

Appendix E

**Central Valley Spring-Run Chinook Salmon and
Steelhead in the Sacramento River Basin
Background Report**

STATE OF CALIFORNIA
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
DIVISION OF ENVIRONMENTAL SERVICES



CENTRAL VALLEY SPRING-RUN CHINOOK SALMON AND STEELHEAD IN THE SACRAMENTO RIVER BASIN BACKGROUND REPORT

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List of Acronyms

AFRP	Anadromous Fish Restoration Program
AROG	American River Operations Work Group
BCWC	Butte Creek Watershed Conservancy
CCWG	Cottonwood Creek Watershed Group
CCWMP	Cow Creek Watershed Management Program
CDFG	California Department of Fish and Game
CNFH	Coleman National Fish Hatchery
CSU	California State University
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
DCID	Deer Creek Irrigation District
DCWC	Deer Creek Watershed Conservancy
Delta	Sacramento-San Joaquin Delta
DIDSON	dual-frequency identification sonar
DWR	California Department of Water Resources
ERP	Ecosystem Restoration Program
ESA	federal Endangered Species Act
ESU	environmentally significant unit
EWP	Environmental Water Program
FERC	Federal Energy Regulatory Commission
FERC Project 2100	Pacific Gas and Electric Company's Oroville Facilities Project
FERC Project 2105	Pacific Gas and Electric Company's Upper North Fork Feather River Project
FERC Project 2107	Pacific Gas and Electric Company's Poe Project
FISH	Fisheries and Instream Habitat
Forest Service	U. S. Department of Agriculture Forest Service
GCID	Glenn-Colusa Irrigation District

GIS	geographic information systems
HEA	Habitat Expansion Agreement
IFIM	instream flow incremental methodology
km	kilometer(s)
LMMWC	Los Molinos Mutual Water Company
MOU	Memorandum of Understanding
NMFS	U. S. Department of Commerce, National Marine Fisheries Service
PG&E	Pacific Gas and Electric Company
PVA	population viability assessment
RCMP	River Corridor Management Plan
Reclamation	U. S. Bureau of Reclamation
Restoration Project	Battle Creek Salmon and Steelhead Restoration Project
RM	River Mile
State Water Board	California State Water Resources Control Board
Study Team	Upper Yuba River Studies Program Study Team
SVRIC	Stanford-Vina Ranch Irrigation Company
USACE	U. S. Army Corps of Engineers
USFWS	U. S. Fish and Wildlife Service
VSP	viable salmonid population
WUA	weighted usable area
YOY	young of the year
Yuba Accord	Lower Yuba River Accord

Central Valley Spring-Run Chinook Salmon and Steelhead in the Sacramento River Basin Background Report

Introduction

Effective November 20, 2007, Pacific Gas and Electric Company (PG&E) and the California Department of Water Resources (DWR) entered into the Habitat Expansion Agreement (HEA) with the following parties: American Rivers, Arthur G. Baggett, Jr. (signing as a recommendation to the California State Water Resources Control Board [State Water Board]), California Department of Fish and Game (CDFG), U.S. Department of Agriculture Forest Service (Forest Service), U.S. Department of Commerce National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USFWS), and State Water Contractors, Inc. Under the agreement, PG&E and DWR have 2 years to jointly identify, evaluate, and select the most promising and cost-effective action(s) to expand spawning, rearing, and adult holding habitat for spring-run Chinook salmon and steelhead in the Sacramento River basin, as an alternative to the Resource Agencies and other parties seeking project-specific fish passage prescriptions or license conditions in the New Project Licenses for PG&E's Upper North Fork Feather River Project (Federal Energy Regulatory Commission [FERC] Project No. 2105) and Poe Project (FERC Project No. 2107) and DWR's Oroville Facilities Project (FERC Project No. 2100).

The purpose of this *Central Valley Spring-Run Chinook Salmon and Steelhead in the Sacramento River Basin Background Report* (Background Report) is to provide background information on the status of spring-run Chinook salmon and Central Valley steelhead populations throughout watersheds in the Sacramento River basin. The information synthesized in the report will be used to support PG&E and DWR in identifying, evaluating, and selecting potential habitat expansion actions, to fulfill their obligations under the HEA.

Central Valley Spring-Run Chinook Salmon

Listing Status

In 1999, NMFS listed the Central Valley spring-run Chinook salmon evolutionarily significant unit (ESU) as threatened under the federal Endangered Species Act (ESA) (NMFS 1999). The Central Valley ESU includes all naturally spawned populations in the Sacramento River, tributaries of the Sacramento River, and the Feather River (DWR 2007). In 2005, NMFS published a final listing determination for Central Valley spring-run that added Feather River Hatchery spring-run to the designation (DWR 2007). In 2005, NMFS published the final designation of critical habitat, which includes the Sacramento, lower Feather, and Yuba Rivers; and Beegum, Battle, Clear, Cottonwood, Antelope, Mill, Deer, Butte, and Big Chico Creeks (DWR 2007).

General Life History

Central Valley spring-run Chinook salmon generally leave the ocean and enter the Sacramento River from March to July as immature fish. Once they arrive at the spawning grounds, spring-run adults mature over the summer and spawn between late August and early October (NMFS 2002). Historically, spring-run adults ascended to higher elevation reaches to avoid excessive summer temperatures during this holding period (Healey 1991). Spring-run Chinook spawn in gravel beds located at the tails of holding pools (USFWS 1995). The eggs are deposited in the gravel, where incubation, hatching, and emergence occur.

The emergence of spring-run fry occurs from November to March, depending on water temperatures (CDFG 1998). Central Valley spring-run Chinook exhibit both of the freshwater life history types described by Healey (1991). The *stream-type* Chinook reside in freshwater for a year or more following emergence, and the *ocean-type* Chinook salmon migrate to the ocean within their first year. The fry use shallow, nearshore areas with slow current and good cover (CDFG 1998).

Higher elevation streams such as Mill and Deer Creeks generally have a higher proportion of spring-run exhibiting the stream-type life history. The proportion varies annually depending on stream conditions (Harvey-Arrison pers. comm.). These juveniles spend 9 to 10 months in their natal streams and up to 18 months in freshwater (USFWS 1995, CDFG 1998). In lower elevation streams such as Butte Creek, the juveniles exhibit more of an ocean-type life history with a higher proportion of the production leaving the tributaries from December to February (CDFG 2000). These young-of-the-year (YOY) Chinook may rear in the bypasses, the lower Sacramento River, and the Sacramento-San Joaquin River Delta (Delta) until ready to enter the ocean. CDFG conducted a life history investigation on Butte Creek from 1995 to 2003 and found that spring-run that emigrated from the creek as yearlings contributed greatly to the ocean harvest rate, suggesting that yearlings survive at higher rates than YOY (CDFG 2004b).

In general, Chinook salmon spend between 1 and 4 years in the ocean before returning to spawn (Myers et al. 1998). Fisher (1994) estimated that 87% of spring-run Chinook return as 3-year-olds based on data collected at Red Bluff Diversion Dam. In another study, Cramer and Demko (1997) estimated that 80 to 90% of the spring-run smolts from the Feather River Hatchery matured at age 4 and that 85% of those fish were harvested by the time they reached age 4. Based on data from the life history investigation, CDFG found that age 4 fish can make up a high percentage of the escapement in some years, ranging from 44 to 89% (CDFG 2004a). These numbers were calculated using coded-wire tag data that were standardized for release size.

Historical Distribution

Yoshiyama et al. (2001) provided a narrative description of the historical distributional limits and abundances of Chinook within the Central Valley watersheds. Schick et al. (2005) expanded on this work using a geographic information system (GIS) to add more explicit spatial information. They grouped spring-run into four diversity units: (1) upper Sacramento spring-fed (Little Sacramento, Pit, Fall, Hat, McCloud, Battle, Mill, and Deer Creeks); (2) upper Sacramento rain driven (Butte, Big Chico, Antelope, Clear, Cottonwood/Beegum, Thomes, and Stony Creeks); (3) lower Sacramento-San Joaquin northern Sierra (Feather, Yuba, and American Rivers); and (4) lower Sacramento-San Joaquin southern Sierra (Mokelumne, Stanislaus, Tuolumne, Merced, San Joaquin, and Kings Rivers).

Lindley et al. (2007) divided spring-run into slightly different diversity units: (1) basalt and porous lava (Little Sacramento, Pit, Fall, Hat, McCloud and Battle Creeks); (2) Northern Sierra Nevada (Mill, Deer, Antelope, Butte, and Big Chico creeks and Feather, Yuba, American, and Mokelumne Rivers); (3) Northwestern California (Clear, Cottonwood/ Beegum, Thomes, and Stony Creeks); and (4) Southern Sierra Nevada (Stanislaus, Tuolumne, Merced, San Joaquin, and Kings Rivers).

This Background Report relies heavily on the historical distribution of spring-run and steelhead information presented in Yoshiyama et al. (2001) and Schick et al. (2005). Because the HEA specifies that the target of habitat expansion actions is the Sacramento River basin, this report addresses only the first three diversity units described by Schick et al. (2005).

In the upper Sacramento spring-fed unit, spring-run Chinook could have accessed approximately 43 kilometers (km) (27 miles) of habitat in the Pit River, 11.5 km (7 miles) in the Fall River, 3.5 km (2 miles) in Hat Creek, and 25 km (15.5 miles) in the McCloud River prior to the construction of Shasta Dam (Schick et al. 2005). The Pit River was a “noted salmon stream” in the late 1800s, but a substantial decline occurred prior to 1929 (Yoshiyama et al. 2001). Both the Fall River and Hat Creek are tributaries of the Pit River and were noted to support spring-run spawning, but not to the same extent as Pit River (Yoshiyama et al. 2001). Yoshiyama et al. (2001) noted that access to all of the tributaries was impeded by gold mining and irrigation activities prior to the construction of Shasta Dam.

For the tributaries below Shasta Dam, spring-run Chinook could have accessed approximately 26 km (16 miles) of habitat in Battle Creek (including both the North and South Forks), 25 km (15.5 miles) in Mill Creek, and 20.5 km (13 miles) in Deer Creek (Schick et al. 2005). All three of these tributaries naturally provided spatial separation between spring-run and fall-run (Yoshiyama et al. 2001). Reynolds et al. (1993) noted that surveys conducted prior to the construction of Shasta Dam indicated that Battle Creek could support 1,800 spawning pairs in the reaches above the Coleman National Fish Hatchery. By the 1920s, spawning reaches on both the North and South Forks were blocked by diversion dams associated with hydroelectric projects, which also altered streamflows. Clark (1929) noted that a small spring run still existed above the U.S. Bureau of Fisheries egg-collecting station and hatchery. By the 1980s, however, very few if any spring-run Chinook were observed in Battle Creek (Campbell and Moyle 1990). Spring-run Chinook have been observed in both Cow Creek and Bear Creek in low numbers (CH2M Hill 1998). Both creeks are predominantly rain fed and were probably used by spring-run only in years with above-normal rainfall (CH2M Hill 1998).

