flow for each tributary was generated by multiplying the percent contribution of that tributary to total unimpaired runoff (1922-1992) by Delta inflow needed to achieve the restoration goal for the MWT index. Separate flow recommendations were generated for each of the five Sacramento or San Joaquin water year types.

Related actions that may impede or augment the action: Temperature recommendations for American shad; flow and temperature recommendations for other anadromous fish species..

Agency and organization roles and responsibilities: DWR would be responsible for meeting the recommended flow schedule. DWR, with possible assistance from DFG and/or USFWS would be responsible for monitoring results and adjusting flows to provide optimum benefits.

Potential obstacles to implementation: Flows recommended for American shad are generally higher than those recommended for other species. Reservoir storage may be insufficient to supply recommended flows in many years. Use of water to meet flow needs for shad would reduce ability to meet requirements for other species and limit availability to water users.

Projected benefits: It is anticipated that providing the recommended flows, in concert with other actions recommended by the technical team, have the potential to at least double production of American shad.

Action 2: Maintain mean daily water temperatures between 61°F and 65°F for at least 1 month between April 1 and June 30 by managing pumpback operations at Thermalito Reservoir.

Objective: Improve spawning success and egg survival in the Feather River.

Location: Feather River.

Narrative description: Maintaining mean daily water temperatures between 61°F and 65°F for 1 month between April 1 and June 30 will provide conditions needed for successful spawning and incubation. No additional water beyond that defined above for instream requirements needs to be released to meet these temperature recommendations, but management of multilevel outlet structures should be used if available.

Related actions that may impede or augment the action: Meeting flow standards specified under Action 1 will contribute to temperature reductions, depending on the source of water for these flows.

Agency and organization roles and responsibilities: All public and private entities with control over sources and quantities of water flowing into the Feather River share responsibility for meeting temperature criteria.

Potential obstacles to implementation: Implementation will require identification of flows necessary to meet temperature criteria (work currently conducted by University of California, Davis researchers). Implementation will likely require Oroville Dam releases to meet temperature standards downstream. Increased Oroville Dam releases are likely to decrease power generation.

Projected benefits: Maintaining temperatures within the specified range should increase survival of eggs and larvae in the lower Sacramento River. Insufficient data are available to determine the specific increase in survival.

Yuba River

Limiting factors and potential solutions -

Table 3-Xg-7. Limiting factors and potential solutions for American shad in the Yuba River.

Limiting factors	Potential solutions
1. Flows are frequently inadequate for attraction, spawning, incubation, and rearing	Increase Yuba and Feather River flows to levels specified in the proposed restoration program
2. Water temperatures outside the optimum range during May and June (temperatures below 61°F or above 68°F)	1. If higher than optimum mean daily water temperatures, increase flows to levels specified in the proposed restoration program 2. Maintain mean daily water temperatures between 61°F and 65°F at Marysville by using multilevel outlet at New Bullards Bar Reservoir

Restoration actions -

Action 1: Provide adequate flows as presented in the following table.

Table 3-Xg-8. Instream flow regime believed necessary to double natural production of American shad in the Yuba River for five water year types.

Month	Wet	Above normal	Below normal	Dry	Critical
April	8,200	7,100	7,200	5,500	2,800
May	9,900	8,100	7,100	4,900	2,600
June	6,400	3,900	3,200	2,000	1,400

Objective: Improve shad attraction and spawning and survival of eggs and larvae.

Location: Yuba River at Marysville.

Narrative description: Delta inflow was assumed to be an index of flow needs in tributaries known to support spawning runs of American shad. Flow for each tributary was generated by multiplying the percent contribution of that tributary to total unimpaired runoff (1922-1992) by Delta inflow needed to achieve the restoration goal for the MWT index. Separate flow recommendations were generated for each of the five Sacramento or San Joaquin water year types.

Related actions that may impede or augment the action: Temperature recommendations for American shad; flow and temperature recommendations for other anadromous fish species.

Agency and organization roles and responsibilities: Yuba County Water Agency would be responsible for implementation. DFG and/or USFWS would be responsible for monitoring and making recommendations to improve conditions for American shad.

Potential obstacles to implementation: April-June flows recommended for American shad are higher than those proposed for chinook salmon or steelhead. Flows may exceed reservoir unimpaired flow in some years. Meeting these flow requirements would probably reduce the quantity of water available to meet needs of other species or various water users.

Projected benefits: It is anticipated that providing the recommended flows, in concert with other actions recommended by the technical team, has the potential to at least double production of American shad.

Action 2: Maintain mean daily water temperatures between 61^{o} F and 65^{o}F for at least 1 month between April 1 and June 30 using multilevel outlets.

Objective: Improve shad spawning success and egg survival in Yuba River.

Location: Yuba River.

Narrative description: To the extent possible, mean daily water temperatures during May and June should be kept between 61^{o}F and 65^{o}F for optimum spawning and egg incubation in the Yuba River. No additional water beyond that defined above for instream requirements needs to be released to meet these temperature recommendations, but management of the New Bullards Bar Dam multilevel outlets should be used. USBR would need to enter into an agreement with Yuba County Water Agency, the dam operator, to implement this action.

Related actions that may impede or augment the action: Flows recommended for American shad and other species.

Agency and organization roles and responsibilities: Yuba County Water Agency would be responsible for managing water temperatures.

Potential obstacles to implementation: Competing water uses.

Projected benefits: Increased survival of eggs and larvae is expected in the Yuba River. Insufficient data are available to determine the specific increase in survival expected.

American River

Limiting factors and potential solutions -

Table 3-Xg-9. Limiting factors and potential solutions for American shad in the American River.

Limiting factors	Potential solutions
1. Flows are frequently inadequate for attraction, spawning, incubation, and rearing	Increase American River flows to levels specified in the proposed restoration program
2. Higher than optimum water temperatures during May and June (temperatures below 61°F or above 68°F)	If higher than optimum mean daily water temperatures, increase flows to levels specified in the proposed restoration program Note: Without multilevel outlets at Folsom Dam, water temperatures cannot be controlled in the American river, except by flows

Restoration actions -

Action 1: Provide adequate flows as presented in the following table.

Table 3-Xg-10. Instream flow regime believed necessary to double natural production of American shad in the American River for five water year types.

Month	Wet	Above normal	Below normal	Dry	Critical
April	10,200	8,400	8,600	6,500	3,100
May	12,200	9,600	8,700	6,100	3,100
June	8,100	4,800	4,200	2,700	1,700

Objective: Improve shad spawning success and egg and larvae survival.

Location: American River at H Street Bridge.

Narrative description: Delta inflow was assumed to be an index of flow in tributaries known to support spawning runs of American shad. Flow for each tributary was generated by multiplying the percent contribution of that tributary to total unimpaired runoff (1922-1992) by Delta inflow needed to achieve the restoration goal for the MWT index. Separate flow recommendations were generated for each of the five Sacramento or San Joaquin water year types.

Related actions that may impede or augment the action: Temperature recommendations for American shad; flow and temperature recommendations for chinook salmon and steelhead.

Agency and organization roles and responsibilities: USBR would be responsible for implementation, but USFWS and/or DFG would be responsible for monitoring success and making recommendations to modify the action.

Potential obstacles to implementation: April-June flows recommended for American shad are generally higher than those proposed for chinook salmon or steelhead. Flows may exceed reservoir unimpaired flow in some years. Meeting these flow requirements would probably reduce the quantity of water available to meet needs of other species or various water users.

Projected benefits: It is anticipated that providing the recommended flows, in concert with other actions recommended by the technical team, has the potential to at least double production of American shad.

Mokelumne River

Limiting factors and potential solutions -

Table 3-Xg-11. Limiting factors and potential solutions for American shad in the Mokelumne River.

Limiting factors	Potential solutions
1. Flows are frequently inadequate for attraction, spawning, incubation, and rearing	1. Increase Mokelumne River flows to levels specified in the proposed restoration program 2. Minimize flow fluctuations resulting from peaking power operations at Comanche Dam
2. Higher than optimum water temperatures during May and June (temperatures	Increase Mokelumne River flows to levels specified in the proposed restoration program

Limiting factors	Potential solutions
above 68°F)	

Restoration actions -

Action 1: Provide adequate flows as presented in the following table.

Table 3-Xg-12. Instream flow regime believed necessary to double natural production of American shad in the Mokelumne River for five water year types.

Month	Wet	Above normal	Below normal	Dry	Critical
April	2,600	2,300	2,400	2,000	1,100
May	4,500	3,800	3,400	2,500	1,300
June	3,500	2,200	1,900	1,100	700

Objective: Improve shad spawning success and egg and larvae survival.

Location: Mokelumne River downstream of Woodbridge Dam.

Narrative description: Delta inflow was assumed to be an index of flow in tributaries known to support spawning runs of American shad. Flow for each tributary was generated by multiplying the percent contribution of that tributary to total unimpaired runoff (1922-1992) by Delta inflow needed to achieve the restoration goal for the MWT index. Separate flow recommendations were generated for each of the five Sacramento or San Joaquin water year types.

Related actions that may impede or augment the action: Temperature recommendation for American shad; flow and temperature recommendations for chinook salmon.

Agency and organization roles and responsibilities: EBMUD and FERC would implement recommended flows and USFWS and/or DFG would monitor populations.

Potential obstacles to implementation: April-June flows recommended for American shad are higher than those proposed for chinook salmon or steelhead. Flows may exceed reservoir unimpaired flow in some years. Meeting these flow requirements would probably reduce the quantity of water available to meet needs of other species or various water users.

Projected benefits: Providing the recommended flows, in concert with other actions recommended by the technical team, has the potential to at least double production of American shad.

Action 2: Minimize flow fluctuations resulting from peaking power operations at Camanche Dam.

Objective: Improve survival of eggs, larvae, and juvenile shad in the Mokelumne River.

Location: Mokelumne River.

Narrative description: Flow fluctuations resulting from peaking power operations at Camanche Dam affect fisheries resources downstream. These operations would likely adversely affect shad production in the Mokelumne River.

Related actions that may impede or augment the action: Flows specified for other species.

Agency and organization roles and responsibilities: EBMUD and FERC would implement recommended flows and USFWS and/or DFG would monitor populations.

Potential obstacles to implementation: April-June flows recommended for American shad are generally higher than those proposed for chinook salmon or steelhead. Flows may exceed reservoir unimpaired flow in some years. Meeting these flow requirements would probably reduce the quantity of water available to meet the needs of other water users.

Projected benefits: Reduced flow fluctuations would benefit shad production by increasing survival of eggs, larvae, and juveniles.

Sacramento-San Joaquin Delta

Limiting factors and potential solutions -

Table 3-Xg-13. Limiting factors and potential solutions for American shad in the Sacramento-San Joaquin Delta.

Limiting factors	Potential solutions
1. Delta inflow and outflow are frequently inadequate for dispersing juvenile shad downstream and to provide optimum rearing conditions within the Delta	Establish Delta inflow to levels specified in the proposed restoration program

Limiting factors	Potential solutions
2. Poor Delta water quality	Dilute toxic compounds by increasing Delta inflow to levels specified in the proposed restoration program
3. Fish entrainment at Delta diversions	1. Increase Delta inflow to levels specified in the proposed restoration program 2. Close the DCC during the peak fall migration period (October-December)

Restoration actions -

Action 1: Provide systemwide flows needed for successful American shad spawning, incubation, and early downstream migration.

Table 3-Xg-14. Delta inflow required to double natural production of American shad in the Sacramento-San Joaquin Rivers.

Month	Wet	Above normal	Below normal	Dry	Critical
April	104,800	79,500	74,500	54,400	28,900
May	104,500	82,000	69,700	49,800	29,800
June	74,100	49,800	40,4000	27,800	19,700

Objective: Improve shad spawning and egg and larvae survival.

Location: Delta inflow is a calculated quantity.

Narrative description: These required minimum flows, in association with higher flows that would occur during high natural runoff conditions and during reservoir releases to meet other beneficial uses over and above shad needs, would provide the most substantial element in the restoration program for American shad.

The sources of water are not currently available to the federal government in all the river basins, and additional water will need to be purchased or exchanged to meet the needs. A number of water-sharing formulas could also be implemented on a statewide basis to meet the recommended requirements.

Comprehensive systemwide flow increases in April-June are needed to ensure doubling of shad populations. The flow increases for the various tributaries with shad spawning and rearing need to be maintained downstream as Delta inflow so that the systemwide benefits are realized. Only in this manner can shad be distributed throughout the Sacramento-San Joaquin River system and double their populations within each general spawning location.

Related actions that may impede or augment the action: Flow recommendations for all rivers and species.

Agency and organization roles and responsibilities: Meeting the recommended Delta inflow standards would depend on releases from upstream impoundments and would require cooperation and coordination between a number of agencies and organizations. USBR would be responsible for meeting instream flow requirements on rivers with USBR storage and/or diversion facilities. Monitoring would be coordinated with the Interagency Ecological Program and the ongoing efforts to monitor effects of the provisions of the recent Delta Water Quality Standards Decision.

Potential obstacles to implementation: April-June flows recommended for American shad are generally higher than those proposed for chinook salmon or steelhead. Flows may exceed reservoir unimpaired flow in some years. Meeting these flow requirements would probably reduce the quantity of water available to meet needs of other species or various water users.

Projected benefits: Providing the recommended flows, in concert with other actions recommended by the technical team, has the potential to at least double production of American shad. It is estimated that increasing minimum instream flow requirements will increase production by approximately 60%-80%. Unfortunately, no data or models are available to verify this estimate, which is based on professional experience and judgment and on review of the best available information. Instream flow requirements are the most important management tool for doubling American shad production, and there is firm agreement among members of the American Shad Technical Work Group on this point. The specific mechanisms are not documented but are thought to be increased attraction into desirable spawning locations, increased egg-larval survival, and increased survival during early juvenile rearing and outmigration.

Action 2: Close the DCC during the peak fall migration period in October-December.

Objective: Improve survival of juvenile shad migrating downstream in fall.

Location: Delta Cross Channel at Walnut Grove.

Narrative description: The DCC has been effectively operated to increase chinook salmon outmigrant survival. Similar methods should be used to improve survival of American shad by keeping emigrating shad away from the CVP and SWP pumping facilities. The DCC should be closed during the peak fall outmigration period during October-December. USBR would be responsible for implementing this action.

Related actions that may impede or augment the action: Flow and export recommendations for all species. DCC recommendation for chinook salmon.