Mill Creek supported rather “large” runs of spring-run Chinook with few human-made obstacles, mainly diversion dams near the valley floor (Yoshiyama et al. 2001). Escapement ranged from <500 to 3,000 fish between 1947 and 1959 (Fry 1961). Overall, the trend was downward between the 1940s and the 1980s, from an annual average of 2,000 to about 300 fish (CDFG 1990).

Deer Creek also had a strong population of spring-run until diversion dams were built and reduced instream flows (Clark 1929). Habitat in Deer Creek was expanded by about 5 miles above Lower Deer Creek Falls in the early 1940s to mitigate for the construction of Shasta Dam (Needham et al. 1941). Deer Creek has adequate habitat to support a sustainable population of 4,000 spring-run but insufficient flows can impede or prevent upstream passage (Reynolds et al. 1993). Like Mill Creek, escapement ranged from <500 to 4,000 fish between 1940 and 1956 (Fry 1961). The escapement decreased between the 1940s and the 1990s from an average annual of 2,200 to 660 fish (Yoshiyama et al. 2001).

For the east side tributaries in the upper Sacramento rain-fed unit, spring-run Chinook had access to approximately 14.5 km (9 miles) of habitat in Antelope Creek, 29 km (18 miles) in Butte Creek, and 11 km (7 miles) in Big Chico Creek (Schick et al. 2005). Access and use of these tributaries have been limited by water diversions since the 1920s (Yoshiyama et al. 2001).

Antelope Creek historically supported a low number of spring-run Chinook with an estimated escapement of approximately 500 fish (Reynolds et al. 1993). Reynolds et al. (1993) noted that operations of two water diversions during the irrigation season impede or prevent the upstream migration of spring-run in most years. Big Chico Creek also supported low numbers of spring-run and was primarily used opportunistically (Reynolds et al. 1993). Reynolds et al. reported that the population was <500 during the 1950s and 1960s, and dropped to <200 fish in the 1990s. Butte Creek historically supported the largest population of the three tributaries but was heavily impacted by water diversions, dams, and weirs by the 1920s (Clark 1929). CDFG (1960) reported adults still being lost to unscreened diversions as late as 1958 to 1960. Extensive mining and hydroelectric development also reduced the amount of suitable habitat in the watershed (Hanson et al. 1940). Escapement ranged from <500 to 3,000 fish in the 1950s but dropped to 100 to 700 fish by the early 1990s (Fry 1961, CDFG 1998).

The west-side tributaries of the Sacramento River, including Clear Creek, Cottonwood/Beegum Creek, Thomes Creek, and Stony Creek, also provided some suitable habitat for spring-run (Yoshiyama et al. 2001). Clear Creek provided approximately 15 km (9 miles) of suitable habitat while Cottonwood Creek provided 10 km (6 miles) and Stony Creek 28 km (17 miles) (Schick et al. 2005). These creeks, along with a dozen other small tributaries, occasionally supported small runs of <500 fish (Fry 1961). Low flows associated with irrigation noticeably affected both passage and water temperatures for spring-run by the late 1920s (Clark 1929).

Three river systems in the lower Sacramento-San Joaquin Northern Sierra unit drain into the Sacramento River: the Feather, Yuba, and American Rivers. All three river drainages historically supported a substantial number of spring-run Chinook in their upper watersheds (Yoshiyama et al. 2001). Extensive mining, irrigation, and the development of hydroelectric dams significantly reduced the amount of suitable habitat in all three drainages (Yoshiyama et al. 2001). Schick et al. (2005) estimated approximately 114 km (71 miles) of suitable habitat for spring-run in the Feather River. Spring-run used all four major tributaries of the Feather River but primarily used the Middle Fork for spawning (CDFG 1952, Fry 1961, DWR 2007). Hydropower dams and other structures blocked much of the historical habitat prior to the construction of Oroville Dam in 1967, which formed a complete barrier for migration into the upper watershed.

The Yuba River contributed 19.5 km (12 miles) of habitat. Much of this habitat was seriously impacted by both diversion dams and mining activities starting in the late 1800s (Schick et al. 2005, Reynolds et al. 1993). Most of the available habitat was found on the North Fork, but the Middle and South Forks also were used by spring-run (Yoshiyama et al. 2001). Yoshiyama et al. (2001) noted that access to all forks was greatly impeded by Daguerre Point Dam around 1910 and was blocked completely with the completion of Englebright Dam in the late 1930s.

The American River contributed an additional 80.5 km (50 miles) of suitable habitat historically, but access to this habitat was impeded by construction of diversion dams and was completely blocked in 1955 by completion of Folsom and Nimbus Dams. Prior to completion of these dams, spring-run used all three forks of the American River. Spring-run likely used the North Fork up to the falls at

Royal Gorge, the Middle Fork up to the confluence with the Rubicon River, and the South Fork up to the waterfall at Eagle Rock (Yoshiyama et al. 1996).

Current Distribution

In the upper Sacramento spring-fed unit, spring-run Chinook no longer have access to the Pit River, the Fall River, Hat Creek, the McCloud River, or the Little Sacramento River due to construction of Shasta Dam (Schick et al. 2005). For the tributaries below Shasta Dam, spring-run Chinook access to Deer and Mill creeks remains essentially unchanged. However, much of the historical habitat on Battle Creek is no longer accessible (Schick et al. 2005). Approximately 2.9 km (2 miles) of habitat on the mainstem remains accessible, but access is blocked on both the North and South Forks.

For both the east-side and west-side tributaries of the Sacramento River in the upper Sacramento rain-fed unit, the amount of available habitat for spring-run Chinook remains essentially the same (Schick et al. 2005). However, access and use of these tributaries are limited by water diversions. Spring-run habitat on Stony Creek was blocked due to construction of Black Butte Reservoir and is no longer used by spring-run Chinook (Reynolds et al. 1993). In all of the other tributaries, except Butte Creek, only remnant spring-run populations remain (Yoshiyama et al. 2001). The Butte Creek population has been increasing over the last decade due to passage improvements made in the late 1990s (CDFG 2004b).

In the lower Sacramento-San Joaquin Northern Sierra unit, much of the historical habitat is blocked by dams. On the Feather River, only 35 km (22 miles) of habitat on the mainstem below Oroville Dam remains, and there is no spatial or temporal separation between spring-run and fall-run Chinook (Schick et al. 2005). This has resulted in the hybridization of the two runs from in-river spawning and past hatchery operations (Yoshiyama et al. 2001). However, an early-returning population persists within both the Feather and Yuba Rivers and is supported by Feather River Hatchery operations (Yoshiyama et al. 2001, DWR 2007, Lindley et al. 2007). On the Yuba River, most of the historical habitat was blocked by construction of Daguerre Point and Englebright Dams. Access to the North Yuba, Middle Yuba, and South Yuba Rivers is blocked, leaving about 12 km (7.5 miles) of spawning habitat on the lower Yuba River below Englebright Dam (Schick et al. 2005). The Yuba River has experienced the same problem with hybridization between spring-run and fall-run due to the lack of spatial and temporal separation (Yoshiyama et al. 2001). There is no suitable habitat for spring-run on the American River below Nimbus Dam.

Population Viability Assessment

In 2000, NMFS published a technical memo describing the viable salmonid population (VSP) concept and providing guidance for determining the conservation status of populations (McElhany et al. 2000). Lindley et al. (2007) built upon that work and developed a more quantitative framework for assessing the viability of Chinook and steelhead ESUs in the Central Valley.

McElhany et al. (2000) defined a viable salmonid population as an independent population that has a negligible risk of extinction over a 100-year time frame, where an independent population has one or more local breeding units whose dynamics are not substantially altered by exchanges of individuals with other populations. McElhany et al. used four parameters (abundance, population growth rate, population spatial structure, and diversity) to evaluate population viability status. The following discussion of the four parameters is drawn from their report.

According to the abundance VSP guidelines, a viable population size would meet the following criteria: (1) large enough to have a high probability of surviving environmental variation comparable to what has been observed in the past and expected in the future; (2) large enough for compensatory processes to provide resilience; (3) large enough to maintain genetic diversity over the long term; (4) large enough to provide important ecological functions throughout its life cycle; and (5) population estimates on average are above the population targets over a period of time. If the population size meets any of the following critical size guidelines, it cannot be considered viable: (1) compensatory processes are likely to reduce it below replacement; (2) risk of inbreeding or fixation of deleterious mutations; (3) high risk of productivity variation due to demographic stochasticity (population highly unpredictable); or (4) population estimates on average are below the population targets over a short period of time.

When estimates of population growth rates indicate that a population is consistently failing to replace, the risk of extinction is increased regardless of the cause. McElhany et al. (2000) focused on the population growth rate over the entire life cycle but noted that it is also important to estimate stage-specific productivity when evaluating population viability. Even if stage-specific declines do not result in a reduction in the total population, they may indicate a lack of resilience to variation. On the other hand, a viable population would meet the following population growth rate VSP guidelines: (1) natural productivity is sufficient to maintain abundance above the viable level (cohort-replacement rate ≥ 1); (2) if the population includes naturally spawning hatchery fish, the productivity of the naturally produced spawners is sufficient to maintain abundance at or above viability thresholds without the hatchery subsidy; (3) productivity is sufficient during freshwater life history to maintain a viable abundance even during poor ocean conditions; (4) does not exhibit sustained declines that span multiple generations and multiple brood-year cycles; (5) does not exhibit trends or shift in traits (i.e., the size and age of spawners) that portend declines in the growth rate; and (6) has an adequate time series of abundance to detect ecologically significant trends before substantial changes to abundance have occurred.

The spatial structure guidelines address both the geographic distribution of individuals and the processes that generate that distribution. Because a population's structure depends on habitat quality, spatial configuration, dynamics, and the dispersal characteristics of the individuals the VSP guidelines include (1) habitat patches that are not destroyed faster than they are naturally created; (2) natural straying rates among subpopulations is not be substantially increased or decreased by human actions; (3) some suitable or marginally suitable habitat patches that currently contain no fish are maintained; (4) source subpopulations are maintained; and (5) historical spatial processes are preserved as a default goal.

Diversity (i.e., variation in traits) within and among populations is important for population viability. Salmon traits such as anadromy, morphology, fecundity, run timing, spawn timing and behavior, juvenile behavior, age at smolting and maturity, egg size, developmental rate, ocean distribution, and genetic characteristics allow for considerable diversity. Nevertheless, any actions that affect basic demographic and evolutionary processes can affect a population's diversity. Diversity guidelines for a viable population include (1) variation in traits such as run timing, age structure, size, fecundity, morphology, behavior, and molecular genetic characteristics that are not substantially altered by human-caused factors; (2) natural processes of dispersal are maintained and human-caused factors do not substantially change the gene flow rate among populations; (3) natural processes that cause ecological variation are maintained; and (4) historical phenotypic diversity is used as a default goal in maintaining viable populations.

McElhany et al. (2000) also developed guidelines for assessing the viability of ESUs. The guidelines are (1) the ESU has multiple populations; (2) some populations are geographically widespread; (3) some populations are geographically close; (4) populations do not all share common catastrophic risks; (5) populations display diverse life histories and phenotypes; (6) some populations exceed VSP guidelines; and (7) historical number and distribution of populations are used as a default goal for maintaining viable ESUs.

Using a criteria-based assessment, Lindley et al. (2007) found that the Central Valley spring-run ESU is not viable because only a small portion of the historical ESU is represented and the remaining populations are vulnerable to catastrophic disturbance. However, those existing populations are at low risk of extinction. Lindley et al. (2007) identified four ecoregions within the ESU historically: (1) basalt and porous lava region; (2) northern Sierra Nevada region; (3) southern Sierra Nevada region; and (4) Northwestern California region. The only viable spring-run Chinook populations remaining are in the northern Sierra Nevada region (Butte, Mill, and Deer Creeks). This current distribution leaves the ESU vulnerable to catastrophic disturbances from volcanic activity (Mt. Lassen), drought, and wildfires.

Butte Creek and Deer Creek spring-run populations satisfied both the population viability assessment (PVA) and other viability criteria putting them at low risk of extinction while Mill Creek is at moderate risk of extinction based on the PVA but satisfies other viability criteria (Lindley et al. 2007). Some uncertainty remains about whether Mill and Deer Creek populations are independent or if they belong to a single larger population (Lindley et al. 2004). Lindley et al. (2007) also noted the presence of ephemeral or dependent populations in the Northwestern California region. Due to insufficient data, they were not able to assess the status of the early-returning Chinook within the Feather River Hatchery population that spawn in both the Feather and Yuba Rivers.

Viability assessments use conditions from the recent past to address whether a population will persist in the future. Future conditions are unlikely to be similar to the recent past, however, because of expected climatic changes. Lindley et al. (2007) noted that the criteria they proposed may not offer sufficient protection if a prolonged period of unfavorable climatic conditions occurs. Regional-scale climate models for California broadly agree that future temperatures will be warmer and that total precipitation may decline with a significant decline in snowfall. Given these changes, all Central Valley salmonids are likely to be negatively affected, especially those using freshwater in summer (Lindley et al. 2007). Lindley et al. noted that habitat availability will decrease as the lower distributional limit rises, given the current upper distributional limits due to dams.

Lindley et al. (2007) assessed three different scenarios for the potential increase in mean summer temperature by 2100 and its effect on the availability of historical habitat above the 25 °C isotherm. Under the most conservative increase of 2 °C, the loss of historical habitat would be low except for in the southern Sierra eco-region and in Butte Creek (Lindley et al. 2007). With a more likely increase of 5 °C, historical habitat loss would be significant with some remnant habitat in the upper reaches of the basalt and porous lava (Pit and McCloud Rivers) and the northern Sierra ecoregions (Battle and Mill Creeks, and Feather and Yuba Rivers). Under this scenario, most of the remaining habitat would be found on the Feather and Yuba Rivers. Lindley et al. (2007) also estimated that, under an 8 °C increase, spring-run habitat would be found only in the uppermost reaches of the North Fork Feather River, Battle Creek, and Mill Creek. Changes in hydrology are also expected to impact Central Valley salmonids by reducing the quantity and quality of freshwater habitat.

Central Valley Steelhead

Listing Status

As noted, in 1998, NMFS listed the Central Valley steelhead ESU as threatened under the federal ESA (NMFS 1998). This ESU includes all naturally spawned populations of steelhead in the Sacramento and San Joaquin Rivers and their tributaries (NMFS 1998 as cited in DWR 2007). The original critical habitat designation was withdrawn, and NMFS published a final designation of critical habitat in 2005 (DWR 2007). The critical habitat designation includes the Sacramento, lower Feather, and Yuba Rivers; Battle, Cottonwood, Antelope, Mill, Deer, Butte, and Big Chico Creeks; and the Cosumnes, Mokelumne, Calaveras, and San Joaquin Rivers and tributaries to the San Joaquin (NMFS 2004).

General Life History

The life history of steelhead is more complex than other Pacific salmonids; steelhead exhibit both anadromous and freshwater resident traits. The freshwater residents are referred to as rainbow trout. Steelhead are divided into two basic reproductive ecotypes. Stream-maturing steelhead, also referred to as *summer steelhead*, are sexually immature upon freshwater entry and mature in the river over the summer (Busby et al. 1996). The ocean-maturing steelhead, or winter steelhead, enter freshwater with well developed gonads and spawn soon after reaching the spawning grounds. Unlike Chinook, steelhead are iteroparous (capable of spawning more than once), but they rarely spawn more than twice (Busby et al. 1996). Historically, both summer and winter steelhead were found in the Central Valley (Needham et al. 1941). Currently, only winter steelhead have been identified in the Central Valley (McEwan 2001).

Winter steelhead enter freshwater between August and April, and spawning occurs from December to May (Busby et al. 1996, NMFS 2002). In the Sacramento River basin, spawning generally peaks between January and March (NMFS 2002). Steelhead use cool, well oxygenated water with velocities ranging from 1 to 3.6 feet per second for spawning (McEwan 2001). The incubation time depends on water temperature, dissolved oxygen concentration, and substrate; fry generally emerge in late spring (NMFS 2002). The fry use shallow water along perennial streambanks, where they establish and defend feeding stations (Nickelson et al. 1992, McEwan 2001).

YOY steelhead primarily use higher velocity areas in pools for rearing but are also known to use glides and riffles (NMFS 2002). Juveniles use a wider range of habitat types but prefer areas with large and small woody debris and overhead cover (McEwan 2001, NMFS 2002). Older juveniles can also move downstream to rear in larger tributaries or rivers (Nickelson et al. 1992). The juveniles will reside in freshwater from 1 to 4 years and typically emigrate between February and April (NMFS 2002). Central Valley steelhead generally spend 1 to 2 years in the ocean before returning to spawn (Busby et al. 1996).

Recent studies have shown that Central Valley steelhead and rainbow trout are polymorphic, finding that anadromous females can produce non-anadromous progeny and non-anadromous females can produce anadromous progeny (McEwan 2001, Zimmerman et al. 2008). Research by Zimmerman et al. (2008) suggests that the portion of steelhead progeny may differ between location and years.

Historical Distribution

Information on the historical distribution of Central Valley steelhead is limited and not as well documented as for Central Valley Chinook salmon. McEwan (2001) provides evidence supporting the conclusion that steelhead distribution can be inferred from Chinook salmon distribution, especially spring-run Chinook salmon which has many of the same requirements for spawning and rearing. Yoshiyama et al. (1996) concluded that steelhead distribution was probably broader than Chinook salmon:

[Steelhead were] undoubtedly more extensively distributed [than Chinook salmon in the Central Valley]. Due to their superior jumping ability, the timing of their upstream migration, which coincided with the winter rainy season, and their less restrictive preferences for spawning gravels, steelhead could have used at least hundreds of miles of smaller tributaries not accessible to the earlier-spawning salmon.

The available information indicates that steelhead used both the Sacramento River and San Joaquin River basins from the Pit River south to the Kings River (McEwan 2001). Like Chinook salmon, extensive mining, dams, and low flows impacted the distribution of steelhead starting in the late 1800s.

Lindley et al. (2006) reconstructed the historical distribution and population structure using models to predict the spatial location of stream locations and identifying suitable habitats within stream segments. They identified 81 independent populations of steelhead within four major subdivisions in the Central Valley ESU. The four subdivisions are (1) Sacramento River basin; (2) Suisun Bay area tributaries; (3) San Joaquin tributaries draining the Sierra Nevada; and (4) streams that drained to the Buena Vista and Tulare basins. Like McEwan (2001) and Yoshiyama et al. (1996) they found that *O. mykiss* was probably more abundant in the Sacramento basin than in the San Joaquin basin. The San Joaquin tributaries have steeper gradients and sometimes lower flow and therefore have more natural barriers to migration (Lindley et al. 2006).

This report focuses on the distribution of steelhead in the Sacramento River basin.

Current Distribution

The current distribution is limited in most areas due to impassable dams in the Central Valley. Reynolds et al. (1993) reported that approximately 95% of the historical habitat has been lost due to both mining and water development activities.

Because of limited steelhead monitoring efforts, the current distribution is not clearly known (McEwan 2001). Based on Chinook monitoring data collected by CDFG and USFWS, steelhead are still found in several upper Sacramento tributaries, including Clear, Antelope, Deer, Mill, Butte, and Battle Creeks (Busby 1996, Low et al. 2007). Lindley et al. (2006) reported that historical habitat may still be accessible in a few streams including Mill, Deer, Butte, and Cottonwood Creeks. Naturally spawning steelhead are also found on the American, Feather, Yuba, Mokelumne, and mainstem Sacramento Rivers; but the hatchery influence on these fish remains unknown (Busby et al. 1996). Changes to the thermal regime and food web structure (Lieberman et al. 2001) on these regulated rivers may be more beneficial for the resident forms, thus altering the proportion of anadromous to resident forms in these larger rivers.

Population Viability Assessment

Lindley et al. (2007) were not able to quantitatively assess the viability of Central Valley steelhead due to data deficiencies. Although they did not find any evidence of a low extinction risk for the ESU, the significant loss of historical habitat, habitat fragmentation, and degradation are likely adversely affecting both the anadromous and resident *O. mykiss* populations. Based on qualitative data and assessment of hatchery-supported populations, Lindley et al. (2007) determined that the existing populations are not viable and that the Central Valley ESU has a moderate to high risk of extinction.

Like spring-run Chinook, Central Valley steelhead populations are susceptible to the impacts of the predicted climate changes addressed by Lindley et al. (2007). Because spring-run and steelhead currently use much of the same habitat in the Sacramento River basin, steelhead will probably be affected much to the same extent in the tributaries as described for spring-run.