Agency and organization roles and responsibilities: USBR would be responsible for operating the Delta Cross Channel in a manner that would prevent entrainment of juvenile American shad. Insufficient data are available to determine the specific increase in survival that could be expected, but it is anticipated that the increase would be significant.

Potential obstacles to implementation: Measures to protect outmigrating salmon restricted on Delta Cross Channel use at other times of the year. This action would increase the period of time during which cross channel use and export capabilities would be affected.

Projected benefits: This action would result in increased survival of downstream-migrating American shad from the Sacramento River system. Insufficient data are available to determine the specific increase in survival that could be expected, but it is anticipated that the increase would be significant.

San Joaquin River

Limiting factors and potential solutions -

Table 3-Xg-15. Limiting factors and potential solutions for American shad in the San Joaquin River.

Limiting factors	Potential solutions
1. Inadequate San Joaquin River flows during key life history activities (April-June)	Increase San Joaquin River flows to levels specified in the proposed restoration program
2. Water temperatures outside the optimum range during May and June (temperatures below 61° F or above 68° F)	1. If higher than optimum mean daily water temperatures, increase flows to levels specified in the proposed restoration program 2. Maintain mean daily water temperatures between 65° F and 68° F at Vernalis by using multilevel outlets of upstream reservoirs
3. Poor San Joaquin River water quality	1. Increase San Joaquin River flows to levels specified in the proposed restoration program

Limiting factors	Potential solutions
	2. Corrective actions implemented for striped bass will benefit American shad
4. Fish entrainment at diversions located below the Stanislaus River	Increase San Joaquin River flows to levels specified in the proposed restoration program
5. Reduced quality of lower San Joaquin River rearing habitat	1. Increase San Joaquin River flows to levels specified in the proposed restoration program 2. Implement an overall lower San Joaquin River aquatic habitat improvement program between the Stanislaus River confluence and Vernalis

Restoration actions -

Action 1: Provide adequate flows as presented in the following table.

Table 3-Xg-16. Instream flow regime believed necessary to double natural production of American shad in the San Joaquin River for five water year types.

Month	Wet	Above normal	Below normal	Dry	Critical
April	5,200	4,400	4,600	3,500	2,200
May	10,200	8,900	7,400	5,400	3,100
June	10,300	8,200	5,700	3,900	2,400

Objective: Improve shad spawning and egg survival and larvae survival.

Location: San Joaquin River at Vernalis.

Narrative description: Delta inflow was assumed to be an index of flow needs in tributaries known to support spawning runs of American shad. Flow for each tributary was generated by multiplying the percent contribution of that tributary to total unimpaired runoff (1922-1992) by Delta inflow needed to achieve the restoration goal for the MWT index. Separate flow recommendations were generated for each of the five Sacramento or San Joaquin water year types.

Related actions that may impede or augment the action: Temperature recommendations for American shad. Chinook salmon flow and temperature recommendations for San Joaquin River tributaries.

Agency and organization roles and responsibilities: Providing the recommended flows for the San Joaquin River would require cooperation between multiple agencies and organizations.

Potential obstacles to implementation: April-June flows recommended for American shad are higher than those proposed for chinook salmon or steelhead. Flows may exceed reservoir unimpaired flow in some years. Meeting these flow requirements would probably reduce the quantity of water available to meet needs of other species or various water users.

Projected benefits: Providing the recommended flows, in concert with other actions recommended by the technical team, has the potential to at least double production of American shad.

Action 2: Maintain mean daily water temperatures between 61°F and 65°F for 1 month between April 1 and June 30 below dams with temperature control facilities.

Objective: Improve shad spawning success, egg survival, and larvae survival of shad in the lower San Joaquin River.

Location: Lower San Joaquin River.

Narrative description: To the extent possible, mean daily water temperatures during a 1-month period from April through June should be between 65°F and 68°F for optimum spawning and egg incubation in the lower San Joaquin River. No additional water beyond that defined above for instream requirements needs to be released to meet these temperature recommendations, but management of multilevel outlet structures should be used if available. USBR would be responsible for implementing this action, in association with other dam operators with the ability to control temperatures of water releases.

Related actions that may impede or augment the action: Flow recommendations for American shad. Flow and temperature recommendations for chinook salmon in San Joaquin River tributaries.

Agency and organization roles and responsibilities: Meeting recommended temperature criteria for the San Joaquin River would require cooperation between multiple agencies and organizations.

Potential obstacles to implementation: April-June flows recommended for American shad are generally higher than those proposed for chinook salmon or steelhead. Flows may exceed reservoir unimpaired flow in some years. Meeting these flow requirements would probably reduce the quantity of water available to meet needs of other species or various water users.

Projected benefits: Increased survival of eggs and larvae is expected in the lower San Joaquin River. Insufficient data are available to determine the specific increase in survival expected. Meeting the recommended temperature criteria, in concert with other actions recommended by the technical team, has the potential to at least double production of American shad.

Lower San Joaquin River Tributaries - Stanislaus River

Limiting factors and potential solutions -

Table 3-Xg-17. Limiting factors and potential solutions for American shad in the Stanislaus River.

Limiting factors	Potential solutions
1. Inadequate Stanislaus River flows during key life history activities (April-June)	Increase Sacramento River and tributary flows to levels specified in proposed restoration program
2. Higher than optimum water temperatures during May and June (temperatures below 61°F or above 68°F)	1. Manage Sacramento River and tributary flows to levels specified in proposed restoration program. 2. Manage Shasta Dam releases to maintain water temperatures between 61°F and 65°F in the Sacramento River

Action 1: Provide adequate flows as presented in the following table.

Objective: Improve shad spawning and egg and larval survival.

Location: Stanislaus River at Goodwin Dam.

Table 3-Xg-18. Instream flow regime believed necessary to double natural production of American shad in the Stanislaus River for five water years types.

Month	Wet	Above normal	Below normal	Dry	Critical
April	4,200	3,700	3,800	3,000	1,600
May	6,800	5,700	5,000	3,400	1,800
June	5,100	3,400	2,800	1,800	1,000

Narrative description: Delta inflow was assumed to be an index of flow needs in tributaries known to support spawning runs of American shad. Flow for each tributary was generated by multiplying the percent contribution of that tributary to total unimpaired runoff (1922-1992) by Delta inflow needed to achieve the restoration goal for the MWT index. Separate flow recommendations were generated for each of the five Sacramento or San Joaquin water year types.

Related actions that may impede or augment the action: Existing flow agreement between USBR and DFG. Vernalis flow recommendations. Section 3406(b)(2), dedication of 800,000 af of water annually for fish, wildlife, and habitat restoration. Section 3408(b) purchase of land and water from willing sellers.

Agency and organization roles and responsibilities: Implementation of flows will require cooperation and coordination between USFWS, DFG, USBR, and numerous water user groups and irrigation districts.

Potential obstacles to implementation: Neither the existing USBR/DFG agreement nor the 800,000 af of water dedicated to fish and wildlife purposes by 3406(b)(2) of Title 34 are sufficient to meet flow needs identified by the Anadromous Fish Restoration Program. Implementing the AFRP flow schedule would reduce water availability to meet needs of other user groups and would thus require purchase of additional water.

Projected benefits: Providing the recommended flows in concert with other recommended actions has the potential to at least double production of American shad.

Action 2: Maintain mean daily water temperatures between 61°F and 65°F for 1 month between April 1 and June 30 below dams with temperature control structures.

Objective: Improve shad spawning success, egg survival, and larvae survival of shad in the Stanislaus River.

Location: Stanislaus River

Narrative description:

Related actions that may impede or augment the action: Flows specified under Action 1 may help meet temperature requirements.

Agency and organization roles and responsibilities: USBR is responsible for New Melones Dam releases that may be necessary for temperature control.

Potential obstacles to implementation: Competing water uses.

Projected benefits: Maintaining temperatures within specified range should increase survival of egg and larvae in the Stanislaus River.

H. WHITE AND GREEN STURGEON

Baseline Natural Production and Goals

White sturgeon tagging and data analysis - Tagging studies were carried out by DFG to obtain mark-recapture population estimates of white sturgeon greater than or equal to 40 inches total length (TL) (the minimum legal size until 1990). Sturgeon were captured using trammel nets during fall in San Pablo and Suisun bays. Captured fish were measured for total length, tagged with disc-dangler reward tags attached below the anterior edge of the dorsal fin, and released near the site of capture. Tag recaptures during tagging were used to estimate abundance using the mark-recapture methods of Petersen and Schumacher-Eschmeyer.

Some assumptions inherent in mark-recapture techniques are likely to be violated. These are:

1) Assumptions of random distribution of tagged fish in the untagged population and equal vulnerability of tagged and untagged fish to the fishing gear are likely violated by the multiple census technique of Schumacher-Eschmeyer.

2) Both methods deal with a population that is probably not closed and the proportion of the entire population represented by the estimate is unknown and may vary between estimates.

Annual harvest rates, mortality rates, and migration patterns were estimated from reward tags returned by anglers. Harvest and natural production estimates for the baseline period were available for only 8 years. For the other years, no sampling took place. Catch was estimated by multiplying the population estimate by harvest rate. Production was estimated by multiplying the population estimate by an estimated age fraction determined through length-age analysis. Age 15 is approximately the mean age of recruitment of females to the spawning population.

Escapement is not addressed because of the multi-age spawning population structure of sturgeons. Spawning periodicity reported by several investigators is quite varied. Welch and Beamsederfer (1993) suggest that spawning occurs every 2 to 4 years in Columbia River white sturgeon, while Roussow (1957) reports spawning intervals between 4 years and 7 years in lake sturgeon. Kohlhorst (pers. comm.) found evidence of white sturgeon spawning every 4 years in females and every 2 years in males in the Sacramento-San Joaquin Estuary. As a result of this variable spawning periodicity, there also can be variability in strength of year classes returning to spawn as a result of annual environmental influence.

Table 3-Xh-1. Catch and natural production (abundance at age 15) for white sturgeon in the Sacramento-San Joaquin Estuary during the baseline period.

Year	Population estimate	Catch	Natural production
1967	114,700	8,373	11,470
1968	40,000	2,600	3,200
1974	20,700	1,159	1,449
1979	74,500	6,183	3,725
1984	119,800	10,466	7,188
1985	107,700	12,385	7,539
1987	106,100	7,482	7,427
1990	36,700	858	2,569
Mean			5,571

Goal - Based on mark-recapture and length-age data, the mean annual production for white sturgeon during the baseline period is estimated to be 5,571. The goal of the CVPIA is to at least reach a population level of twice that amount, or 11,142.

Green sturgeon tagging and data analysis - During the baseline period, 143 green sturgeon were tagged. An additional 26 were tagged between 1954 and 1965. None have been recaptured during subsequent sampling, so no independent estimate of abundance was possible. As an alternative, green sturgeon abundance in the estuary in fall was estimated by dividing white sturgeon abundance estimates by the ratio of white sturgeon to green sturgeon observed during tagging (Table 3-Xh-2). Additionally, since the number of green sturgeon captured each year was so low, no length-age analysis was available to provide information regarding production. Assumptions in the calculation of green sturgeon abundance are: 1) green and white sturgeon are equally vulnerable to trammel nets, 2) green and white sturgeon are randomly dispersed, and 3) equal numbers of green and white sturgeon reside within the sampling area. Green sturgeon abundance estimates are probably low because fewer green sturgeon are believed to reside year-round in San Pablo and San Francisco bays compared to white sturgeon.

Goal - Based on the ratio of white to green sturgeon observed during tagging, the estimate of green sturgeon abundance during the baseline period is 983. The goal under the CVPIA is to reach a population level of twice the amount, or 1,966.

Table 3-Xh-2. Green sturgeon abundance estimates in the Sacramento-San Joaquin Estuary during the baseline period.

Year	White sturgeon abundance	Ratio of white to green sturgeon	Green sturgeon abundance
1967	11,4700	62:1	1,850
1968	40,000	38.6:1	1,036
1974	20,700	101.9:1	203
1979	74,500	52.6:1	1,416
1984	119,800	106.3:1	1,127
1985	107,700	127.3:1	846
1987	106,100	163.7:1	648
1990	36,700	49.6:1	738
Mean	77,525		983

Approach

The Sturgeon Technical Team's approach to developing recommendations for the AFRP was to assign drainages to individual team members (Table 3-Xh-3). Each team member was responsible for taking the lead role in developing recommendations for that assigned drainage. Individual team members enlisted the help of additional authors to help write sections, or additional authors were enlisted by the team leader.

Table 3-Xh-3. List of team members and additional authors assigned to writing sections for each of the listed drainages.

Drainage[a]	Assigned member	Additional authors[b]
Sacramento	Kurt Brown, USFWS	Jim De Staso, USFWS
Feather	Patrick Foley, UCD	Jim De Staso, USFWS
Bear	Jim De Staso, USFWS	
San Joaquin	Dan Castleberry, USFWS	
Delta	Dave Kohlhorst, DFG	Jim De Staso, USFWS

[a] The list of drainages includes rivers for which the team could find evidence of sturgeon spawning during the baseline period.

[b] In addition to the listed authors, formatting and editorial changes were made by USFWS, primarily at the request of the Core Group.

To develop this report, the team first developed a list of potential limiting factors. This list is not included in the report. Each team member then selected those factors that were potentially limiting in the drainage and included those factors under the header "Limiting factors and potential solutions". Team members then selected a subset of those factors that they considered to be of primary importance and described restoration actions for these factors under the header "Restoration actions".

The task for the team was complicated by the fact that little is known about white sturgeon and less is known about green sturgeon in the Central Valley. Investigations have not been conducted to determine where and when sturgeon spawn, except for white sturgeon on the mainstem Sacramento River. The team often depended on information from anglers and DFG wardens and on entrainment data to help determine where and when sturgeon spawned. Also, except for Delta outflow, no information was available on flows needed for successful spawning and recruitment of sturgeon in the Central Valley. Because data collected for sturgeon in other drainages showed a direct relationship between high spring flows and recruitment, and because data for white sturgeon in the Delta showed the same relationship, the team developed a method for estimating flows necessary for successful reproduction of sturgeon.

Methods used to develop flow recommendations and predict benefits - Year-class indices (YCIs) and data on sturgeon salvage at the SWP, contained in WRINT-DFG-Exhibit 28, were used to identify years with good recruitment of white sturgeon in the Sacramento-San Joaquin river system. Of the years for which YCIs were presented in Figures 3 and 4 of Exhibit 28 (1968-1990), those with YCIs of at least twice the other YCIs were classified as good recruitment years. These years were 1969, 1975, 1978, 1980, 1982, and 1983. All remaining years were classified as poor recruitment years.