Restoration Activities in the Sacramento River Basin

Central Valley Project Improvement Act

In the mid-1990s, several state and federal restoration programs were developed to protect and restore anadromous salmonid populations within the Central Valley. The Central Valley Project Improvement Act (CVPIA) was amended to assign equal priority to fish and wildlife protection, restoration, and mitigation as to other Central Valley Project (CVP) projects (Reclamation and USFWS 2001). Under Section 3406 of the CVPIA, the Department of Interior was required to implement the Anadromous Fish Restoration Program (AFRP) which includes reoperation of the CVP to achieve the goals outlined in the AFRP Final Restoration Plan, implementing a Habitat Restoration Program, and dedicating 800,000 acre-feet of CVP yield annually for fish and wildlife (known as *(b)(2) water*) on CVP-operated rivers and streams (Reclamation and USFWS 2001). The CVP yield is used to improve upstream flows, meet water quality standards set forth in State Water Board Decision D-1641, and reduce entrainment at the CVP pumping facility in Tracy. The CVPIA also requires implementation of a supplemental water acquisition program, anadromous fish flow pulses, elimination of flow fluctuations, Clear Creek restoration, gravel replenishment, a Comprehensive Assessment and Monitoring Program, and an Anadromous Fish Screen Program (Reclamation and USFWS 2001).

The CVPIA required the Secretary of the Interior to develop and implement the AFRP, which was to make all reasonable efforts to ensure that by 2002 the natural production of anadromous fish in the Central Valley rivers and streams be self-sustaining at levels at least double the average levels from 1967 to 1991 (USFWS 2001). In 1995, the AFRP Core Group prepared a Working Paper on Restoration Needs; in 2001, they completed the Final Restoration Plan for the AFRP. Since the mid-1990s, USFWS has implemented AFRP restoration activities on several tributaries in the upper Sacramento River basin, including Mill, Deer, Butte, Clear, and Battle Creeks, to support these restoration goals.

As the amended CVPIA was being implemented, other programs were being developed, including CALFED and the Trinity River Mainstem Fishery Restoration Program (Reclamation and USFWS 2001). In light of that, many CVPIA efforts were coordinated with CALFED efforts in the Central Valley, especially the CALFED Ecosystem Restoration Program (ERP), as described below.

CALFED

In 1994, state and federal agencies joined with stakeholders and agreed to the Bay-Delta Accord, an agreement to develop a long-term comprehensive plan to restore the Bay-Delta for all beneficial uses. The Bay-Delta Accord led to the formation of CALFED, a cooperative effort to restore the ecological health of the Bay-Delta, improve water supply reliability, protect drinking water quality, and protect Delta levees (Reclamation and USFWS 2001). One of the several programs created through this process was the ERP.

The ERP was designed to maintain, improve, and increase both aquatic and terrestrial habitats in the Bay-Delta through the restoration of ecological processes (CALFED 2001). The ERP also was designed to recover at-risk species, such as anadromous salmonids, that are dependent on the Delta. The ERP is implemented using an ecosystem-based adaptive management approach with defined goals and objectives for ecosystem habitat and species rehabilitation projects (CALFED 2001). Three types of management actions (targeted research, pilot or demonstration projects, and full-scale implementation projects) are funded through the ERP (CALFED 2001). Since 1997, the ERP has funded numerous restoration projects in the upper Sacramento River basin.

NMFS is currently preparing a recovery plan for winter and spring-run Chinook and Central Valley steelhead. A co-manager review draft of the recovery plan was released in May 2008 that identified numerous recovery actions for the Sacramento River basin tributaries to benefit spring-run Chinook and steelhead. These actions include identifying and implementing projects to improve water temperature (reduce fire risk, restore meadows, and increase riparian shade), conduct fish passage evaluations at agricultural diversions, evaluate and dedicate instream flows to facilitate passage, implement gravel augmentation projects, fortify streambanks to reduce fine sediments, monitor water quality, and modify sport fishing regulations (NMFS 2008).

Sacramento River Basin Tributaries: Status of Spring-Run Chinook Salmon and Steelhead

Table 1 displays the historical estimates of spring-run Chinook salmon escapement in the Sacramento River basin tributaries along with the range of escapement estimates for the period from 1960 to 2007. Figures 1 through 3 display the estimated adult spring-run populations from 1960 to 2007 in tributaries where estimates are available.

Data acquired from CDFG GrandTab. Data for 2005 to 2007 are preliminary and subject to revision.

The Feather River estimate includes both in-river and hatchery counts. Data acquired from CDFG GrandTab. Data for 2005 to 2007 are preliminary and subject to revision.

Data acquired from CDFG GrandTab. Data for 2005 to 2007 are preliminary and subject to revision.

For this report, monitoring information was taken from the Central Valley Salmon and Steelhead Monitoring Program Summary (Low et al. 2007) unless otherwise stated. This report focuses on the monitoring activities for adult salmonids and does not include information on juvenile salmonid monitoring in the Central Valley.

The following sections describe the spawning/holding habitat, rearing habitat, monitoring activities, limiting factors, and restoration activities for tributaries that are known to support spring-run Chinook or steelhead in the upper Sacramento River basin.

Table 1. Escapement Estimates for Spring-Run Chinook in the Sacramento River Basin Tributaries from Historical Records and Monitoring Data (1960–2007)

Tributary	Historical Abundance	Source	CDFG GrandTab Estimate 1960–2007 (min-max)
Battle Creek	1,700–2,200; 1,800	CDFG (1998); Reynolds et al. (1993)	2–291
Cow Creek	unknown		No survey for spring-run
Bear Creek	unknown		No survey for spring-run
Clear Creek	< 500	Fry (1961)	0–194
Antelope Creek	<= 500	Reynolds et al. (1993)	0–154
Mill Creek	300–3,000; <= 3,500; 3,000–4,000	Fry (1961) & CDFG (1990); CH2M Hill (1998); CDFG (1998)	61–3,500
Deer Creek	500–4,000	Fry (1961) & Yoshiyama et al. (2001)	84–8,500
Butte Creek	100–3,000	Fry (1961) & CDFG (1998)	10–20,259
Big Chico Creek	< 200–500; 1,000	Reynolds et al. (1993); CH2M Hill (1998)	0–500
Cottonwood Creek	<= 500	Fry (1961)	0–477
Thomes Creek	< 500	Fry (1961)	0–2
Stony Creek	< 500	Fry (1961)	(Extirpated)
Feather River (in-river)	1,700; 500–4,000; 8,000–20,000	CH2M Hill (1998); CDFG (1998) & Fry (1961); Moyle (2002)	2–2,908
Yuba River	unknown; 6,000–10,000	no early CDFG records; Moyle (2002)	108–200
American River	unknown; >= 10,000	no early CDFG records; Moyle (2002)	(Extirpated)

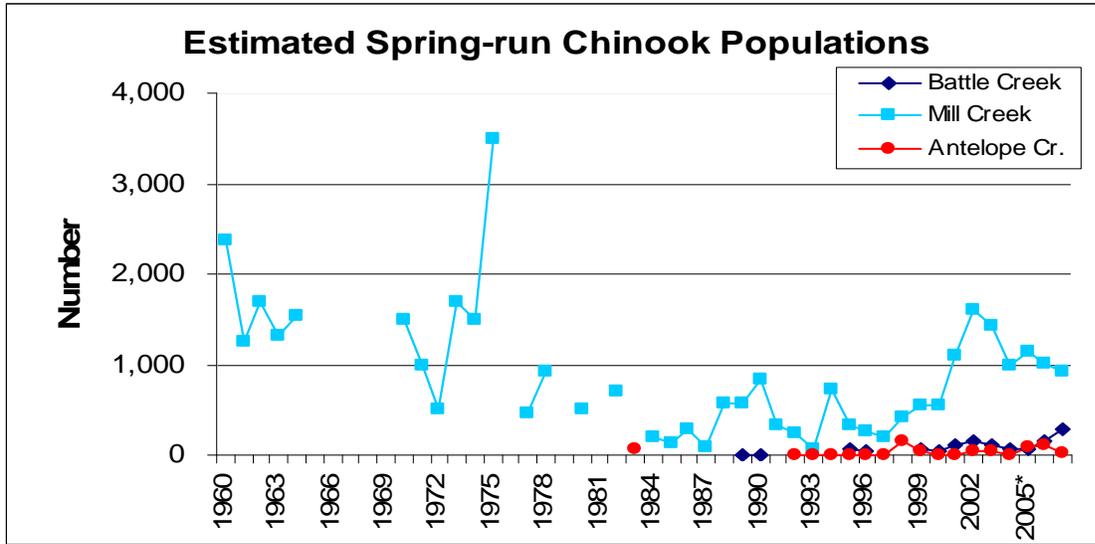


Figure 1. Estimated Adult Spring-Run Chinook Populations for Battle, Mill, and Antelope Creeks (1960–2007)

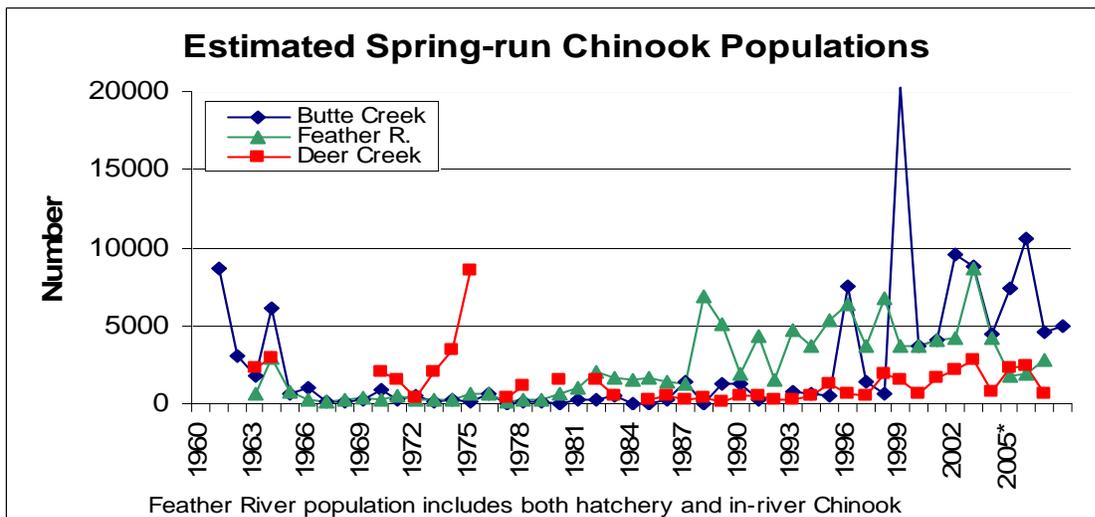


Figure 2. Estimated Adult Spring-Run Chinook Populations for Butte Creek, Deer Creek, and Feather River (1960–2007)

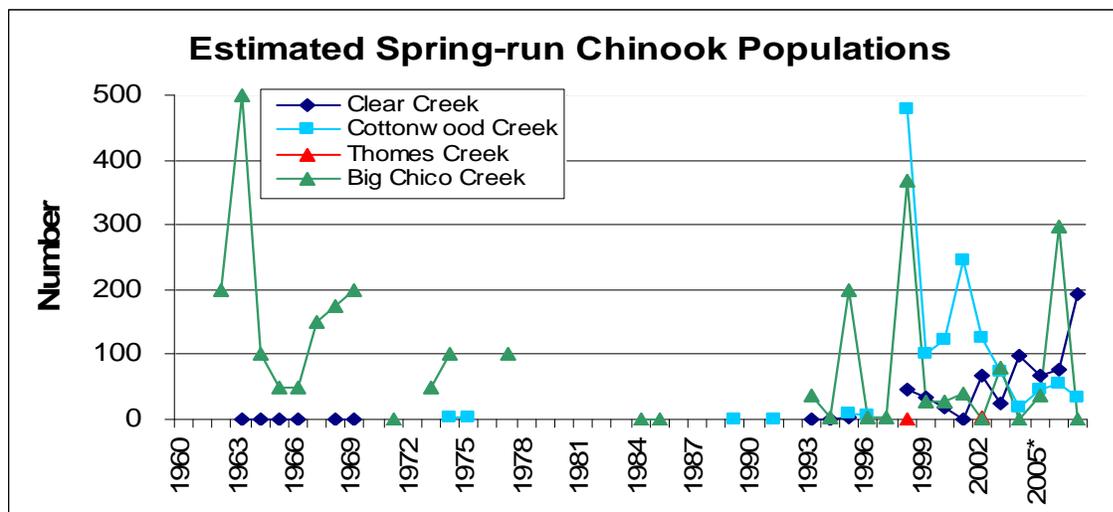


Figure 3. Estimated Adult Spring-Run Populations for Clear, Cottonwood, Thomes, and Big Chico Creeks (1960–2007)

Clear Creek

Spawning/Holding Habitat

Clear Creek is approximately 18.1 miles long between the confluence with the Sacramento River and Whiskeytown Dam. Whiskeytown Dam is a total barrier to salmonid migration in Clear Creek. The elevation for this reach drops from 1,000 feet to 400 feet above mean sea level (Newton and Brown 2004). USFWS identified two predominant stream channel types in Clear Creek. The upper reaches from Whiskeytown Dam down to Clear Creek Road Bridge (River Mile [RM] 8.5) have steep canyon walls with falls, high-gradient riffles, and deep pools. Below Clear Creek Road Bridge, the stream channel widens into an alluvial reach with a much lower gradient.

Since 2001, the Dedicated Project Yield Program—authorized by Section 3406(b)2 of the CVPIA—has provided additional water year-round to increase streamflow. The increased flows and resulting lower water temperatures improve passage, holding, spawning, and rearing conditions for both spring-run Chinook and steelhead (Giovannetti and Brown 2007). The goal of the flow targets is to provide access to 90% of the maximum possible weighted usable area (Reclamation and USFWS 2007).

The additional streamflows to manage water temperature also allow fall-run Chinook to access the reaches above Gorge Cascade (RM 6.5). Because USFWS was concerned about the effects of hybridization and redd superimposition between spring-run and fall-run Chinook, they installed a temporary picket weir at RM 8.09 in 2003 (Newton and Brown 2005). The weir limits spring-run Chinook to approximately 10 miles of spawning and holding habitat but ensures spatial separation of the two runs. The weir is installed in late August and removed in early November to allow steelhead access to the entire creek.

Water temperatures are managed to support spring-run spawning and egg incubation. Water temperature is maintained at <56 °F at the Igo gage (RM 10.8) for spring-run spawning from

September 15 through October 30 under the biological opinion for the operation of the CVP and the State Water Project (NMFS 2002).

Gravel augmentation has substantially increased the amount of spawning habitat for both Chinook and steelhead in Clear Creek (Giovannetti and Brown 2007). Smaller gravel has been injected below Whiskeytown Dam specifically to improve steelhead spawning. Giovannetti and Brown (2007) found that 30 to 40% of the steelhead redds had injection gravel in them between 2001 and 2007, suggesting that habitat is still limiting spawning or that the gravel injection is providing more suitable spawning habitat for steelhead.

Rearing Habitat

Brown (1996) calculated the change in percent of optimum habitat at various instream flows and estimated a 15% increase in rearing habitat when flows were increased from 50 to 150 cubic feet per second (cfs). Currently, flows are maintained at 200 cfs from mid-September through mid-June to support juvenile salmonid rearing and emigration.

USFWS and the CALFED Environmental Water Program (EWP) are currently working with the U.S. Bureau of Reclamation (Reclamation) to reoperate Whiskeytown Dam in spring to reactivate fluvial processes within Clear Creek (Reclamation and USFWS 2007). The reoperation would involve producing a 1-day flow of 3,250 cfs three times in a 10-year period. The process would help support juvenile salmonid rearing by re-creating and maintaining diverse instream and floodplain habitat in Clear Creek. In addition, ongoing floodplain and channel reconstruction projects have helped restore the natural form and functions to rearing habitat in the lower watershed (Giovannetti and Brown 2007).

Monitoring Activities

USFWS staff conducts a snorkel survey monthly from late April through August and twice a month from September to early November to determine the relative abundance of adult spring-run Chinook in Clear Creek. Nearly the entire length of Clear Creek is surveyed starting near the mouth at RM 1.7 up to Whiskeytown Dam. The survey is also used to evaluate the distribution of immigrating and spawning Chinook. USFWS has conducted this survey annually since 1999. No long-term annual spring-run escapement surveys were conducted prior to 1999 in Clear Creek.

As part of the spring-run snorkel survey, USFWS staff counts live steelhead/ rainbow trout. USFWS also conducts a late-fall Chinook and steelhead redd survey by kayaking essentially the entire length of Clear Creek monthly from December through April. USFWS has conducted the survey since 1999, providing data on the number of steelhead/rainbow trout redds and the temporal and spatial spawning distribution within Clear Creek.

Limiting Factors

Whiskeytown Dam remains a total barrier limiting habitat access and gravel transportation. Flow and water temperature are controlled by dam operations and could be affected by climate change. The stable flows also modify fluvial processes that can affect the quality of juvenile rearing habitat. There is also no permanent spatial separation of fall and spring-run Chinook in Clear Creek.

Restoration Activities

Built in 1903, McCormick Saeltzer Dam (RM 6.5) was a total barrier to spring-run Chinook migration. A fish passage structure was added in 1958, but it was unsuccessful. In 1992, the structure was modified to improve fish passage. Passage increased slightly, but debris commonly blocked access through the structure (Newton and Brown 2004). The McCormick Saeltzer Dam was completely removed in 2000, providing access to the full length of Clear Creek up to Whiskeytown Dam.

The current flow schedule to increase flows and lower water temperature was developed based on an instream flow incremental methodology (IFIM) study conducted in the 1980s. The schedule may be revised based on a new IFIM study being developed by USFWS (Reclamation and USFWS 2007).

Gravel augmentation below Whiskeytown Dam started in 1995; since then, approximately 110,000 tons of gravel has been injected into the creek (Reclamation and USFWS 2007). The goal of the project is to replace the amount of spawning habitat that existed before construction of the dam by 2020. Meeting this goal will provide approximately 347,000 square feet of spawning habitat (Reclamation and USFWS 2007).

A 2-mile section in the lower portion of the creek that was significantly degraded by mining is currently being restored. Phases 1, 2A, and 2B of the Stream Channel Restoration Project were completed between 1998 and 2001. Gravel extraction pits were filled in to reduce stranding and predation and to restore floodplain function. Phase 3A was completed in 2002 by relocating a section of stream channel along with continued restoration of the floodplain. Monitoring in the new channel documented more than a 400% increase in spawning area use for fall Chinook (Reclamation and USFWS 2007). Geomorphic monitoring associated with the Stream Channel Restoration Project indicated that the stream channel and floodplain are functioning as intended and juvenile Chinook rearing was higher than expected (Reclamation and USFWS 2007). Phase 3B was completed in 2008 and involved creating spawning riffles and continuing revegetation efforts. The final phase (Phase 3C), currently in the design and permitting phase, involves realigning the stream channel and rebuilding the floodplain in the lowest reach of the restoration project to improve rearing habitat.

The extensive restoration efforts and flow supplementation have improved conditions in Clear Creek for both spring-run Chinook and steelhead. This restoration has allowed for the successful re-establishment of spring-run Chinook into the watershed and has increased the steelhead population.

Cow Creek

Spawning/ Holding Habitat

The Cow Creek watershed contains six major tributaries, for a combined length of 164.4 river miles (WSRCD and Cow Creek Watershed Management Group 2005). CDFG does not consider Cow Creek suitable for spring-run due to low flows, high water temperatures, and lack of holding pools (CH2M Hill 1998). However spring-run have been documented using Cow Creek and may use the watershed in above-normal water years.

The mainstem of Cow Creek does support fall-run, late fall-run, and limited steelhead spawning (<200); but the lack of summer holding pools makes it unsuitable for spring-run Chinook (SHN Consulting 2001). On Little Cow Creek, Diddy Wells Falls creates a barrier to upstream migration,

except possibly in above-normal flow years. Clover Creek provides spawning habitat up to Clover Creek Falls for fall-run and steelhead. The falls are a total barrier to upstream migration. Upper Whitmore Falls on Old Cow Creek creates a barrier to upstream migration during normal water years (SHN Consulting 2001). The available habitat, above and below the Upper Whitmore Falls, lacks holding pools and adequate spawning gravel for spring-run Chinook; but it does provide some spawning habitat for steelhead (SHN Consulting 2001).

South Cow Creek supports the most anadromous fish use in the Cow Creek watershed; spring-run Chinook have been observed below the PG&E Mill Creek Diversion Dam (SHN Consulting 2001). Adequate spawning grounds are identified above and below the diversion dam for both spring-run and steelhead. This section of the creek also has dense riparian vegetation to help moderate water temperatures (SHN Consulting 2001). Access to spawning areas can be limited in some years due to low flows.

Rearing Habitat

Cow Creek currently provides some habitat for non-natal spring-run Chinook and steelhead rearing but is limited in most years by low flows and high water temperatures (WSRCD and Cow Creek Watershed Management Group 2005).

Monitoring Activities

No systematic monitoring is conducted on Cow Creek for spring-run Chinook or steelhead.

Limiting Factors

WSRCD and Cow Creek Watershed Management Group (2005) identified several factors limiting Chinook populations in Cow Creek, including flows, water temperature, and the lack of fish ladders and screens on diversions. Low flows are caused by numerous irrigation and hydroelectric diversions, and currently Cow Creek is fully adjudicated. Predation of juvenile Chinook by Sacramento pikeminnow, smallmouth bass, and largemouth bass also may be a limiting factor in the lower portions of Cow Creek (SHN Consulting 2001). Grazing, habitat conversion, non-native plants, and land management have altered the vegetation (WSRCD and Cow Creek Watershed Management Group 2005). In addition, fire suppression management has resulted in higher potential for catastrophic wildfires. SHN Consulting (2001) noted that Cow Creek does not have a major storage dam, allowing a more natural hydrograph. Because many diversions do not have minimum flow requirements, flow is limited in most years.