Flow recommendations were developed for gauging stations on the Sacramento, Feather, Bear, and San Joaquin rivers and in the Delta. For each year between 1968 and 1990, the mean monthly February-May flows were ranked from highest to lowest discharge. All good recruitment years occurred in either wet or above-normal years and their flows ranked at or near the top. Generally, the good recruitment year with the lowest mean monthly February-May flow was adopted as the flow standard. However, for some stations the good recruitment year with the second lowest mean February-May flow was selected as the flow standard because adoption of the lowest year's flow did not appreciably increase baseline production. Newly derived flow standards were set only for wet and above-normal water years.

Predicted benefits from implementation of flow recommendations were also calculated for each river. A mean YCI was calculated for years between 1968 and 1990. A mean YCI was also calculated for years having flows equal to or greater than that recommended. The mean YCI from years with flows equal to or greater than the recommendation were substituted for YCIs in wet and above-normal years with flows less than the recommendation. After these substitutions, a new mean YCI was calculated for the period between 1968 and 1990. The new YCI for the years 1968 through 1990 represents increased sturgeon production after implementation of flow standards. Percent increase in mean YCIs before and after flow implementation was calculated and assumed to represent increases in sturgeon production after increasing flows.

Research Needs

1. Continue tagging adult sturgeon to estimate abundance, distribution, mortality rates, and movement patterns. These activities will be necessary to determine the success of restoration actions.

2. Map and survey available broodstocks and spawning grounds, including their physical and chemical parameters, number of brood fish, Aspawnability@, and embryo survival.

3. Estimate juvenile sturgeon abundance and year-class strength. Monitor environmental parameters to relate year-class strengths to environmental conditions.

4. Evaluate effects of trace elements and organic contaminants on adult health, gamete viability, and early life stages. Address sources of contamination if adult health, viability of gametes, or early life-stage development is found to limit production. In particular, examine effects of selenium and PCBs.

5. Determine diets of larval and juvenile sturgeon. No studies on wild larval sturgeon diets have been conducted (Pacific States Marine Fisheries Commission 1992). White sturgeon larval diet probably consists of zooplankton while YOY white sturgeon, less than 51 inches, eat small crustaceans and aquatic insect larvae (Pacific States Marine Fisheries Commission 1992). If prey items are limiting, efforts to increase their abundance may increase larval survival.

6. Determine effects of predation on sturgeon eggs and early life stages. Currently, information on sturgeon egg and larva predation is limited. In the Columbia River, bottom feeders such as prickly sculpin, largescale sucker, common carp, and northern squawfish prey on white sturgeon eggs (Miller and Beckman 1993). In the Central Valley, carp (Anonymous 1940) and white catfish (Turner 1966) ingest sturgeon eggs, and striped bass may prey on early life stages (Anonymous 1940). Steelhead, squawfish, and various centrarchids that prey on juvenile salmon may also prey on early life stages of sturgeon. Predation rates may also increase near structures creating water turbulence and casting shadows on the water surface and boundary edges (Cooper and Crowder 1979).

7. Develop a green sturgeon culture program. A culture program would be beneficial in determining food preferences, physical and chemical habitat requirements and tolerances, early life stage development, and effects of toxins.

Sacramento River

Limiting factors and potential solutions - Information is currently being gathered on poaching, harvest regulations, predation, and habitat suitability. Actions for these limiting factors may be added to future drafts.

Table 3-Xh-4. Limiting factors and potential solutions for white and green sturgeon in the Sacramento River.

Limiting factors	Potential solutions
1. Inadequate flows for attraction, migration, and spawning of adults and transport and rearing of larvae and juveniles	1. Provide minimum or greater flows to ensure suitable conditions for sturgeon to migrate and spawn and their progeny to survive 2. Reduce or eliminate drastic changes in flow during critical periods (i.e., maintain constant flows).
2. Inadequate temperatures for initiation of spawning and final maturation of adults and survival of larvae and juveniles	1. Provide water at temperatures suitable for sturgeon to migrate, undergo the final stages of sexual maturation, and spawn and for their progeny to survive 2. Reduce or eliminate drastic temperature fluctuations during critical periods (e.g., large releases of cold water from reservoirs)
3. Loss of larval and juvenile sturgeon at water diversions	1. Identify extent of the problem 2. Reduce or eliminate entrainment of sturgeon larvae and juveniles
4. Passage past RBDD	Raise RBDD gates from mid-September through June
5. Poor water quality	1. Increase flow of high-quality water 2. Prevent Iron Mountain Mine waste release into the Sacramento River 3. Decrease contamination of the river by agricultural chemicals and drainwater 4. Decrease exposure to excessive levels of trace

	elements or other contaminants to acceptable levels
6. Possible construction of the GRF at the GCID diversion	Find alternative means of increasing head differential at GCID

Restoration actions -

Action 1: Provide mean monthly flows of at least 17,700 cfs at Grimes (RM 125) and at least 31,100 cfs at Verona (RM 80) between February and May for wet and above-normal water years.

Objective: Provide flows to allow adult migration from the estuary or ocean to spawning grounds, spawning, and downstream larval transport.

Location: Sacramento River at Grimes and Verona.

Narrative description: Flows for successful sturgeon reproduction in the Sacramento River have not been identified. In good recruitment years, mean monthly February-May flows ranged from 13,836 cfs to 25,763 cfs at Grimes and 31,050 cfs to 60,202 cfs at Verona (Table 3-Xh-5).

Table 3-Xh-5. Mean monthly February-May discharge (cfs) at Grimes (USGS station 11390500) and Verona (USGS station 11425500) on the Sacramento River.

Year	Mean February-May discharge at Grimes	Year	Mean February-May discharge at Verona
1983	25,763	1983	60,202
1982	20,928	1982	49,176
1974	20,676	1974	44,873
1975	19,161	**1969**	42,080
1969	18,712	1986	37,741
1978	17,710	1975	34,276
1973	16,686	1978	33,874
1986	16,599	1973	33,168
1971	15,677	1980	31,050
1970	14,368	1970	29,977
1980	13,836	1971	28,644

Year	Mean February-May discharge at Grimes	Year	Mean February-May discharge at Verona
1968	13,456	1968	22,816
1981	11,500	1984	20,548
1972	11,098	1989	20,079
1979	10,632	1979	19,052
1984	10,579	1981	18,000
1989	10,307	1972	16,087
1987	9,770	1987	14,378
1976	8,372	1985	12,581
1988	7,858	1990	12,221
1985	7,202	1988	11,633
1990	6,411	1976	11,392
1977	5,259	1977	7,028

Note: Years are ranked from highest to lowest discharge with years with good white sturgeon recruitment in bold print.

In addition to empirical relationships of flow with reproduction, other information (e.g., water depth necessary for successful passage, discharge necessary to cue spawning, preferred water depths and velocities for spawning, and discharge necessary for larval transport and rearing) should be considered before final flow recommendations are adopted. Until these data are available interim flow standards should be as follows: for above-normal and wet years, mean monthly February-May flows of at least 17,700 cfs at Grimes (flows needed for spawning) and at least 31,100 cfs at Verona (flows needed for attraction).

Related actions that may impede or augment the action: Sacramento River flows must be accompanied by other habitat restoration measures in the Sacramento-San Joaquin Delta and in San Francisco and San Pablo bays. Because larvae and YOY fish have been found in the Delta and Suisun Bay, Sacramento River production could be reduced by mortality in these other areas.

Agency and organization roles and responsibilities. The Sacramento River is a CVP stream with flow controlled by USBR.

Potential obstacles to implementation. Competing water uses and lack of technical information on sturgeon ecology.

Predicted benefits: Between 1968 and 1990, wet and above-normal water years occurred 12 times. During those 12 years, flows of at least 17,700 cfs occurred six times at Grimes, and flows of at least

31,100 cfs occurred nine times at Verona. Increasing flows in the remaining 6 above-normal and wet years to at least 17,700 cfs at Grimes will increase sturgeon production by 40%; increasing flows in the remaining 3 above-normal and wet years to at least 31,100 cfs at Verona will increase production by 20%.

Action 2: Maintain water temperatures below 17°C (63°F) in sturgeon spawning areas from February to June in wet and above-normal water years.

Objective: Ensure that in-river temperatures are maintained at levels that optimize spawning, incubation, and survival of sturgeon early life stages.

Location: Sacramento River from ACID's irrigation dam (RM 299) to Verona.

Narrative description: Water temperatures greater than 17°C (63°F) can increase sturgeon egg and larval mortality (PSMFC 1992). Water temperatures near RBDD historically occur within optimum ranges for sturgeon reproduction. However, temperatures downstream of RBDD, especially later in the spawning season, are frequently above 17°C.

Observations from DFG and USFWS biologists indicate that sturgeon spawning has taken place near RBDD, and that temperatures during these times ranged from 10°C to 17°C (50-63°F). Water temperatures between Keswick Dam (RM 302) and RBDD historically have been suitable for spawning and early life-stage development. In 1973, 93% of spawning occurred in March and April at water temperatures between 46° and 64°F and eggs hatched at water temperatures up to 72°F.

Water temperatures downstream of RBDD are not always suitable for sturgeon reproduction. Daily minimum water temperatures were examined for the Sacramento River at Grimes for above-normal and wet years between February and June 1968-1994. Minimum temperatures were greater than or equal to 17°C (63°F) in 5 of 12 years in May, and 9 of 11 years in June. High water temperatures may deleteriously effect egg and larval survival, especially for late-spawning fish in drier water years. Minimum/maximum water temperatures at Verona were unavailable, but temperatures are assumed to increase downstream of Grimes to Verona further affecting early life-stage survival. Water temperatures should be maintained below 17°C (63°F) in sturgeon spawning areas from February through May during above-normal and wet years.

Related actions that may impede or augment the action: Meeting flow standards specified under Action 1 may contribute to temperature reductions that would depend on the source of water for these flows. Use of the USBR temperature control model and other model development will help evaluate the potential for maintaining optimum sturgeon temperatures.

Agency and organization roles and responsibilities: USBR controls releases from Shasta and Keswick dams. Releases from these dams would be necessary for temperature control in the Sacramento River.

Potential obstacles to implementation: Implementation will require identification of flows necessary to meet temperature criteria. Maintaining temperature standards late in the season may be difficult. Small tributary streams, with water temperatures that cannot be controlled, may affect Sacramento River temperatures downstream of RBDD.

Predicted benefits: Temperatures in the Sacramento River appear high enough in some years to reduce egg and larval survival. Temperature reductions below 17°C in May and June have the potential to restore spawning habitat and increase survival of early life stages of sturgeon. The contribution toward restoration goals cannot be quantified.

Action 3: Reduce sturgeon entrainment at both screened and unscreened diversions.

Objective: Increase sturgeon production by reducing entrainment losses.

Location: Sacramento River from Keswick Dam to Verona. Sites of specific concern are the Bonnyview pumping plant (RM 292), RBDD, GCID (RM 206), and the ACID diversion (RM 298.5).

Narrative description: More than 300 unscreened diversions exist on the Sacramento River from Keswick to Verona. The majority of diversions operate from April through October, which could result in larval and juvenile sturgeon entrainment. Specific studies on sturgeon entrainment in the Sacramento River do not exist, but limited data show that entrainment occurs at RBDD and GCID.

At RBDD, salmonid entrainment has nearly been eliminated with the installation of a new drum screen facility in 1991. However, eight larval sturgeon were captured in the TCC fyke nets between 1987 and 1991, even though screens meet NMFS criteria to protect salmon fry. Because sturgeon larvae are considerably smaller than salmonid fry of the same age, current mesh criteria may not prevent entrainment. To determine if larval sturgeon entrainment is significant, monitoring in the TCC and the Corning Canals should continue. Juvenile sturgeon entrainment also occurs at RBDD. Several juvenile green sturgeon were impinged on a diffuser grate, apparently unable to escape water velocities entering a diffuser bay. Inadequate diffuser bay design and approach velocities may result in juvenile impingement.

Estimates of sturgeon entrainment at GCID are unknown, but it is likely that 1,162 sturgeon were captured at or near GCID between 1986 and 1993. Of the limited number of larvae and juveniles identified, all were green sturgeon. To minimize entrainment, fish screens were installed at GCID in 1972, but since then screen effectiveness has been reduced by substantial changes in water depth and velocity at the diversion entrance. DFG has identified increased approach velocities and predation as main causes of juvenile fish mortality.

Legislation passed in 1992 authorized 75% federal funding for new screens (Waterline 1993). Until the design is agreed on and the EIR reviewed, GCID will rely on interim modifications to alleviate the problem. The diversion should continue to be monitored to assess impacts on larval and juvenile sturgeon.

To reduce losses at unscreened diversions, USBR conducted screening workshops for Sacramento River diverters in 1993. Attendees included diverters, screen designers, fabricators, and vendors. Another action initiated under CVPIA Section 3406(b)(21) is the unscreened diversions program. USFWS developed an accelerated effort to allow the screening of some diversions in fiscal year 1994. Roughly 23 proposed projects have been selected and will be evaluated for effectiveness.

For entrainment to be reduced at screened and unscreened diversions, information should be gathered on the following: 1) numbers, types, and sizes of unscreened and screened diversions on the Sacramento River; 2) fish losses caused by diversions; 3) feasibility of installing positive barrier screens to reduce losses; 4) estimated costs of screen design, installation, maintenance, and evaluation; 5) availability of funding; 6) feasibility of seasonal management options (e.g., pumping restrictions, monitoring requirements, or alternative water supplies) that would reduce losses; and 7) swimming capabilities of various sturgeon life stages.

Sturgeon entrainment at both screened and unscreened diversions should be reduced through employment of state-of-the-art screening technology and evaluation of management options. Also, design of diffuser gates and bays at RBDD should be examined.

Related actions that may impede or augment the action: Work on the Research Pumping Plant may produce alternative methods for diverting water while minimizing entrainment at RBDD.

Agency and organization roles and responsibilities: Federal and state agencies, as well as irrigation districts and local diverters.

Potential obstacles to implementation: Costs associated with redesigning screens to prevent entrainment.

Predicted benefits: Because no numeric estimates of sturgeon entrainment are available at GCID, RBDD, or other diversions, benefits cannot be quantified. If sturgeon entrainment is reduced or eliminated, production would increase.

Action 4: Raise RBDD gates from mid-September through June.