Restoration Activities

The Cow Creek Watershed Management Group worked in partnership with the Western Shasta Resource Conservation District (RCD) to develop the Cow Creek Watershed Management Plan (CCWMP). The CCWMP outlines specific steps to enhance the watershed in each of five categories: water quality and quantity, fisheries, botanical and wildlife resources, fire prevention and fuel management, and education and outreach (WSRCD and Cow Creek Watershed Management Group 2005). The CCWMP objectives for anadromous fish include addressing monitoring needs, developing programs to install screens and ladders, and implementing actions to increase instream flows. The CCWMP also identifies objectives for monitoring water quality, improving water quality

and quantity, protecting and enhancing riparian corridors, and fuel management to avoid catastrophic fires within the watershed.

In March 2009, PG&E filed a License to Surrender Application with FERC for the Kilarc-Cow Creek Hydroelectric Project, FERC No. 606 (Kilarc-Cow Creek Project). As part of the process, PG&E will decommission and remove the Kilarc Development on Old Cow Creek and the Cow Creek Development on South Cow Creek (PG&E 2007a). The Kilarc-Cow Creek Project includes several small diversion dams, approximately 7 miles of water conveyance facilities, and two powerhouses. The project diverts water from North and South Canyon Creeks, Old Cow Creek, Mill Creek, and South Cow Creek (PG&E 2007a). PG&E holds three pre-1914 water rights for a combined diversion of 62 cfs in Old Cow Creek and two pre-1914 water rights for a combined diversion of 70 cfs in South Cow Creek (PG&E 2007a). The Cow Creek Adjudication (decree entered 1969) states that, if the Kilarc-Cow Creek Project is authorized or ordered to decommission, the water rights will be transferred to and used by a resource agency to protect, preserve, or enhance aquatic resources (PG&E 2007a). Decommissioning and removal of the Kilarc-Cow Creek Project should improve passage for Chinook and steelhead in both Old Cow Creek and South Cow Creek.

South Cow Creek has the most suitable spawning and holding habitat for spring-run Chinook in the Cow Creek watershed; however, there is a potential for spatial and temporal overlap with fall-run Chinook.

Restoration of Cow Creek would likely provide more benefits for steelhead than for spring-run Chinook due to the lack of holding habitat in Cow Creek. Past estimates by CDFG suggested that Cow Creek could support steelhead runs of approximately 500 (CDFG 1965 as reported in SHN Consulting 2001).

Bear Creek

Spawning/ Holding Habitat

Bear Creek is a small east-side tributary where rainfall is the primary source of flow (CH2M Hill 1998). Although salmon have access to approximately 24 miles, in low-flow years, the stream can run dry prior to reaching the Sacramento River because diversions exceed the natural flow (CH2M Hill 1998). Due to low flows, warm water temperatures, and lack of large holding pools, only fall-run Chinook and steelhead use Bear Creek consistently (ENPLAN 2006). Spawning runs were estimated at 300 fall-run and 200 steelhead in the 1960s; because no systematic surveys are conducted in Bear Creek, the current population of steelhead is unknown (ENPLAN 2006). Spring-run are not known to spawn in Bear Creek (CDFG 1993). Steelhead have been documented using the mainstem of Bear Creek, North Fork Bear Creek, and Snow Creek. There are no known barriers to migrations in these reaches; however, low flows may prevent adult steelhead from accessing them (ENPLAN 2006).

Rearing Habitat

Non-natal juvenile spring-run Chinook have been reported to use Bear Creek in above-normal water years (ENPLAN 2006). Rearing habitat is a function of the natural hydrologic regime in the Bear Creek watershed; many creeks become intermittent or completely dry in years with below-average precipitation, thus limiting steelhead rearing (ENPLAN 2006). Water diversions in the lower portion of the watershed further reduce rearing habitat for both non-natal spring-run and steelhead.

Limiting Factors

The primary factor limiting spring-run Chinook use of Bear Creek is low flow and the associated increased water temperatures. Limited holding pools; unscreened agricultural diversions; and the effects of timber harvest, fire management, and predation also are limiting factors in this watershed (ENPLAN 2006). DWR is currently conducting a fish passage barrier assessment on Bear Creek, but no recent surveys have been conducted on the amount of suitable spawning habitat and holding pools that exists in the Bear Creek watershed.

Monitoring Activities

No annual monitoring is conducted on Bear Creek for spring-run Chinook or steelhead.

Restoration Activities

The Bear Creek Watershed Group was formed in 2002. With the help of the Western Shasta RCD, they completed both a watershed assessment and water management plan in 2006. Each of the implementation plans outlined in the management plan will be developed as funding becomes available (WSRCD 2006).

The hydrology and water quality objectives include developing and implementing a long-term monitoring program, establishing a baseline geomorphology for the major streams, and implementing projects to increase water quantity and quality within the Bear Creek watershed. The botanical objectives include conducting vegetation inventories, protecting and restoring riparian corridors, and developing a management strategy for non-native species. The fisheries objectives include establishing a comprehensive monitoring program for anadromous species and developing a program to assist landowners to install screens and ladders at diversions. Other objectives focus on land use and fire and fuels management, and education and outreach within the watershed (WSRCD 2006.)

Historically, this watershed supported only small populations of both Chinook and steelhead. Therefore, while these restoration actions will improve conditions in Bear Creek, the opportunity for establishing independent self-sustaining populations is limited.

Cottonwood/Beegum Creeks

Spawning/ Holding Habitat

The Cottonwood Creek watershed encompasses 929 square miles and has three main tributaries, the South Fork, the North Fork, and Beegum Creek (off the Middle Fork), which provide approximately 130 miles of Chinook spawning habitat (CH2M Hill 2007). Like Clear Creek, Cottonwood Creek has steep, narrow canyons starting from the headwaters and transitioning to braided alluvial streams in the valley reach (CH2M Hill 2002).

Spring-run spawning and holding habitat is limited primarily to Beegum Creek and the South Fork above Maple Creek (CH2M Hill 1998); however, some spawning has been documented on the North Fork (CH2M Hill 2002). Several natural partial barriers can block migration into portions of Beegum Creek under certain flow conditions; on the South Fork, a human-made barrier exists about 3.5 miles upstream of Maple Creek (CH2M Hill 2002). Prior to this barrier, spring-run were

observed 7 to 8 miles upstream of Maple Creek (CH2M Hill 2002). On the North Fork, a natural barrier is upstream of the Ono Bridge. Historical records indicate that up to 500 spring-run spawned in Cottonwood and Beegum Creeks (CH2M Hill 2007).

Steelhead utilize all the forks and the mainstem of Cottonwood Creek. Approximately 42% of the mainstem has suitable spawning areas for steelhead and fall-run Chinook; however, low flows can restrict access to a large portion of these areas (CH2M Hill 2002).

Rearing Habitat

Rainfall provides most of the natural flow in the Cottonwood Creek watershed, resulting in a hydrology with abrupt swings correlated to storm events; higher flows are in winter and spring, and low flows are in summer and fall (CH2M Hill 2002). In years with low rainfall, both flow and water temperatures can impede escapement and successful recruitment of juvenile salmonids (CH2M Hill 2002). However, the mainstem does have deep pools and riffles to provide cooler holding areas during summer and fall (CH2M Hill 2002). In addition, Cottonwood Creek has an established riparian corridor that is beneficial for juvenile rearing (CH2M Hill 2002).

Limiting Factors

Low flows in years with limited precipitation can limit the availability of habitat given the flashy nature and limited aquifer recharge within the Cottonwood Creek watershed (CH2M Hill 2002). Other limiting factors include heavy sediment loads, gravel extraction, agricultural practices including the Anderson-Cottonwood Irrigation District canal, timber harvesting, and urban development. One of the recommendations in the Cottonwood Creek Watershed Management Plan is for the Cottonwood Creek Watershed Group (CCWG) to conduct or facilitate a limiting factors analysis to fully evaluate the existing limitations for salmonids (CH2M Hill 2007).

Monitoring Activities

CDFG staff conducts a snorkel survey on Beegum Creek to estimate the annual spring-run escapement. The survey is conducted three times a year on the North Fork from RM 0.5 to the Highway 36 Bridge. The survey also provides information on the spatial distribution of holding Chinook. CDFG has conducted the survey in most years since 1973. No annual monitoring is of Cottonwood Creek for steelhead.

Restoration Activities

CCWG was formed in 1999 to “preserve the environment, private property and water rights, and economic resources of the Cottonwood Creek Watershed through responsible stewardship, liaison, cooperation, and education” (CH2M Hill 2007). CH2M Hill, with funding from the State Water Board and CALFED and input from stakeholders, prepared a watershed management plan for the CCWG. The management plan identifies issues in the watershed and establishes goals, objectives, and actions for addressing them.

The watershed management plan identifies issues in four categories: water resources and future development; channel and riparian conditions; fishery, vegetation, and wildlife resources; and fire and fuels management (CH2M Hill 2007). The goals that directly impact salmonids include addressing bank and channel instability, developing a sustainable gravel management program,

sustaining and enhancing native fish populations, sustaining and expanding riparian habitat, sustaining and enhancing water quality, increasing both stormwater infiltration and base flows, and reducing fine-grained sediment discharge into the waterways (CH2M Hill 2007). In part, the watershed management plan recommends that the CCWG should establish both juvenile and adult salmonid monitoring programs, conduct a limiting factors analysis for salmonids, assess the impacts of bank stabilization projects on riparian and aquatic habitats, and implement CALFED ERP targets that are applicable to Cottonwood Creek (CH2M Hill 2007). The ERP targets include maintaining and improving existing habitat and facilitating passage of spring-run and steelhead to holding, spawning, and rearing habitat.

Cottonwood Creek is the third largest tributary on the western side of the Sacramento River basin and the largest undammed watershed in the northern Central Valley (CH2M Hill 2002). The watershed is relatively undeveloped with an active, established, riparian corridor and provides important habitat for spring-run Chinook and steelhead that could be both expanded and enhanced with watershed improvements.

Battle Creek

Spawning/ Holding Habitat

Battle Creek is an east-side tributary of the Sacramento River that drains from the southern Cascade Range, with attributes similar to tributaries upstream of Shasta Dam (Kier Associates 1999, Lindley et al. 2007). Large snowfields and spring-fed creeks maintain streamflow until late summer in both the North and South Forks of Battle Creek, providing suitable holding and spawning water temperatures. Spring-run Chinook and steelhead can access approximately 14 miles of spawning and holding habitat in the North fork and approximately 18 miles in South Fork (Kier Associates 1999).

The spawning habitat in the North Fork has high-gradient stream segments, similar to those in Mill and Deer Creeks, upstream of Eagle Canyon Dam and elevations over 2,000 feet occur above North Battle Creek Feeder Dam. On the South Fork, similar high-gradient stream segments exist upstream of Inskip Dam; elevations over 2,000 feet occur upstream of the South Dam (Kier Associates 1999).