Objective: Provide unimpeded adult sturgeon migration to spawning habitat above RBDD.

Location: RBDD.

Narrative description: Major physical barriers to adult sturgeon migration on the mainstem Sacramento River are RBDD and ACID's diversion dam. Unimpeded migration past RBDD occurs when gates are raised roughly between mid-September through early May as mandated by NMFS. Passage past the ACID diversion dam occurs from November through March when flashboards are removed. Both RBDD and the ACID diversion dam have fish ladders primarily designed to facilitate salmonid passage.

With RBDD gates and ACID open, Keswick Dam (RM 302) is theoretically the upstream migration barrier. Current upstream migration limits are unknown, but when sturgeon are provided with the opportunity to migrate to Keswick Dam, migration appears to end between Ball's Ferry and Jelly's Ferry bridges (Wigham pers. comm.). No adult sturgeon have been observed above or below the ACID diversion dam in recent memory (Preston pers. comm.).

Current operations closing RBDD gates in mid-May pose three problems for sturgeon. First, some sturgeon may be prevented from spawning. Evidence suggests that females prevented from reaching preferred spawning grounds reabsorb eggs and forgo spawning (Barannikova 1968). Second, potential spawning habitat is blocked. Keeping gates open through June will provide 25 additional miles of spawning habitat for an additional 45 days. Habitat between RBDD and Jelly's Ferry Bridge (RM 267) contains swift current and pools over 20 feet deep preferred by spawning sturgeon. Third, adult and larvae are prevented from migrating downstream after spawning. Larvae trapped behind RBDD gates may experience mortality as a result of entrainment and from high shear forces as larvae pass under the gates. Mortality of juvenile salmon passing under RBDD gates is high as a result of shear forces, and similar effects are likely for larval sturgeon (Williams pers. comm.). Effects on adult sturgeon attempting downstream migration with gates lowered are unknown. Measures to provide unimpeded passage past RBDD are likely to benefit mostly green sturgeon because most appear to spawn further upstream than white sturgeon.

To facilitate passage of adult and juvenile sturgeon, RBDD gates should be raised from mid-September through June.

Related actions that may impede or augment the action: Actions for other anadromous fish may recommend keeping gates open longer. Completion and testing of the Research Pumping Plant may permit water diversion without RBDD gates being closed. At present, the Research Pumping Plant may not be able to provide enough water for demands through June.

Agency and organization roles and responsibilities: USBR has control over RBDD operations. Also, the Tehama-Colusa Irrigation District and other water users may play a role in operations.

Potential obstacles to implementation: Tehama-Colusa Irrigation District, USBR, and recreational users may resist implementation.

Predicted benefits: Keeping gates open through June will provide increased spawning habitat and allow unimpeded downstream migration of larvae and adults. Benefits cannot be quantified.

Action 5: Improve water quality.

Objective: Improve sturgeon production by providing water quality essential to adult and early life-stage survival.

Location: Sacramento River from Keswick Dam to Verona.

Narrative description: Organic contaminants from agricultural drainwater, urban and agricultural runoff from storm events, and high trace element concentrations may deleteriously affect early life-stage survival of fish in the Sacramento River. Principal sources of organic contamination in the Sacramento River are rice field discharges from Butte Slough, USBR District 108, Colusa Basin Drain, Sacramento Slough, and Jack Slough, and the principal source of heavy metal pollution is Iron Mountain Mine discharges.

Discharge of rice irrigation water and its collection at the edge of the zone of initial dilution has caused mortality to both *Ceriodaphnia* and fathead minnows in the Sacramento River. Mortality was attributed to various organic compounds contained in rice field discharges. Also, DFG found correlations between larval striped bass abundance in the Delta and pounds of methyl parathion applied to rice fields (CVRWQCB 1991). Based on available data, it is believed that rice field discharges in May and June could effect sturgeon larvae survival. Also, recent studies in the Sacramento-San Joaquin basin indicate that application of the dormant spray pesticide dianzinon during January can lead to pulses in the Sacramento and San Joaquin rivers following rain. Pulses in both rivers were found to be acutely toxic to aquatic invertebrates. Effects on sturgeon through direct or indirect exposure are unknown (Foe 1995).

Trace elements can also decrease sturgeon early life-stage survival. Trace elements can cause abnormal development and high mortality in yolk-sac fry sturgeon at concentrations at the level of parts per billion (Dettlaff et al. 1981). Water discharges from Iron Mountain Mine, contaminated with heavy metals, have affected survival of fish downstream of Keswick Dam. Trace element concentrations were reduced in 1963 with construction of Spring Creek Debris Dam. Iron Mountain Mine drainage is partially controlled by water being stored and discharged with available dilution flows from Shasta Dam and Spring Creek Debris Dam. But storage limitations in Spring Creek Reservoir and limited availability of dilution flows cause downstream copper and zinc levels to exceed salmonid tolerances. Five fish kills have occurred downstream of Keswick Dam since 1963. Also, rainbow trout livers sampled between 1981 and 1987 contained high levels of cadmium, chromium, copper, lead, nickel, selenium, silver, and zinc. Although the impact of trace elements (specifically from Iron Mountain Mine) on sturgeon production is not completely understood, negative impacts are suspected. It is also not known how far downstream impacts occur and under what conditions trace elements are mobilized.

To reduce impacts of heavy metal contamination, implementation of the EPA Superfund Program, which would eventually eliminate Iron Mountain Mine dilution flow releases, should continue.

Related actions that may impede or augment the action: Increased flows of uncontaminated water may help dilute contaminant concentrations in the water.

Agency and organization roles and responsibilities: USBR, EPA, RWQCB, and other agencies involved with setting water quality standards.

Potential obstacles to implementation: Entities accustomed to using chemicals and discharging contaminated water into the Sacramento River are likely to resist implementation of the action. Cost associated with treatment of runoff, if necessary, may cause resistance to implementation.

Predicted benefits: Reduced contaminant levels would improve habitat for all aquatic organisms. Sturgeon egg and larval survival would increase, but benefits cannot be quantified.

Action 6: Devise alternative methods other than the GRF to increase head differential for the GCID bypass system.

Objective: Facilitate unimpeded passage past GCID.

Location: GCID diversion.

Narrative description: GCID diverts water from the Sacramento River at RM 206. A plan exists for screen modifications and possible construction of a GRF. The GRF consists of an instream structure designed to raise upstream river levels, allowing more flow directed toward the screening facility and pumping plant.

A draft EIR/EIS (Resource Consultants and Engineers 1994) reports that the GRF may impede upstream-migrating adult sturgeon and downstream transport of larvae. Current information on sturgeon swimming speeds is not sufficient for evaluation of potential passage problems imposed by the GRF. Swimming speeds vary for each sturgeon life stage and the GRF configuration may not suit all stages (HDR Engineering 1994). The draft EIR/EIS does not include a GRF as a preferred alternative, but recommends consideration of other methods, such as a screw pump system.

Related actions that may impede or augment the action: Work on the Research Pumping Plant at Red Bluff may negate the need for a GRF.

Agency and organization roles and responsibilities: NMFS, USFWS, DFG, and GCID.

Potential obstacles to implementation: Cost associated with developing alternatives to the GRF.

Predicted benefits: Alternative methods for increasing head differential that would lessen impacts on adult and larval sturgeon passage will decrease losses of larval and juvenile sturgeon at GCID. Benefits cannot be quantified.

Feather River

Limiting factors and potential solutions -

Table 3-Xh-6. Limiting factors and potential solutions for white and green sturgeon in the Feather River.

Limiting factors	Potential solutions
1. Inadequate flows for attraction, migration, and spawning of adults and transport and rearing of larvae and juveniles	1. Provide mean monthly February-May flows of at least 7,000 cfs at Gridley and at least 11,500 cfs at Nicolaus during above-normal and wet water years 2. Reduce or eliminate drastic changes in flow during critical periods
2. Inadequate temperatures for initiation of spawning and final maturation of adults and survival of larvae and juveniles	1. Maintain water temperatures below 17°C (63°F) in sturgeon spawning areas and below 20°C (68°F) throughout the Feather River during February-May during wet and normal years 2. Reduce or eliminate drastic temperature fluctuations during critical periods
3. Barriers that prevent or slow the migration of sturgeon to spawning habitat	1. Identify potential barriers (physical as well as water quality barriers) 2. Evaluate the extent of the problem 3. Remove barriers or facilitate passage around barriers
4. Loss of sturgeon larvae and juveniles resulting from entrainment	1. Identify the extent of the problem 2. Reduce or eliminate entrainment of sturgeon larvae

5. Size of spawning stock	1. Improve conditions for production of sturgeon 2. Reduce mortality of early life stages 3. Reduce mortality of adults (identify extent of fishing mortality and poaching)
6. Poor water quality	1. Increase flows of high-quality water 2. Decrease contamination of the river by agricultural chemicals and drain water 3. Decrease exposure to excessive levels of trace elements or other contaminants to acceptable levels
7. Availability of suitable spawning habitat	1. Identify spawning sites 2. Evaluate availability of suitable spawning substrates 3. If substrates limit success of sturgeon spawning, take appropriate corrective action

Restoration actions -

Action 1: Provide mean monthly February-May flows of at least 7,000 cfs at Gridley and at least 11,500 cfs at Nicolaus during wet and above-normal water years.

<u>Objective</u>: Provide minimum or greater flows to ensure suitable conditions for adult sturgeon to migrate upstream and spawn and for their progeny to survive. Reduce or eliminate drastic flow changes during critical reproductive periods.

<u>Location</u>: Feather River from Thermalito Afterbay outlet to the confluence with the Sacramento River.

<u>Narrative description</u>: Little information exists on green or white sturgeon in the Feather River. Although sturgeon are known to migrate into the Feather River, little effort has been made to document reproduction. Despite the lack of technical information, enough evidence exists in the form of observations by biologists, anglers, fishing guides, and tackle shop employees to provide a basis for making recommendations needed to increase sturgeon production in the Feather River.

Adult sturgeon migrated into the Feather River historically and in more recent times. Several articles recount large sturgeon having been caught in the Feather River in the early 1900s (Talbitzer 1959, Anonymous

1918). More recent observations include the recovery of one tagged adult sturgeon in April 1968 (Miller 1972a). Green sturgeon were caught every year during the mid-1970s to early 1980s (anonymous fishing guide). The majority of catches occurred between March and May with occasional catches in July and August. Although adult sturgeon were present in the Feather River in the 1970s, efforts to sample larval sturgeon at the mouth of the Feather River in 1973 were unsuccessful. During spring 1991, two radio-tagged adult white sturgeon were tracked 2.5 miles up the Feather River. Subsequent efforts to relocate these fish were unsuccessful (Schaffter 1991). Finally, during spring 1993, several adult green sturgeon (lengths of 60-72 inches) were caught at Thermalito Afterbay outlet (Foley pers. comm.).

White sturgeon in the Sacramento River start migrating in October and spawning in February (Schaffter pers. comm.). Most white sturgeon in the Central Valley spawn in March and April, and approximately 20%-30% spawn in February and June (Doroshov pers. comm.). Adult green and white sturgeon catches in the Feather River indicate that most spawning occurs between March and May. Exact spawning locations are unknown, but based on angler catches, likely spawning locations are considered to be downstream of Thermalito Afterbay outlet and Cox's Spillway, just downstream of Gridley Bridge. The upstream migration barrier is likely a steep riffle 1 mile upstream of the Afterbay outlet. This riffle is approximately 394 feet long with average water depth of 6 inches.

In good sturgeon recruitment years, mean monthly February-May flows ranged from 3,488 cfs to 20,505 cfs at Gridley and 7,028 cfs to 35,234 cfs at Nicolaus (Table 3-Xh-7).

Table 3-Xh-7. Mean monthly February-May discharge (cfs) at Gridley (USGS station 11407150) and Nicolaus (USGS station 11425000) on the Feather River.

Gridley		Nicolaus	
Year	**Discharge**	**Year**	**Discharge**
1983	20,505	**1983**	35,234
1986	15,370	**1982**	29,513
1982	14,797	1970	26,511
1974	12,611	1974	22,489
1969	10,911	**1969**	21,028
1971	7,427	1973	11,582
1980	6,956	**1978**	11,453
1970	6,067	1971	11,113
1973	5,914	**1975**	8,272
1978	5,090	**1980**	7,028

Gridley		Nicolaus	
1984	4,409	1979	6,627
1975	3,488	1981	4,336
1979	3,186	1972	4,070
1990	3,171	1976	2,582
1985	2,818	1977	1,458
1981	2,780		
1972	2,552		
1988	2,261		
1976	2,001		
1989	1,928		
1987	1,846		
1968	1,354		
1977	1,275		

Note: Years ranked from highest to lowest discharge, with years with good white sturgeon recruitment in bold print. Only years for which discharge data were available for each site are listed. Data for the Nicolaus station were recorded only between 1969 and 1983.

In addition to empirical relationships of flow with reproduction, other information (e.g., water depth necessary for successful passage, discharge necessary to cue spawning, preferred water depths and velocities for spawning, and discharge necessary for larval transport and rearing) should be considered before final flow recommendations are set. Until these data are available, interim flow standards should be as follows: above-normal and wet water-year mean February-March flows of at least 7,000 cfs at Gridley and at least 11,500 cfs at Nicolaus.

Related actions that may impede or augment the action: Feather River flows must be accompanied by other habitat restoration measures in the Sacramento River, Sacramento-San Joaquin Delta, and San Francisco and San Pablo bays. Because larvae and YOY fish have been found in the Delta and Suisun Bay, Feather River production could be reduced by mortality in these other areas.

Agency and organization roles and responsibilities: All public and private entities responsible for setting and meeting flow standards on the Feather River.

Potential obstacles to implementation: Competing water uses and lack of technical information on sturgeon ecology.

Predicted benefits: Twelve above-normal and wet water years occurred between 1968 and 1990. Flows exceeded 7,000 cfs at Gridley in 7 of 12 years. Increasing flows to at least 7,000 cfs at Gridley in the remaining 5 years will increase production by 20%.

Action 2: Maintain water temperatures below 17^{o}C (63^{o}F) in sturgeon spawning areas and below 20^{o}C (68^{o}F) throughout the Feather River during February-May during above-normal and wet water years.

Objectives: Provide water temperatures required for initiation of spawning, final sexual maturation of adults, and survival of eggs and larvae. Reduce or eliminate drastic temperature fluctuations during critical periods (e.g., large releases of cold water from Oroville Dam).

Location: Feather River from Thermalito Afterbay outlet to the confluence with the Sacramento River.

Narrative description: Daily minimum and maximum water temperatures were examined in the Feather River just downstream of Thermalito Afterbay outlet for March-June 1991-1994. Minimum daily temperatures exceeded 17^{o}C in April in 1 year and exceeded 17^{o}C in June in all 4 years. High water temperatures are in part caused by water releases from Thermalito Afterbay. Releases can raise water temperatures in approximately 14 miles of river (from the Afterbay outlet to the mouth of Honcut Creek) compared to water in the low-flow channel. Effects of Thermalito Afterbay releases can vary with ambient air temperature, release rates, residence time, and flow contribution from the low-flow channel. Based on these data, it is likely that high water temperatures may deleteriously affect sturgeon egg and larval development, especially for late-spawning fish in drier water years.

Water temperatures should be maintained below 17^{o}C (63^{o}F) in sturgeon spawning areas, and below 20^{o}C (68^{o}F) throughout the Feather River during February-May of above-normal and wet years.

Related actions that may impede or augment the action: Meeting flow standards specified under Action 1 will contribute to temperature reductions that would depend on the source of water for these flows. DWR has contracted with the University of California, Davis, to develop a water temperature model for the Feather River. This model could be used to help manage water temperatures for successful sturgeon spawning. Completion of the temperature model should improve ability of managers to meet temperature criteria. Control of water temperatures may be complicated by Thermalito Afterbay releases, agricultural returns, and warmer ambient air temperatures as spring progresses.

Agency and organization roles and responsibilities: DWR, local municipalities, and private irrigation districts control the quantity of water flowing into the Feather River share responsibility in meeting temperature criteria.

Potential obstacles to implementation: Implementation will require identification of flows necessary to meet temperature criteria. Increased Oroville Dam releases may be required to meet temperature standards downstream. Increased Oroville Dam releases are likely to decrease power generation.

Predicted benefits: Temperatures in the Feather River appear high enough in some years to reduce egg and larval survival. Temperature reductions below 17°C in May and June have the potential to restore spawning habitat and increase survival of early life-stages of sturgeon. The contribution toward restoration goals cannot be quantified.

Action 3: Remove physical and water quality barriers that impede access to spawning habitat.

Objective: Identify potential physical and water quality barriers and determine the extent of the problem. Once barriers identified, remove or facilitate passage around these barriers.

Location: Feather River from Thermalito Afterbay outlet to the confluence with the Sacramento River.

Narrative description: Although not well documented, low flows and physical obstructions can impede sturgeon migration. For example, blasting was required to remove an in-river obstacle on the Klamath River that was determined to impede sturgeon migration (USFWS 1982). If delays at barriers cause later spawning, then removal should result in earlier spawning. Earlier spawning sturgeon are less likely to be exposed to high temperatures and poor water quality commonly occurring in April and May. Delayed upstream migration at barriers also has the potential to increase the vulnerability of migrating sturgeon to fishing and poaching. Potential physical barriers to upstream migration in the Feather River are a rock dam at Sutter Extension Water District's sunrise pumps, shallow water at Shanghai Bend, and several shallow riffles between the confluence of Honcut Creek upstream to Thermalito Afterbay outlet. Ted Sommer (pers. comm.) thought each of the above listed physical barriers could impede adult upstream migration during low flows.

Potential water quality barriers on the Feather River have not been identified. However, discharge from the Gridley Waste Water Treatment Plant and agriculture drainwater, particularly from Jack Slough, may produce low dissolved oxygen levels and contain organic contaminants creating water quality problems impeding migration.

Sturgeon migration barriers should be identified and action taken to eliminate or reduce impacts.

Related actions that may impede or augment the action: Flows specified under Action 1 should help reduce passage problems associated with low flows.

Agency and organization roles and responsibilities: All public and private entities with control over placement and removal of barriers and setting Feather River flow standards. Also, all entities responsible for waste or drainwater discharge into the Feather River.

Potential obstacles to implementation: To the extent that flows may be needed to address passage problems, availability of water to provide flows may be an obstacle to implementation. Dischargers are likely to resist implementation.

Predicted benefits: If barriers exist, then their removal will allow sturgeon access to new spawning habitat, allow access to spawning habitat earlier in the spawning season, require less energy for sturgeon to reach spawning habitat, and decrease the vulnerability of sturgeon to capture during migration. If barriers exist and are removed or modified, sturgeon production may increase, but such increase cannot be quantified.

Action 4: Reduce sturgeon entrainment.

Objective: Identify the extent of sturgeon entrainment. Increase survival of sturgeon larvae and juveniles by reducing or eliminating entrainment.

Location: The Feather River from Thermalito Afterbay outlet to the confluence with the Sacramento River.

Narrative description: Eight large diversions (greater than 10 cfs) are located on the Feather River between the confluence with the Sacramento River and Thermalito Afterbay outlet: Hamatani Brothers (RM 9.75), Garden Highway Mutual Water Company (RM 13.1), Feather Water District (RM 15.2), Plumas Mutual Water Company (RM 17.5), Tudor Mutual Water Company (RM 18.4), Feather Water District (RM 20.4), City of Yuba City (RM 29.6), and Sutter Extension Water District's sunrise pumps (RM 38.1). Additionally, approximately 60 small, unscreened diversions exist along the Feather River, each with pumping rates of approximately 1-10 cfs (Libby pers. comm.).

No studies have specifically examined sturgeon entrainment on the Feather River. However, Menchen (1980) showed that diverters could entrain significant numbers of chinook salmon. In 1977-1978, DFG studied juvenile salmon entrainment at the Sutter Extension Water District's sunrise pumps. In 1977, 23,461 af of water was diverted, resulting in an estimated loss of 30,413 salmon. In 1978, 6,877 af of water was diverted, resulting in salmon losses estimated at 3,887 (Menchen 1980). Although Menchen (pers. comm.) recalls no larval or juvenile sturgeon being captured, the use of 3-inch mesh at the cod end likely allowed larval sturgeon to pass through.

Sturgeon are vulnerable to entrainment elsewhere in the Central Valley. Sturgeon have been collected at RBDD and the GCID diversion dam on the Sacramento River and at the CVP and SWP pumps in the Delta.

The extent of the problem on the Feather River should be investigated. If a problem is found to exist, these diversions should be screened with state-of-the-art fish screening technology. Entrainment can also be reduced by limitations being placed on diversions.

Related actions that may impede or augment the action: Flows described in Action 1 may decrease residence time of larval sturgeon, thereby reducing time they are susceptible to entrainment.

Agency and organization roles and responsibilities: Federal and state agencies, as well as irrigation districts and other diverters.

Potential obstacles to implementation: Lack of information on extent of sturgeon entrainment on the Feather River. Also, the cost of installing and maintaining screens may be an obstacle.

Predicted benefits: Entrainment of sturgeon, if a problem, should be eliminated. The level of contribution toward the restoration goal remains unknown, but benefits would include decreased early life-stage mortality.

Action 5: Determine effects of poaching and fishing on spawning stock size.

Objective: Increase the size of the spawning stock if it is significantly reduced by poaching or fishing.

Location: The Feather River from Thermalito Afterbay outlet to the confluence with the Sacramento River.

Narrative description: A sturgeon fishery exists on the Feather River with catches occurring every year, especially during wet years. However, lack of catch, effort, and stock size data precludes exploitation estimates. Estimates on the above parameters would allow managers to regulate the fishery to optimize production. Areas just downstream of Thermalito Afterbay outlet and Cox's Spillway, and several barriers impeding migration may be areas of high adult mortality from increased fishing effort and poaching.

Poaching appears rare on the Feather River and therefore probably has a minimal impact on adult mortality (Hodges pers. comm.). Although poaching does not appear to be a significant problem, poaching on the Bear River (see "Bear River" subsection, below) raises concern over similar activities on the Feather River.

Because so little is known about how stock size, exploitation rates, and poaching affect production, the Feather River sturgeon fishery should be closely monitored by biologists and game wardens. If production is significantly reduced by fishing or poaching, corrective efforts should be initiated.

Related actions that may impede or augment the action: Increased flows and removal or modification of barriers would make sturgeon less vulnerable to angling and poaching.

Agency and organization roles and responsibilities: Population monitoring can be conducted by federal, state, and private consulting firms. The California Fish and Game Commission and DFG are responsible for fishing regulations and law enforcement activities.

Potential obstacles to implementation: None identified.

Predicted benefits: Because so little is known about how stock size, exploitation rates, and poaching affect production, monitoring and surveillance of the fishery will provide data necessary to regulate production.

Action 6: Improve water quality.

Objective: Improve the survival and condition of sturgeon.

Location: Feather River from Thermalito Afterbay outlet to the confluence with the Sacramento River.

Narrative description: Organic contaminants from agricultural returns, urban and agricultural runoff from storm events, and high trace-element concentrations may affect early life stages of fish in the Feather River (Foe pers. comm.; Schnagl pers. comm.).

Feather River water collected at Verona on May 27 and June 5, 1987, resulted in a 50% and 60% mortality in *Ceriodaphnia* and fathead minnow bioassays, respectively. Similar effects of Feather River water were seen in 1988 and 1989 (RWQCB 1991). Toxic effects were attributed to organic contaminants in rice irrigation water released into Jack Slough and into Honcut Creek and Bear River to a lesser degree (Foe pers. comm.). Based on these data, it is reasonable to suspect negative impacts on sturgeon eggs and larvae in the Feather River in May and June.

Trace elements can also negatively affect embryos and prelarval sturgeon survival, with concentrations as low as a few micrograms per liter being toxic to fish (Dettlaff 1993). From 1978 to 1987, various fish species in the Feather River had levels of arsenic, chromium, copper, and mercury exceeding median international standards. Presence of these trace elements may negatively affect sturgeon early life-stage development.

Contaminant levels in the Feather River should be reduced through enforcement of existing regulations or by creation and enforcement of new regulations. Monitoring should be increased especially at known discharge points.

Related actions that may impede or augment the action: Increased flows of uncontaminated water would help dilute contaminant concentrations in the water.

Agency and organization roles and responsibilities: Water dischargers and chemical users in the Feather River drainage. Federal, state, and local agencies involved with enforcement and creation of water quality standards.

Potential obstacles to implementation: Dischargers are likely to resist implementation of the action. Cost associated with treatment of runoff, if necessary, may cause resistance to implementation.

Predicted benefits: Reduced contaminant levels would improve habitat for all aquatic organisms. Increased egg and larval survival would increase production. Benefits cannot be quantified.

Action 7: Identify availability of suitable spawning habitat.

Objective: Identify potential sturgeon spawning sites and evaluate availability of such sites to adults. Take corrective actions if suitable spawning habitat is limiting.

Location: The Feather River from Thermalito Afterbay outlet to the confluence with the Sacramento River.

Narrative description: Sturgeon spawning habitat can vary greatly by species, geographic location, and habitat availability. Sturgeon outside the Central Valley commonly spawn over large gravel, rocks, or compact clay substrates with depths greater than 32.8 feet and velocities of 4.9-9.8 fps (Doroshov pers. comm.). Schaffter (1990) found evidence of Sacramento River sturgeon spawning over gravel and rubble bottoms, and sturgeon spawning in the San Joaquin River were observed using shallow, soft-bottom stream reaches (Rutherford pers. comm.).

Spawning habitat/substrate of sturgeon in the Feather River is unknown. Spawning may be limited to areas directly below Thermalito Afterbay outlet and Cox's Spillway. Substrate in the Feather River closely resembles that of the upper Sacramento River (above Hamilton City). Nearly exclusive collection of young green sturgeon near GCID and the apparent high ratio of green to white sturgeon on the Feather River may indicate different spawning habitat preferences for white and green sturgeon. Sturgeon spawning habitat and its accessibility should be determined.

Related actions that may impede or augment the action: Increased flow and removal or modification of barriers could increase available spawning sites.

Agency and organization roles and responsibilities: Those entities responsible for flows, channel morphology and restoration, and removal or modification of barriers.

Potential obstacles to implementation: Information on sturgeon spawning needs is fragmentary. Because of depths and velocities of suspected spawning habitat, information is difficult to obtain.

Predicted benefits: If lack of spawning habitat and/or access to spawning habitat is limiting, corrective measures could increase reproduction. Benefits cannot be quantified.

Bear River

Limiting factors and potential solutions -

Table 3-Xh-8. Limiting factors and potential solutions for white and green sturgeon in the Bear River.

Limiting factors	Potential solutions
1. Insufficient flows for attraction, upstream migration, spawning, rearing and downstream larvae transport	Provide mean monthly flows of at least 900 cfs at Wheatland from February to May for wet and above-normal water years
2. Inadequate water temperatures for initiation of spawning, final maturation of adults, and survival of eggs and larvae	Maintain water temperatures below 17°C (63°F) throughout the Bear River from February to May for wet and above-normal water years
3. Decreased production from poaching and early life-stage mortality	1. Improve conditions for the production of sturgeon 2. Reduce mortality of adults (poaching and potentially fishing) 3. Reduce mortality of early life stages (see entrainment, water quality, water temperature, etc.)
4. Barriers that prevent or slow sturgeon migration to spawning habitat	1. Identify potential barriers to upstream sturgeon migration (physical and/or water quality barriers) 2. Evaluate extent of the problem 3. Remove barriers or facilitate passage around
5. Loss of sturgeon larvae resulting from entrainment	1. Identify possible entrainment sites 2. Reduce or eliminate entrainment of sturgeon larvae
6. Poor habitat quality resulting from organic compound and	1. Identify potential sites of poor water quality

heavy metal contamination	2. Increase flow of uncontaminated water 3. Decrease contamination by agricultural return flows and heavy metals 4. Decrease exposure to contaminants to acceptable levels
7. Lack of suitable spawning habitat	1. Identify spawning sites 2. Evaluate availability of suitable spawning substrates 3. If spawning habitat is limited, take appropriate corrective measures

Restoration actions -

Action 1: Provide mean monthly February-May flows of at least 900 cfs at Wheatland for above-normal and wet water years.

Objective: Provide minimum or greater flows to ensure suitable conditions for adult sturgeon to migrate upstream and spawn and for their progeny to survive. Reduce or eliminate drastic flow changes during critical reproductive periods.

Location: Bear River from SSWD's diversion dam to the confluence with the Feather River.