The Coleman National Fish Hatchery (CNFH) barrier weir, the CHFH Intake 3 diversion weir, the Orwick Diversion Dam, and the Coleman Powerhouse tailrace are potential passage barriers or impediments on the mainstem (DWR 2005). The fish ladder on the CNFH barrier weir is used during the adult steelhead migration period for broodstock collection; however, since 1996, all naturally spawned adult steelhead are allowed to pass the barrier (Jones & Stokes 2005). Steelhead also can pass over the barrier weir and access the upper watershed during periods of higher flow (>300 cfs) (Kier Associates 1999).

The North Fork has three diversion dams (Wildcat, Eagle Canyon, and North Battle Creek) and the South Fork has three diversion dams (South Diversion, Inskip, and Coleman) that can impede adult migration (DWR 2005). PG&E currently provides minimum flows of 30 cfs under an interim flow agreement to improve passage in both the North and South forks (Kier Associates 1999).

Rearing Habitat

The Battle Creek Watershed Conservancy developed a set of biologically optimum flows for each reach and month using an IFIM study. The biologically optimum flows that were selected provide at least 95% of the maximum weighted usable area (WUA) for the limiting life history stage (Kier Associates 1999). If implemented, these flows would provide sufficient habitat for salmonids rearing in Battle Creek. The current interim flow agreement targets also improve habitat conditions for spring-run and steelhead rearing in part by reducing water temperature in the lower reaches of the watershed.

Limiting Factors

The primary limiting factors on Battle Creek are associated with hydroelectric and agricultural diversions (Kier Associates 1999). Past hatchery operations also limited passage of spring-run and steelhead into the upper watershed until a disease-free water supply was established in the late 1990s (Kier Associates 1999).

The hydroelectric operations and agricultural diversions affect instream flow, water temperatures, fish passage, entrainment, and gravel supplies. PG&E currently operates five powerhouses; two small storage reservoirs; three forebays; and eight diversions along with a network of approximately 20 canals, ditches, flumes, and pipelines (Kier Associates 1999). In 1995, PG&E agreed to an interim flow agreement to increase flows above the minimum FERC requirements until a more permanent arrangement is reached (Kier Associates 1999).

Monitoring Activities

Spring-run escapement surveys were conducted from 1946 to 1956 using spawning area surveys and/or redd counts. In the early 1950s, some counts of spring-run Chinook passing CNFH were recorded, and stream surveys were conducted in the early 1960s (Kier Associates 1999). In 1995, USFWS installed a trap on the CNFH barrier weir and installed an underwater video camera to record passage of spring-run Chinook and steelhead. The weir trap is operated daily from March through May, and the underwater video monitoring is conducted from June through July. In 2002, USFWS added jumper video monitoring during daylight hours from August through December. These three monitoring programs provide passage estimates into upper Battle Creek.

In 2001, USFWS standardized the snorkel survey to sample from the mainstem at RM 2.8 up to the confluence, the North Fork up to Eagle Canyon Dam, and the South Fork up to Coleman Diversion Dam. USFWS staff conducts the survey once or twice a month from May until mid-November to identify spawning locations and timing for both spring-run Chinook and steelhead.

Between 2002 and 2006, USFWS also conducted a steelhead redd survey on the mainstem, on the North Fork from the confluence to Eagle Canyon Dam, and on the South Fork from the confluence to Coleman Diversion Dam. The survey is conducted twice a month from November through April to collect data on the number of redds and the spatial and temporal spawning distribution.

Restoration Activities

Battle Creek offers a unique opportunity to support spring-run and steelhead recovery due to its geological and hydrological features. The proposed Battle Creek Salmon and Steelhead Restoration

Project (Restoration Project) would restore and enhance approximately 42 miles of habitat by modifying hydroelectric operations in a way that minimizes the loss of clean, renewable energy (Jones & Stokes 2005). In 1999 Reclamation, NMFS, USFWS, CDFG, and PG&E signed a memorandum of understanding (MOU) outlining the Restoration Project (Jones & Stokes 2005). Under the MOU, PG&E agreed to forego some energy generation in order to provide instream flows, pursue an amendment to the FERC license, and transfer certain water rights to CDFG (Jones & Stokes 2005). Other actions address flow management, passage, restoration of stream function, diversions, and water routing.

The proposed actions include removing five hydroelectric diversion dams (Wildcat, South, Soap Creek Feeder, Lower Ripley Creek Feeder, and Coleman), installing screens and ladders on three diversion dams (North Battle Creek Feeder, Eagle Canyon, and Inskip), increasing flows, dedicating instream water rights, and eliminating the mixing between the North Fork and South Fork water (Jones & Stokes 2005). The actions are divided into three phases, 1A, 1B, and 2. Funding agreements were reached in July 2008 to provide \$49.25 million to implement Phase 1A which focuses on the North Fork (Marshall 2008). In Phase 1A, fish screens and ladders will be installed on Battle Creek Feeder and Eagle Canyon Dams, Wildcat Diversion Dam and appurtenant conveyance systems will be removed, the Eagle Canyon Canal pipeline will be installed, and Asbury Dam will be modified (Marshall 2008).

Phase 1B involves installing a tailrace connector and bypass at Inskip Powerhouse; funding is being actively pursued. Potential funding for Phase 2 has not been identified. Phase 2 includes installing a fish screen and ladder on Inskip Dam, installing a tailrace connector at South Powerhouse, and removing several diversion dams and appurtenant conveyance systems on the South Fork.

The Restoration Project will allow Chinook salmon and steelhead to access prime habitat from the confluence with the Sacramento River to the natural barriers above the hydroelectric dams as they did historically (Jones & Stokes 2005).

Thomes Creek

Spawning/ Holding Habitat

Historically, spring-run Chinook were observed sporadically in Thomes Creek, but the intermittent nature of the flow in this tributary limits the use by spring-run Chinook for spawning and holding. Steelhead can use Thomes Creek for spawning in years with adequate streamflows (Vestra 2006). CDFG identified a low-elevation impassable barrier immediately above the confluence with Horse Trough Creek that limits the amount of spawning and holding habitat for both spring-run and steelhead (Vestra 2006).

Rearing Habitat

Thomes Creek has potential for non-natal rearing of spring-run juveniles in years with adequate flow (Vestra 2006). Juvenile steelhead rearing is limited in Thomes Creek due to the reduced streamflows in years with below-normal precipitation. There is potential for natal and non-natal steelhead rearing in some years when suitable conditions exist (Vesta 2006).

Limiting Factors

Low flows in Thomes Creek are the major limiting factor for both spring-run and steelhead. Spring-run and steelhead production also is limited by high water temperature, lack of holding pools, erosion, and gravel mining (CH2M Hill 1998). Potential entrainment of juvenile salmonids by two seasonal diversions dams also may contribute to reduced production (Vestra 2006).

Monitoring Activities

No annual monitoring is conducted on Thomes Creek for spring-run Chinook or steelhead.

Restoration Activities

In 2007, the Tehama County RCD prepared a bi-annual report outlining their management actions from July 2005 through June 2007 to improve the Tehama West Watershed (TCRCD 2007). The report focused on actions in two areas, land use and planning and watershed management and health. The actions included completing the Tehama West Watershed Assessment and development of the Tehama West Watershed Management Plan (TCRCD 2007). The draft management plan that was released in August 2008 outlines actions to protect and enhance fall-run Chinook and steelhead populations in Thomes Creek (TCRCD 2008). These actions would benefit any spring-run that use Thomes Creek in wet years. However, the intermittent flow characteristics limit establishment of self-sustaining populations of spring-run Chinook or steelhead in Thomes Creek (Vestra 2006).

Stony Creek

Spawning/ Holding Habitat

Historically, spring-run Chinook spawning occurred upstream of the Stony Gorge Dam, which was built in 1928 (CH2M Hill 1998). Downstream of Stony Gorge, Black Butte Dam is a total barrier to salmonid migration (USFWS 1995). Fall-run Chinook have been documented spawning 6 miles downstream of Black Butte Dam at the North Diversion Dam, but no spring-run have been observed spawning in that area. The North Diversion Dam is a migration barrier to fall-run Chinook under most flow conditions (CH2M Hill 1998). Because of an impassable barrier at the Glenn-Colusa Irrigation District (GCID) canal at RM 3, an underground siphon was installed in 1999 (H. T. Harvey & Associates et al. 2007a). No passage studies have been conducted at the siphon site.

Steelhead spawning is possible in some years in Stony Creek and is used opportunistically when attraction flows are present (H.T. Harvey & Associates et al. 2007b). Gravel recruitment is limited due to entrapment behind Black Butte Dam, thus reducing the amount of useable spawning habitat for steelhead. Low flows may be a passage barrier for steelhead in years with below-normal precipitation.

Rearing Habitat

Non-natal spring-run Chinook and steelhead rearing has been documented in Stony Creek, but stranding and entrainment is known to occur due to operation of the Tehama-Colusa canal and the GCID canal (CH2M Hill 1998). Low flows and high water temperatures limit the amount of rearing habitat in Stony Creek in some years (H.T. Harvey & Associates et al. 2007b).

Limiting Factors

Migration barriers, low flows, high water temperatures, limited spawning habitat, and poor water quality limit salmonid production in Stony Creek (CH2M Hill 1998). Entrainment and standing caused by operations of the Tehama-Colusa canal and the GCID canal affect both juvenile rearing and adult escapement to Stony Creek (CH2M Hill 1998). Streambank erosion, loss of riparian habitat, and gravel mining also limit salmonid production (H. T. Harvey & Associates 2007b).

Monitoring Activities

No annual monitoring is conducted on Stony Creek for spring-run Chinook or steelhead.

Restoration Activities

Stony Creek is the second largest west-side tributary of the Sacramento River; it has undergone substantial geomorphic change, channel instability, and degradation of native riparian plant communities (H.T. Harvey & Associates 2007b). Historically, Stony Creek was a flashy, episodic channel; because of dam operations and extensive gravel mining, the creek now meanders within an artificially narrow channel causing both bed and bank erosion (H.T. Harvey & Associates 2007b).

In 2004, the Glenn County RCD organized a Landowner Advisory Committee and a Technical Advisory Committee to help with implementing projects in the Lower Stony Creek Watershed (GCRCD 2008). The Stony Creek Watershed Assessment was completed in 2007, and work began on the Lower Stony Creek Watershed Restoration Plan (GCRCD 2008). The Glenn County RCD also established a demonstration site for invasive plant removal and bank stabilization, and implemented a monitoring program (GCRCD 2008). An adopted long-range plan set goals related to water resources, loss of agricultural land and urban encroachment, range management, weed control, and loss of habitat (GCRCD 2006).