Narrative description: Little information exists for green or white sturgeon in the Bear River. Although sturgeon are known to migrate into the Bear River, no effort has been made to document reproduction. Despite the lack of technical information, enough evidence exists in the form of observations by biologists, anglers, fishing guides, and tackle shop employees to provide a basis for making recommendations needed to increase sturgeon production in the Bear River.

Both green and white sturgeon are known to enter the Bear River typically during spring of most wet and some normal water years (Lenihan, Meyer, and Turner pers. comms.). Adult sturgeon were observed in shallow pools between the Highway 70 and Highway 65 bridges during spring of 1989, 1990, and 1992 (Lenihan pers. comm.).

During July 1989, approximately 100 sturgeon were trapped in pools between the Highway 70 and Highway 65 bridges as a result of reduced flows (Meyer pers. comm.). At least 30-40 sturgeon (ranging from 60 pounds and 100 pounds and at least 5 feet long) were poached from this area during a 2-week period in July. Of seven sturgeon confiscated by DFG Game Wardens, all were white sturgeon.

Direct evidence of sturgeon reproduction does not exist, but observations of adults between Highway 70 and Highway 65 bridges indicates that spawning is likely in this area. The presence of preferred spawning habitat of pools 20-30 feet deep and firm substrate also support the conclusion that spawning in this area is likely. Although no adult sturgeon have been observed above the Highway 65 Bridge, anecdotal accounts of large fish being hooked below the SSWD irrigation dam may indicate that sturgeon migrate to this point (Milton pers. comm.).

Flows for successful sturgeon reproduction in the Bear River have not been identified. During good production years, mean monthly February-May flow was at least 900 cfs at Wheatland. Until data are available to establish final flow standards, interim flow standards should be as follows: for above-normal and wet water years, mean monthly February-May flows of at least 900 cfs at Wheatland.

Related actions that may impede or augment the action: Bear River flows must be accompanied by other habitat restoration measures in the Feather and Sacramento rivers, the Delta, and San Pablo and San Francisco bays. Because larvae and YOY fish have been found in the Delta and Suisun Bay, Bear River production could be decreased by mortality in these downstream areas.

Agency and organization roles and responsibilities: All public and private entities responsible for setting and meeting flow standards on the Bear River.

Potential obstacles to implementation: Competing water uses and lack of technical information on sturgeon ecology.

Predicted benefits: Twelve above-normal and wet water years occurred between 1969 and 1987. Nine of the 12 years had flows above 900 cfs. Increasing flows in the remaining 3 years to at least 900 cfs would increase sturgeon production in the Bear River by 20%.

Action 2: Maintain water temperatures below 17°C (63°F) throughout the Bear River from February through May during above-normal and wet water years.

Objective: Improve cues for sturgeon migration and final sexual maturation and improve spawning success and larval survival.

Location: Bear River from SSWD's diversion dam to the confluence with the Feather River.

Narrative description: Data on daily minimum and maximum temperatures for the Bear River are unavailable. However, limited water temperature data presented in the incomplete *Lower Bear River*

Fishery Management Plan indicate that temperatures have been consistently above 75°F at Wheatland in July and August since 1963.

Temperatures should be maintained below 17°C (63°F) throughout the Bear River from February through May during above-normal to wet water years. Development of a temperature model dictating operations of Camp Far West Reservoir, other upstream reservoirs, and diversions downstream of Camp Far West Reservoir may be required for managers to meet criteria. Because data are lacking, installation of thermographs should occur during sturgeon spawning months to determine if water temperatures limit production.

Related actions that may impede or augment the action: Meeting flow standards specified under Action 1 will contribute to temperature reductions.

Agency and organization roles and responsibilities: All public and private entities with control over sources and quantities of water flowing into the Bear River share responsibility for meeting temperature criteria.

Potential obstacles to implementation: Implementation will require identification of flows necessary to meet temperature criteria. If additional flow is required to meet temperature criteria, water users may oppose this action.

Predicted benefits: Temperatures in the Bear River appear high enough in some months and years to reduce egg and larval survival. Reducing temperatures to below 17°C during February-May has the potential to improve sturgeon production in the Bear River. Benefits cannot be quantified.

Action 3: Reduce mortality of spawners.

Objective: Increase the size of the spawning stock.

Location: The Bear River from SSWD's diversion dam to the confluence with the Feather River.

Narrative description: Both legal harvest and poaching have the potential to decrease sturgeon spawning populations on the Bear River. However, only poaching is known to have recently decreased sturgeon stock size.

During years when sturgeon enter the Bear River, poaching may substantially reduce the number of spawners. For example, during July 1989, approximately 30-40 adult sturgeon in the lower Bear River were illegally harvested during a 2-week period (see Action 1). Despite the large numbers of poachers, DFG Game Wardens were able to quickly stop all poaching activities once they became aware of the problem. Although poaching has only been documented in 1989, it is likely that it has occurred in other years (Lenihan pers. comm.).

Legal harvest of sturgeon on the Bear River is almost nonexistent for the following reasons (Lenihan pers. comm.): 1) large numbers of sturgeon are only intermittently present, 2) most anglers are unaware that sturgeon enter the Bear River, and 3) privately owned land limits river access.

Because so little is known about stock size, exploitation rates, and poaching activities on the Bear River, the sturgeon fishery should be closely monitored by biologists and game wardens. Law enforcement patrols should be increased during years in which sturgeon are expected to enter the Bear River.

Related actions that may impede or augment the action: Increased flow and removal/modification of barriers would make sturgeon less vulnerable to angling and poaching.

Agency and organization roles and responsibilities: Stock monitoring can be conducted by federal and state agencies and private consulting firms. The California Fish and Game Commission and DFG are responsible for fishing regulations and law enforcement activities.

Potential obstacles to implementation: Increased cost and lack of personnel may prevent increased law enforcement.

Predicted benefits: Enforcement may increase the number of sturgeon spawning in the Bear River, which will increase the production of larvae and juveniles in the river.

Action 4: Remove or facilitate passage around migration barriers.

Objective: Identify potential physical and water quality barriers to upstream sturgeon migration and determine the extent to which migration is impeded. Once barriers are identified, facilitate rapid migration of sturgeon around these barriers.

Location: Bear River from SSWD's diversion dam to the confluence with the Feather River.

Narrative description: Barriers can delay upstream migration. If delays at barriers cause later spawning, then removal should result in earlier spawning. Earlier spawning sturgeon are less likely to be exposed to high temperatures and poor water quality commonly occurring in April and May. Delayed upstream migration at barriers also has the potential to increase the vulnerability of migrating sturgeon to fishing and poaching. The upstream limit to sturgeon migration is the SSWD diversion dam. Several miles downstream of the diversion dam is a culvert crossing at Patterson Sand and Gravel. The Patterson Sand and Gravel culvert could impede sturgeon migration in low-flow years (Meyer pers. comm.). When flows are reduced, adult sturgeon outmigration is further impeded by shallow riffle areas downstream of the Highway 65 bridge. Flows should be kept high enough to allow adult outmigration after spawning.

Potential water quality barriers impeding adult migration are currently unknown, but it is believed that organic contaminants from agriculture runoff may affect migration.

Barriers to sturgeon passage and actions necessary to eliminate or reduce impacts should be determined. Flows should remain high enough to permit adult outmigration, especially for late-spawning fish.

<u>Related actions that may impede or augment the action</u>: Flows specified under Action 1 should help reduce passage problems associated with low flows.

<u>Agency and organization roles and responsibilities</u>: All public and private entities with control over placement and removal of barriers and establishment of Bear River flow standards, and all entities responsible for waste or drainwater discharge into the Bear River.

<u>Potential obstacles to implementation</u>: To the extent that flows may be needed to address passage problems, availability of water to provide flows may be an obstacle to implementation.

<u>Predicted benefits</u>: If barriers exist, their removal will likely result in increased sturgeon production because access will be provided to new spawning habitat and to spawning areas earlier in the spawning season, sturgeon will require less energy to reach spawning areas, and the vulnerability of sturgeon to capture during migration will be decreased. Sturgeon production may increase, but such an increase cannot be quantified.

Action 5: Reduce or prevent entrainment of sturgeon larvae.

<u>Objective</u>: Identify possible sources of entrainment, and if sources are identified, reduce or eliminate entrainment.

<u>Location</u>: From SSWD's diversion dam to the confluence with the Feather River.

<u>Narrative description</u>: Despite the presence of water diversions on the Bear River, no entrainment studies have been conducted to determine impacts on sturgeon. The most recent enumeration of Bear River water diversions (1959) shows four small diversion (siphons 5-10 inches in diameter) between RM 7 and RM 11. Although the number of lower Bear River diversions appear small and entrainment is therefore probably minimal, an updated census on diversions and level of entrainment should be conducted.

The extent of entrainment on the Bear River should be investigated. If a problem is found to exist, these diversions should be screened with state-of-the-art fish screening technology. Also, entrainment can be reduced through limitations being placed on diversions.

Related actions that may impede or augment the action: Flows described in Action 1 may decrease residence time of larval sturgeon, thereby reducing the time they are susceptible to entrainment.

Agency and organization roles and responsibilities: Federal and state agencies, as well as irrigation districts and other diverters.

Potential obstacles to implementation: Lack of information on the extent to which sturgeon are entrained on the Bear River. Cost of installing and maintaining screens.

Predicted benefits: Entrainment of sturgeon, if entrainment is found to be a problem, should be eliminated. Benefits include decreased early life-stage mortality. Sturgeon production may increase, but such an increase cannot be quantified.

Action 6: Monitor water quality, especially at sites of known wastewater discharge.

Objective: Maintain adequate water quality needed for upstream migration, spawning, and early life-stage survival.

Location: Bear River from SSWD's diversion dam to the confluence with the Feather River.

Narrative description: Specific studies examining water quality problems on the Bear River do not exist. However, Feather River water sampled between 1987 and 1989 was acutely toxic to invertebrates (CVRWQCB 1991). Toxicity was in part attributed to agriculture return flows entering the Feather River via the Bear River (Foe pers. comm.). The level of Bear River contribution to poor Feather River water quality and the number of contaminant discharge sites are unknown.

Heavy metals can deleteriously affect embryos and pre-larval sturgeon, with concentrations as low as a few micrograms per liter toxic to fish (Dettlaff 1993). Negative impacts on sturgeon from heavy metals in the Bear River are unknown. However, green sunfish liver tissue have shown high levels of nickel and cadmium. Potential for negative impacts of heavy metals on adult and early life-stages exist and should be evaluated.

Sites of agriculture return flows and heavy metal contamination should be located and monitored for impacts. Contaminant levels in the Bear River may be reduced through enforcement of existing regulations or by creation and enforcement of new regulations.

Related actions that may impede or augment the action: Increased flows of uncontaminated water may help dilute contaminant concentrations in the water.

Agency and organization roles and responsibilities: Water dischargers and chemical users within the Bear River drainage. Federal, state, and local agencies involved with enforcing and creation of water quality standards.

Potential obstacles to implementation: Dischargers are likely to resist implementation of the action.

Predicted benefits: Reduced contaminant levels would improve habitat for all aquatic organisms. Increased egg and larvae survival would increase production. Benefits cannot be quantified.

San Joaquin River

Limiting factors and potential solutions -

Table 3-Xh-9. Limiting factors and potential solutions for white and green sturgeon in the mainstem San Joaquin River.

Limiting factors	Potential solutions
1. Inadequate flows for attraction, migration, and spawning of adults and for transport and rearing of larvae and juveniles	Provide mean monthly flows of at least 7,000 cfs at Newman and 14,000 cfs at Vernalis from February to May during wet and above-normal water years
2. Inadequate temperatures for initiation of spawning and final maturation of adults and survival of larvae and juveniles	Maintain water temperatures below 17°C (63°F) in sturgeon spawning areas and below 20°C (68°F) throughout the San Joaquin River during February-May during wet and above-normal water years
3. Barriers that prevent or slow the migration of sturgeon to spawning habitat	1. Identify potential barriers (physical as well as water quality barriers) 2. Evaluate the extent of the problem 3. Remove barriers or facilitate passage around barriers
4. Loss of sturgeon larvae and juveniles at major and minor diversions on the San Joaquin River resulting from entrainment	1. Identify the extent of the problem 2. Reduce or eliminate entrainment of sturgeon larvae and juveniles
5. Size of spawning stock	1. Improve conditions for production of sturgeon 2. Reduce mortality of early life stages (see entrainment, water quality, etc.)

Limiting factors	Potential solutions
	3. Reduce mortality of adults (fishing mortality, especially poaching [including possible contribution of increased flows to reduction in accessibility of migrating and spawning adults to poachers])
6. Poor water quality	1. Increase flows of high quality water 2. Decrease contamination of river by agricultural chemicals and drain water 3. Decrease exposure to excessive levels of trace elements (e.g., selenium) or other contaminants to acceptable levels
7. Availability of suitable spawning habitat	1. Identify spawning sites 2. Evaluate availability of suitable spawning habitat 3. If habitat limits success of sturgeon spawning, take appropriate corrective action
8. Viability of gametes/health of spawners	1. Evaluate viability of gametes, especially trace-element (e.g., selenium from refineries) and contaminant burdens 2. Evaluate health of spawners 3. If viability of gametes or health of spawners limit sturgeon production, take appropriate corrective action (address sources of contamination or poor health)

Restoration actions -

Action 1: Provide mean monthly flows of at least 7,000 cfs at Newman and 14,000 cfs at Vernalis from February to May during above-normal and wet water years.

Objective: Provide minimum or greater flows to ensure suitable conditions for sturgeon to migrate and spawn and for their progeny to survive.

Location: San Joaquin River upstream of sturgeon spawning areas to the confluence with the Delta downstream.

Narrative description: There exists very little information on white or green sturgeon in the San Joaquin River or its tributaries. Although sturgeon are known to migrate into the San Joaquin River (Fry 1973, Kohlhorst et al. 1991), no efforts have been made to document sturgeon reproduction in the San Joaquin River system. In addition, entrainment data are not regularly collected at diversions in the San Joaquin River and those data that do exist either do not identify sturgeon (i.e., sturgeon were lumped in with other species [Rose pers. comm.]) or are for studies that were of short duration and did not capture sturgeon (Hallock and Van Woert 1959). Despite the lack of technical information specific to sturgeon in the San Joaquin River, enough evidence exists in the form of casual observations by biologists, wardens, and anglers to provide a basis for making recommendations to improve conditions for sturgeon production in the river.

Based on the ratio of tagged sturgeon recovered in the San Joaquin River to tagged sturgeon recovered in the Sacramento River, Kohlhorst et al. (1991) estimated that approximately 10% of the white sturgeon in the Sacramento-San Joaquin river system migrate up the San Joaquin River. A small fishery exists for sturgeon (species unknown, but suspected to consist of both white and green sturgeon) on the San Joaquin River upstream of its confluence with the Tuolumne River. Sturgeon are captured from as far south on the San Joaquin River as the mouth of the Merced River. DFG Warden Hugh Rutherford (pers. comm.) has observed anglers in the vicinity of Laird Park and Dos Rios Road (RM 90) taking female and male sturgeon (identified as white sturgeon) in advanced stages of sexual maturation. Warden Rutherford's observations suggest that sturgeon captured there are spawning close to the capture site. Based on these observations, it is likely that sturgeon spawn in the San Joaquin River, at least upstream of the Tuolumne River and downstream of the Merced River. No sampling has been done to confirm the presence of eggs, larvae, or juveniles in the San Joaquin River. It is also possible that sturgeon spawn in the major tributaries to the river.

Data from the Sacramento River indicate that white sturgeon start migrating into the river in October and spawn as early as February (Schaffter pers. comm.). Observations on gonadal development and hatchery spawning of wild-caught and captive white sturgeon suggest that the majority of the Central Valley stocks spawn during March-May, and approximately 20%-30% spawn in February and June (Doroshov pers. comm.). Anglers in the San Joaquin River capture sturgeon as early as late December and fishing improves from January through February, is generally best in March and April, and falls off rapidly as the weather warms, although some stragglers are captured in June (pers. comms. with the following: Red Bartley, angler; Gene Thomas, The Old Fishermen Bait and Tackle; and Ron Wilson, Modesto Bee). Therefore, flow standards would be effective implemented as early as February and possibly as late as June.

Years with good recruitment of white sturgeon showed higher mean monthly discharge rates in February through May than years with poor recruitment (Figure 3-Xh-1). Ranking years by mean monthly outflow in February-May shows that 5 of the 6 years with the highest flows were years with good recruitment of white sturgeon. February-May mean monthly flows in these years were above 7,000 cfs immediately downstream of the Merced River (as indicated by discharge at Newman) and 14,000 cfs where the San Joaquin River meets the Delta (as indicated by discharge at Vernalis). Only one of the years with good recruitment was not in the top six, but it rated ninth at Newman and thirteenth at Vernalis (Table 3-Xh-10). None of the years with good recruitment had February-May mean monthly flows below about 1,900 cfs at Newman or 5,000 cfs at Vernalis.

Figure 3-Xh-1. Mean monthly discharge at two locations on the San Joaquin River for years with good and poor recruitment of sturgeon.

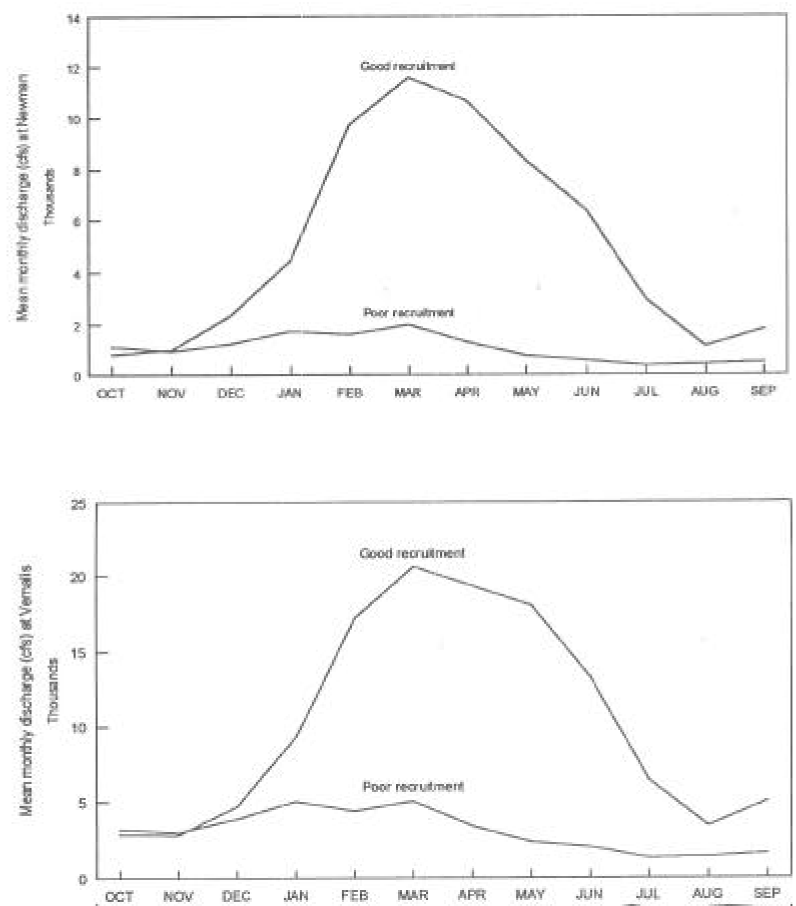


Table 3-Xh-10. Mean monthly discharge (cfs) for February-May at Newman (USGS Hydrologic Unit 18040002, located 650 feet downstream of the Merced River) and Vernalis (Unit 18040003, located 2.6 miles downstream of the Stanislaus River) on the San Joaquin River.

Newman		Vernalis	
Year	Discharge	Year	Discharge
1983	19,545	**1983**	34,965
1969	15,235	**1969**	27,538
1978	9,285	**1980**	16,061
1986	8,116	1986	15,535
1982	7,495	**1982**	14,579
1980	7,221	**1978**	14,485
1973	2,408	1984	6,464
1979	2,080	1973	5,685
1975	1,887	1979	5,455

Newman		Vernalis	
1970	1,643	1970	5,109
1984	1,463	1974	4,967
1974	1,350	**1975**	4,957
1981	892	1971	2,694
1985	837	1987	2,649
1987	828	1985	2,644
1988	667	1981	2,625
1971	652	1968	2,009
1989	647	1988	1,889
1968	601	1989	1,780
1990	549	1976	1,543
1972	527	1972	1,466
1976	517	1990	1,428
1977	232	1977	481

Note: Years are ranked from highest to lowest discharge, and years in bold print were classified as years with good recruitment of white sturgeon.

Flows necessary for successful reproduction of sturgeon need to be determined. In addition to empirical relationships between flow and reproduction, other information (e.g., depth of water necessary for successful passage, discharge necessary to cue spawning, preferred water depths and velocities for spawning, and discharge necessary for larval transport and rearing) should be considered before final flow standards are set. Until these data are available, interim flow standards should be as follows: February-May mean monthly flows of at least 7,000 cfs immediately downstream of the Merced River as indicated by discharge at Newman and at least 14,000 cfs at Vernalis in wet and above-normal years.

Related actions that may impede or augment the action: Provision of flows in the San Joaquin River must be accompanied by other habitat restoration measures in the San Joaquin River, the Delta, and the San Francisco Bay system.

Agency and organization roles and responsibilities: The numerous agencies and public and private entities responsible for setting flow standards and meeting them on the San Joaquin, Merced, Tuolumne, and Stanislaus rivers all share responsibility.

Potential obstacles to implementation: Competing uses of water and lack of substantive data on which to base a recommendation.

Predicted benefits: Twelve of the 22 years between 1968 and 1990 (the years for which YCIs are available) were wet or above-normal water-year types. Of these 12, only 6 had flows above the recommended standard. If the flow standards were met in the remaining 6 wet and above-normal years, the average YCI for 1968 through 1990 would increase by 60%. If the same assumptions were only applied to wet years, the average YCI would increase by 20%.

Action 2: Maintain water temperatures below 17 °C (63 °F) in sturgeon spawning areas and below 20 °C (68 °F) throughout the San Joaquin River from February through May during wet and above-normal water years.

Objective: Provide water at temperatures suitable for sturgeon to migrate, undergo the final stages of sexual maturation, and spawn and for their progeny to survive.

Location: The San Joaquin River upstream of sturgeon spawning areas to the river's confluence with the Delta.

Narrative description: Temperatures in the San Joaquin River potentially limit production of sturgeon. DFG Exhibit 15 to SWRCB for Phase I of the Bay-Delta hearings indicated that in years when the Vernalis flow was 5,000 cfs or less in May, water temperatures were at levels associated with chronic stress in juvenile chinook salmon (Reynolds et al. 1993). The optimal temperatures for spawning and egg and larval survival of white sturgeon are 10-17°C (50-63°F) (PSMFC?? 1992). Survival of early developmental stages is greatly reduced at temperatures above 20°C (68°F) (Doroshov pers. comm.). Maximum temperatures recorded in the San Joaquin River at the USGS gaging station (USGS Hydrologic Unit 18040003) 650 feet downstream of the Merced River exceeded 20°C (68°F) as early as late February and as late as early May during the 4 years for which data exist (1988, 1989, 1993 and 1994). Clearly, temperatures in sturgeon spawning areas often exceed temperatures conducive to successful spawning of sturgeon, suggesting that temperatures may limit production of sturgeon. Temperatures downstream of this area in spring are usually higher and may also limit production, although temperature tolerance increases with age.

Temperatures should be maintained below 17 °C (63°F) in areas in which sturgeon spawn and below 20 °C (68°F) throughout the San Joaquin River from February through May of wet and normal years.

Related actions that may impede or augment the action: Meeting flow standards specified under Action 1 above will contribute to reductions in temperatures that would depend on the source of water for these flows. As spring progresses and air temperatures warm, the relative contribution of agricultural return flows will become an important factor determining water temperatures in the river. Actions taken to restore habitat upstream of Mendota Pool or to restore riparian vegetation in the San Joaquin drainage will potentially reduce the temperature of the water flowing downstream of the Merced River.

Agency and organization roles and responsibilities: The numerous agencies and public and private entities with control over sources and quantities of water flowing into the San Joaquin River share responsibility for meeting temperature criteria on the San Joaquin River.

Potential obstacles to implementation: Implementation will require identification of flows necessary to meet temperature criteria. Identification of flows may be complicated by the complexity of the watershed, especially the contribution of agricultural return flows to overall San Joaquin River flows. Flows necessary to maintain temperatures are likely to exceed available water, especially in April and May.

Predicted benefits: Temperatures are high enough in the San Joaquin River to prevent successful reproduction by sturgeon during all or at least portions of the spawning season. Reducing temperatures below 17 ^{o}C (63^{o}F) has the potential to greatly improve the frequency and success of sturgeon spawning in the San Joaquin River.

Action 3: Remove barriers to sturgeon migration.

Objective: Remove barriers that prevent or slow the migration of sturgeon to areas in which sturgeon spawn.

Location: The San Joaquin River from upstream of sturgeon spawning areas at the upstream limit to its confluence with the Delta on the downstream end.

Narrative description: Although undocumented, low flows may result in passage problems for sturgeon through shallow areas. Anglers describe sturgeon migrating through shallow water, and believe that low water slows migration. Adult passage studies for chinook salmon in the upper San Joaquin River have been conducted (USFWS 1994), but similar studies for sturgeon in the San Joaquin River have not been conducted.

Low dissolved oxygen levels commonly occur in the vicinity of Stockton each fall as a result of dredging activities in the Stockton Ship Channel and turning basin, flow reversals resulting from high Delta exports, and effluent discharge from the Stockton Municipal Sewage Plant and other sources. Low dissolved oxygen levels have been shown to inhibit adult salmon migration in the vicinity of Stockton. The quality and quantity of agricultural drainwater may also inhibit adult sturgeon migration. Whether low dissolved oxygen levels or other water quality conditions inhibit passage of adult sturgeon is unknown and needs to be investigated.

Barriers to sturgeon migration should be identified and actions taken to eliminate or reduce impacts.

Related actions that may impede or augment the action: Flows specified under Action 1 should prevent passage problems associated with low flows or dissolved oxygen levels. Barriers delay upstream migration. If delays at barriers cause sturgeon to spawn later in the spawning season, then removal of barriers should result in sturgeon spawning earlier. Earlier spawning sturgeon are less likely to be exposed to high temperatures that commonly occur in April and May. Delayed upstream migration at barriers also has the potential to increase the vulnerability of migrating sturgeon to fishing and poaching.

DWR installs a barrier at the head of Old River during fall when flows are low or critical problems are predicted. This barrier is believed to improve dissolved oxygen concentrations. Improved treatment of Stockton Municipal Sewage Plant discharge has also helped alleviate the low dissolved oxygen problem. DWR staff members have identified dredging in the ship channel as the major factor contributing to a recent low dissolved oxygen event.

Agency and organization roles and responsibilities: The numerous agencies and public and private entities responsible for setting flow standards and meeting them on the San Joaquin River all share responsibility, as will any entities responsible for waste or drainwater discharge, should these factors be identified as contributing to barriers to sturgeon migration.

Potential obstacles to implementation: To the extent that flows may be needed to address passage problems, availability of water to provide flows may be an obstacle to implementation.

Predicted benefits: If barriers exist, their removal will likely allow sturgeon access to new spawning habitat and to spawning areas earlier in the spawning season, requiring sturgeon to expend less energy to reach spawning areas, and will likely decrease the vulnerability of sturgeon to capture during migration.

Action 4: Reduce or eliminate entrainment of sturgeon.

Objective: Reduce or eliminate entrainment of sturgeon larvae and juveniles at major and minor diversion on the San Joaquin River.

Location: The San Joaquin River from upstream of sturgeon spawning areas at the upstream limit to its confluence with the Delta on the downstream end.

Narrative description: Four major diversions are located on the mainstem San Joaquin River in areas accessible to sturgeon. These are the Banta-Carbona, El Solyo, West Stanislaus, and Patterson Irrigation District diversions. The El Solyo diversion can withdraw up to 80 cfs; the other three diversions each can withdraw 249 cfs. These diversions can cumulatively diver most of the river flow, particularly in dry years. Numerous small- and medium-sized irrigation diversions also exist on the mainstem San Joaquin River.

These diversions entrain significant numbers of chinook salmon (Hallock and Van Woert 1959), but the effects of these diversions on sturgeon are unknown. Entrainment data are not regularly collected at diversions in the San Joaquin River and those data that do exist either do not identify sturgeon (i.e., sturgeon were lumped in with other species [Rose pers. comm.]) or studies were of short duration and did not capture sturgeon (Hallock and Van Woert 1959). Sturgeon are vulnerable to entrainment elsewhere in the Central Valley as evidenced by data collected at the GCID Diversion on the Sacramento River and the CVP and SWP pumps in the Delta. The extent of the problem in the San Joaquin River should be investigated. Any actions taken to alleviate entrainment of chinook salmon should also consider needs of sturgeon.

Several alternatives are being considered to reduce or prevent entrainment of juvenile chinook salmon at these sites: rescreening using state-of-the-art fish screening technology, using alternative electronic or sonic avoidance technology, or providing the irrigation districts with alternative water supplies from the Central Valley Project in lieu of diverting directly from the San Joaquin River. The last alternative is recommended here because it will definitely prevent entrainment of sturgeon in the San Joaquin River (although it might transfer this problem to the Delta), whereas the other alternatives are less likely to succeed. In addition, relocating diversions to the Delta will increase flows throughout the San Joaquin River.

Related actions that may impede or augment the action: This action would keep water that would otherwise be diverted in the San Joaquin River, at least as far as the Delta.

Agency and organization roles and responsibilities: Responsibility would be shared by the state and federal government, especially DWR and USBR, as well as the irrigation districts and other diverters and customers of the SWP and CVP.

Potential obstacles to implementation: Developing alternative water supplies for the districts from the CVP through the Delta-Mendota Canal has been discussed, but little progress has been made (Reynolds et al. 1993). This action would probably require making formal changes in the districts' water rights, constructing new diversion facilities, and extending lateral canals.

Predicted benefits: Benefits would be realized in the form of reduced mortality of juvenile sturgeon from entrainment and increased production of sturgeon resulting from increased San Joaquin River flows and improved riverine habitat.

Action 5: Reduce the mortality of spawners.

Objective: Increase the size of the spawning stock.

Location: San Joaquin River from upstream of sturgeon spawning areas at the upstream limit to its confluence with the Delta on the downstream end.

Narrative description: A fishery exists for sturgeon on the San Joaquin River and some portion of the population is snagged. Dave Kohlhorst (see III.C.5.) observed during tagging studies that about 10% of the tagged white sturgeon were recaptured in the San Joaquin River. Assuming this number to be representative of the proportion of the white sturgeon population that spawns in the San Joaquin River, the spawning population of white sturgeon in the San Joaquin River can be estimated to have been approximately 910 fish (690 males and 220 females) in 1990. DFG Warden Hugh Rutherford (pers. comm.) estimates that 60-100 sturgeon spawn in the San Joaquin River in the vicinity of Laird Park and the end of Dos Rios Road in a single season (estimate is Warden Rutherford's guess based on visual observation of sturgeon activity). Both estimates indicate that the population of white sturgeon spawning in the San Joaquin River is small. Most observers agree that the number of sturgeon spawning in the San Joaquin River has declined during the last 25 years.

The small population experiences heavy fishing pressure on its spawning grounds. Fishing pressure, especially that resulting from illegal snagging of fish, may be more than this small population can support. Kohlhorst et al. (1991) expressed concern that white sturgeon populations overall were being overexploited, and angling regulations were drafted in 1990 to reduce harvest. Because white sturgeon in the San Joaquin River are a small and probably separate component of the Central Valley white sturgeon population, it is likely that exploitation rates acceptable for the population as a whole are unacceptable for white sturgeon in the San Joaquin River.

Illegal snagging can be limited through a combination of passage of new laws restricting terminal weight and hook placement and size and enforcement of those laws. Gear restrictions are currently being considered by the California Fish and Game Commission that would make snagging nearly impossible. If, however, gear restrictions are not implemented or are ineffective in reducing snagging, closure of the sturgeon fishery should be considered.

Related actions that may impede or augment the action: Increases in flow would help make sturgeon less vulnerable to poaching. Possible closure of the sturgeon fishery would be consistent with the closure of the chinook salmon fishery currently in effect on the San Joaquin River and its tributaries.

Agency and organization roles and responsibilities: The California Fish and Game Commission and DFG are responsible for fishing regulations.

Potential obstacles to implementation: No potential obstacles to adoption of gear restrictions have been identified. If closure of the fishery is deemed necessary, angler groups may resist.

Predicted benefits: Eliminating or reducing illegal harvest will increase the number of sturgeon spawning in the San Joaquin River, which will increase the production of larvae and juveniles in the river. Because the number of fish illegally harvested is unknown, benefits cannot be quantified.

Action 6: Improve water quality.

Objective: Improve survival and condition of sturgeon.

Location: The San Joaquin River from upstream of sturgeon spawning areas on the upstream limit to its confluence with the Delta on the downstream end.

Narrative description: Water quality monitoring in the San Joaquin River often shows river water to be toxic to a variety of organisms. Toxicity often occurs during the time period when sturgeon are spawning in the San Joaquin River. Gamete and larval stages of sturgeon are particularly vulnerable to exposure to contaminants. The extent to which contaminants affect sturgeon production in the San Joaquin River is unknown, but is potentially a problem. Contaminants can reduce sturgeon production directly by causing mortality or decreasing physiological condition, or indirectly by reducing availability of food or vulnerability to other direct sources of mortality.

Contaminant levels in the San Joaquin River should be reduced through enforcement of existing regulations or by creation and enforcement of new regulations.

Related actions that may impede or augment the action: Increases in flows of uncontaminated water needed to meet other actions will help dilute contaminant concentrations in the river.

Agency and organization roles and responsibilities: Waste dischargers and chemical users in the San Joaquin River drainage. Federal, state, and local agencies with responsibility for creation and enforcement of environmental regulations.

Potential obstacles to implementation: Dischargers are likely to resist implementation of this action.

Predicted benefits: Benefits are expected to be far reaching, improving habitat for all organisms in the San Joaquin River.

Sacramento-San Joaquin Delta

Limiting factors and potential solutions - Information is currently being gathered on poaching, harvest regulations, and predation. Actions for these limiting factors may be added to future drafts.

Table 3-Xh-11. Limiting factors and potential solutions
for white and green sturgeon in the Delta.

Limiting factors	Potential solutions
1. Inadequate flows for adult sturgeon passage and juvenile production	Provide mean April-May outflow index at Chipps Island of 25,000 cfs in wet and above-normal years; minimum daily Delta outflow index in April not less than 20,000 cfs, and not less than 15,000 cfs in May
2. Loss of larval and juvenile sturgeon at the	Identify the extent of the problem
3. Loss of larval and juvenile sturgeon at	Identify the extent of the problem
4. Poor water quality	1. Increase flows of high quality water 2. Decrease discharge of contaminated water 3. Decrease exposure to excessive levels of trace elements (e.g., selenium) and other contaminants to acceptable levels

Restoration actions -

Action 1: Provide a mean April-May Delta outflow index of at least 25,000 cfs in above-normal and wet year types. The minimum daily Delta outflow index will not be less than 20,000 cfs in April and will not be less than 15,000 cfs in May.

Objective: Increase white sturgeon production by providing adequate Delta outflow in above-normal and wet year types.

Location: Delta outflow index at Chipps Island.

Narrative description: Between 1969 and 1987, good sturgeon production and high Delta outflow occurred in 8 years (1969, 1971, 1974, 1975, 1978, 1980, 1982, and 1983). During these years, mean April-May Delta outflow exceeded approximately 25,000 cfs, with minimum daily Delta outflow of at least 19,712 cfs for April and at least 15,316 cfs for May.

It is not clear whether Delta outflow itself is important in affecting production or whether upstream flows in the Sacramento and San Joaquin rivers and their tributaries, for which Delta outflow is a surrogate, are the important limiting factors. Irrespective of the mechanism of Delta outflow on sturgeon production, outflow requirements should be consistent with upstream flow requirements for sturgeon and other anadromous species so they augment one another.

For successful sturgeon reproduction, a mean April-May Delta outflow index of at least 25,000 cfs in above-normal and wet year types and a minimum daily Delta outflow index of 20,000 cfs in April and 15,000 cfs in May should be provided.

Related actions that may impede or augment the action: Recommended Delta outflows are contingent on recommended flows being met on the Sacramento, San Joaquin, and eastside tributary rivers.

Agency and organization roles and responsibilities: Federal, state, and local agencies responsible for setting Delta flow standards and meeting them.

Potential obstacle to implementation: Implementation of this action may be affected by the availability of water, demands in other months for restoration of other anadromous species, needs of upstream water diverters, and levels of diversions and exports in the Delta.

Predicted benefits: Between 1968 and 1987, there were 12 above-normal and wet water years. Mean April-May Delta outflow exceeded approximately 25,000 cfs in 9 years. Increasing flows in the remaining 3 above-normal and wet years to at least 25,000 cfs would increase average white sturgeon production by approximately 23%. Similar calculations for green sturgeon were not conducted because few green sturgeon were sampled at the facilities and positive identification could not be guaranteed. However, increases in April-May Delta outflow are assumed to also benefit green sturgeon.

Action 2: Limit entrainment at the state and federal pumping facilities.

Objective: Increase sturgeon production by decreasing larval and juvenile sturgeon entrainment.

Location: State and federal pumping facilities in the Delta.

Narrative description: Between 1979 and 1994, the state and federal pumping facilities entrained approximately 39,443 sturgeon. Of the sturgeon measured, approximately 80% were 0.4-0.16 inches in total length. Accurate entrainment estimates of sturgeon less than 2 inches in length are not available because larval and postlarval sturgeon are ineffectively screened. Research on sturgeon swimming capabilities at all life stages is vital to determining approach and sweeping velocities needed for efficient salvage.

Research determining approach and bypass velocities needed to effectively screen larval and juvenile sturgeon should be conducted.

Related actions that may impede or augment the action: Export reductions as recommended by other technical teams may reduce entrainment.

Agency and organization roles and responsibilities: DWR and USBR, as well as customers of the SWP and CVP.

Potential obstacles to implementation: If limiting entrainment requires reducing exports, competing water uses may hinder implementation. Also, funding may limit research needed to determine approach and sweeping velocities and possible screen modifications.

Predicted benefits: Benefits would include increased larval and juvenile sturgeon survival in the Delta. Benefits cannot be quantified.

Action 3: Screen all unscreened water diversions.

Objective: Increase sturgeon production by decreasing larval and juvenile sturgeon entrainment.

Location: Delta.

Narrative description: The abundance of sturgeon larvae in the Delta is related to Delta inflow. During high-flow years sturgeon larvae are transported from upstream spawning areas to the Delta, while during low-flow years larvae remain farther upstream. In 1967, Sacramento flows of 49,217 cfs produced high larval catches in the Delta. In 1966 and 1968, Sacramento flows were 21,820 cfs and 13,600 cfs, respectively. During 1966 few sturgeon larvae were caught in the Delta, and none were caught in 1968.

The level of sturgeon entrainment in Delta agricultural diversions is unknown. A pilot study conducted by Spaar (1992) examined entrainment at Delta agricultural diversions from April to October 1992. No sturgeon larvae or juveniles were collected during the study, probably because of low Sacramento River flow during a critical water year. However, high entrainment of shad, cyprinids, and centrarchid eggs and larvae raises concerns over sturgeon vulnerability during years of high flow.

To reduce or eliminate entrainment, additional information should be gathered on the following: 1) numbers, types, and sizes of unscreened and screened Delta diversions; 2) magnitude of fish losses caused by unscreened diversions; 3) feasibility of installing positive barrier screens to reduce losses; 4) estimated costs of screen design, installation, maintenance, and evaluation; 5) availability of funding mechanisms; and 6) feasibility of management options that would reduce losses (i.e., seasonal pumping restrictions, monitoring requirements, or alternative water supplies). There also is a need for research into the swimming capabilities of early life stages of sturgeon. This information is vital to determining approach and sweeping velocities and how screens should be designed.

Alternatives to reduce entrainment at irrigation diversion and intakes would be screening using state-of-the-art fish screen technology or, potentially, sonic barriers. Investigations to determine minimum mesh size to prevent YOY sturgeon entrainment should be conducted.

Related actions that may impede or augment the action: Techniques used to reduce entrainment at the state and federal water projects may be applied to agricultural diversions.

Agency and organization roles and responsibilities: Federal and state agencies, irrigation districts, and other diverters.

Potential obstacles to implementation: Screening Delta diversions presents many problems resulting from species diversity and water transport rates. Additionally, it may require a long time to develop and evaluate alternative screening methods or sonic barriers.

Predicted benefits: Benefits include reduced entrainment mortality of larvae and juvenile sturgeon. Benefits cannot be quantified.

Action 4: Improve water quality.

Objective: Improve the survival and condition of sturgeon.

Location: The Delta.

Narrative description: Organic compounds and trace elements can negatively affect sturgeon reproduction. White sturgeon in the Sacramento-San Joaquin Estuary accumulate PCBs, dioxin, mercury, and selenium in egg tissue, and these toxins may reduce reproductive potential (Pacific States Marine Fisheries Commission 1992; Kohlhorst 1980; Kohlhorst pers. comm.). PCBs are of special concern for sturgeon in the Central Valley (Kohlhorst 1980). Sturgeon in San Pablo Bay showed gonadal PCB concentrations of 49.3±24.7 ppm and 23.3±27.8 ppm in males and females, respectively (Kohlhorst 1980). Although sturgeon sampled in subsequent years showed lower PCB levels than those reported in 1980, the potential exists for negative impacts on sturgeon.

Trace elements may also adversely affect sturgeon. Sturgeon sampled in the estuary in 1989 and 1990 had selenium levels in muscle tissue of 14.6 ppm (dry weight) and 15.0 ppm (dry weight), respectively. USFWS (USFWS 1990b) reported that selenium levels found in sturgeon are near levels that produce chronic and acute effects in other freshwater fish species. Selenium levels of 16-18 ppm (dry weight, whole body samples [whole body levels most comparable to muscle]) in adult bluegill caused partial to complete mortality of fry during the yolk-sack stage. Also, chinook salmon fry began to die when whole body selenium levels were 5-8 ppm (dry weight). Applicability of these data to sturgeon are unknown. Therefore, effects of selenium and other trace elements on sturgeon production should be investigated.

Related actions that may impede or augment the action: Increases in flows of uncontaminated water needed to meet other actions will help dilute contaminant concentrations in the river.

Agency and organization roles and responsibilities: Waste dischargers and chemical users within the Sacramento-San Joaquin River system. Federal, state, and local agencies with responsibility for creation and enforcement of environmental regulations.

Potential obstacles to implementation: Entities accustomed to using chemicals and discharging contaminated water are likely to resist implementation of this action.

Predicted benefits: Benefits are expected to be far reaching, improving habitat for all organisms in the Delta.

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