The natural recruitment of native riparian seedlings suggests that the hydrological conditions needed to support a riparian corridor already exist in lower Stony Creek (H. T. & Associates et al. 2007a). Although the low elevation, lack of holding pools, low flows, and high water temperatures make Lower Stony Creek unsuitable for spring-run Chinook, restoration efforts could benefit both fall-run Chinook and steelhead.

Antelope Creek

Spawning/ Holding Habitat

The Antelope Creek watershed is relatively long and narrow, with moderate to steep slopes, and is located within the southernmost extension of the Cascade Range (Armentrout et al. 1998). The watershed is similar to both Mill and Deer Creeks, which support self-sustaining runs of spring-run Chinook salmon and steelhead.

Spring-run have access to approximately 9 miles of spawning and holding habitat in Antelope Creek, starting from approximately 1.6 miles downstream of Paynes Creek crossing to McClure Place on the North Fork and Buck's Flat on the South Fork (CDFG 1966, Airola 1983 as reported in Armentrout et al. 1998). Paynes Creek crossing also is referred to as Tehama Wildlife Area Crossing.

Armentrout et al. (1998) used results from the U.S. Forest Service Fisheries Habitat Assessment to determine the number of holding pools present in Antelope Creek. Holding pools were defined as pools greater than 6 feet deep. In Antelope Creek, seven holding pools on the mainstem represent 54% of all pools, six holding pools on the South Fork represent 26% of all pools, and no holding pools are on the North Fork (Armentrout et al. 1998).

Very little information on steelhead distribution and abundance is available for Antelope Creek; however, they probably use the same spawning areas as spring-run Chinook and may have access to habitats beyond what is known for salmon (Armentrout et al. 1998).

Rearing Habitat

The high habitat diversity of Antelope Creek helps support juvenile salmonid rearing (Armentrout et al. 1998). In addition, the deep pools, cool water springs, vegetative shading, and natural diurnal fluctuations in water temperature offset the potential effects of increased water temperature during summer and early fall, supporting the yearling life history stage for both spring-run Chinook and steelhead (Armentrout et al. 1998).

Limiting Factors

Water temperature, low flows, agricultural diversions, loss of natural river morphology, limited spawning habitat, fine sediments, water quality, loss of riparian habitat, and harvest/angling affect salmonid production in Antelope Creek (NMFS 2008). Low flows in the valley portion due to springtime agricultural diversions are the largest limiting factor for spring-run production in Antelope Creek. Low flows also can impede access to Antelope Creek by reducing attraction flows, creating passage issues at agricultural barriers, and increasing water temperatures for holding and spawning salmonids (NMFS 2008).

Monitoring Activities

In 1989, CDFG began conducting snorkel surveys on various stretches of the creek. In 1992, CDFG standardized the snorkel survey methods and has conducted an annual survey during the fourth week of July to estimate the spring-run population. The survey also provides data on the distribution of holding Chinook. Staff surveys the North Fork from the confluence to McClure Place and the South Fork from the confluence to SF Gun Club. No annual monitoring is conducted on Antelope Creek for steelhead.

Restoration Activities

Tehama County RCD is currently preparing a watershed assessment for both Paynes Creek and Antelope Creek. Tehama County RCD will use the information from the assessment to develop the Tehama Eastside Watershed Plan.

Antelope Creek is one of few remaining tributary streams where salmonids have access to the historical headwater stream habitat with a natural hydrograph in the upper watershed (Armentrout et al. 1998). Historically, Antelope Creek was estimated to support 500 spring-run Chinook and 300 steelhead (CH2M Hill 1998). Due to the steep sides of the canyon, human land use impacts are mostly limited to the valley floor portion of the watershed. These factors make Antelope Creek a promising area for expansion and enhancement of spring-run Chinook and steelhead habitat.

Mill Creek

Spawning/ Holding Habitat

Mill Creek is a long, narrow watershed; most of the watershed is bordered by Lassen National Forest (CH2M Hill 1998). Because the upper watershed is relatively inaccessible, it is undisturbed, pristine, salmonid spawning habitat (CH2M Hill 1998). No significant water storage impoundments in the watershed allow for a natural hydrograph that is supported by both seasonal rainfall and snowmelt (CH2M Hill 1998). Mill Creek supports an independent, self-sustaining spring run and provides the highest elevation spawning habitat known in California (CH2M Hill 1998).

Spring-run holding pools exist in the upper canyon areas, and spawning occurs between Little Mill Creek confluence and the Highway 36 Bridge (CH2M Hill 1998). Armentrout et al. (1998) noted that the amount of holding habitat is limited in the upper 7.6 miles of Mill Creek and that holding habitat was more abundant in the section below the Mill Creek Campground. There are 20 holding pools out of 86 pools in the 13 miles of stream that were surveyed downstream of the campground (Armentrout et al. 1998). The amount of holding habitat just below this reach is unknown because it could not be accessed for the survey, but spring-run were previously observed holding in this area (Armentrout et al. 1998).

Mill Creek has higher sediment loading than Antelope or Deer Creeks; however, it does not appear to limit spring-run salmon from spawning. It may impact redds after flood events that redistribute the fines during the incubation period (Armentrout 1998). Low flows in the lower portion of the watershed can impede upstream passage of adult salmonids in some years (CH2M Hill 1998). No physical passage barrier limits upstream migration on Mill Creek; however, the combined effect of higher stream gradients, lower streamflows, and habitat availability sets the upper limit for migration in the headwater reaches (Armentrout et al. 1998).

Very little distribution and abundance data on steelhead spawning are available in Mill Creek, but their range is expected to include the range for spring-run and can extend beyond it (Armentrout et al. 1998).

Historically, Clough Dam, Ward Dam, and Upper Diversion Dam impeded the upstream passage of salmonids under low-flow conditions. Clough Dam was removed in 2003, and Ward Dam was modified in 1997 to improve upstream passage (DWR 2005). In recent years, streamflows have been augmented through a water exchange program to improve upstream passage for spring-run Chinook (DWR 2005).

Rearing Habitat

The upper watershed substrate composition and pools provide a high level of habitat diversity and overwintering cover that supports juvenile salmonid rearing (Armentrout et al. 1998). This portion of the creek is relatively undisturbed by human land use and provides relatively pristine rearing conditions. Water temperatures remain low during the spring-run rearing period and support a stream-type life history. The proportion of fry that remains in the creek to migrate as yearlings varies annually, depending on stream conditions (Harvey-Arrison pers. comm.). The lower portion of Mill Creek also provides good rearing habitat although low flows due to diversions can increase water temperature and impede juvenile migration from the creek (DWR 2005).

Limiting Factors

The Mill Creek watershed is relatively undisturbed with a natural flow regime; however water diversions in the lower portion of the creek can increase water temperatures and impede adult passage upstream and juvenile passage downstream.

Monitoring Activities

CDFG staff has monitored spring-run escapement on Mill Creek since 1947 using spawning area surveys and/or aerial redd counts (1947–1953), ladder counts (1954–1964 and 1986–1987), area surveys (1971–1985), electronic fish counters (1988–1996), carcass surveys, and redd surveys. Since 1997, CDFG staff has conducted a single redd survey at the peak of the spawning period to estimate the annual spring-run spawning population. The survey takes place between October 1 and October 15 from the Lassen National Park boundary to the confluence of Little Mill Creek. Staff collects data on the number of complete redds and the number, age class, and sex of carcasses. The survey also provides information on the spatial spawning distribution and population trends over time.

CDFG staff also conducted a hydroacoustic pilot study in 2006 to evaluate the use of two different hydroacoustic methods, Biosonics split-beam sonar and the dual-frequency identification sonar (DIDSON), to estimate spring-run escapement to Mill Creek at Sherwood Bridge (Creek Mile 2.0). CDFG found the DIDSON system to be more effective because it samples a great volume and detects targets across a broader range of flows and water levels (Johnson et al. 2006). No annual monitoring is conducted for steelhead on Mill Creek.

Restoration Activities

Mill Creek was identified as a priority stream in the USFWS-AFRP Final Restoration Plan (USFWS 2001). In the Restoration Plan, USFWS identified four actions to help increase the natural production of anadromous fish in Mill Creek: (1) continue providing instream flows to facilitate adult and juvenile salmonid passage; (2) develop a watershed strategy to preserve habitat productivity; (3) improve spawning habitat in lower Mill Creek for fall-run Chinook; and (4) establish, restore, and maintain riparian habitat in lower Mill Creek. To date, AFRP has spent approximately \$1,000,000 on restoration projects in Mill Creek (AFRP website).

There are four ongoing watershed projects: (1) the Lower Mill Creek Riparian Restoration Project, (2) the Deer and Mill Creek Watershed Project; (3) the Deer, Mill, and Antelope Creek Stabilization Project; and (4) the Mill Creek Water Exchange Program (DWR 2005). The objective of the Lower Mill Creek Riparian Restoration Project is to maintain and restore riparian habitat in the lower reaches; the project is funded through the Mill Creek Conservancy and The Nature Conservancy (DWR 2005). The Deer and Mill Creek Watershed Project develops and coordinates resource plans to benefit spring-run Chinook and is funded by the State Water Board (DWR 2005). A final Mill Creek Watershed Management Strategy Report was completed in 1997. The Stabilization Project is funded by CALFED to reduce inputs of fine sediments from road-related sources (DWR 2005). The Mill Creek Water Exchange Program is discussed in more detail below.

Historically, Clough Dam fish ladder was considered ineffective in passing salmonids under low-flow conditions (Armentrout et al. 1998). DWR removed the dam and installed an inverted siphon pipe to move the diverted water to the Upper Diversion Dam under a contract awarded by the California

Bay-Delta Authority (DWR 2005). Clough Dam was removed in 2002, and the entire project was finished in 2003 (DWR 2005).

The two diversion dams on Mill Creek, Ward Dam and Upper Diversion Dam, can impede the upstream migration of spring-run due to reductions in streamflow (DWR 2005). CDFG constructed a new modified pool and chute ladder on Ward Dam in 1997 improving upstream passage under lower flow conditions (DWR 2005). A new fish screen also was installed at the Upper Diversion Dam in 2000 to reduce entrainment of juvenile salmonids (DWR 2005).

Streamflows at the diversion dams are augmented through a Water Exchange Program Agreement between CDFG, DWR, and Los Molinos Mutual Water Company (LMMWC) to improve both upstream and downstream passage of salmonids (DWR 2005). The program exchanges instream water for groundwater where landowners forego diversions of up to 16 cfs when additional flows are needed. The Mill Creek Conservancy conducted a study starting in 2004 to investigate and develop a long-term or permanent water management program on Mill Creek (DWR 2005).

Mill Creek, like Antelope Creek, is one of few remaining tributaries streams where salmonids have access to the historical headwater stream habitat with a natural hydrograph in the upper watershed (Armentrout et al. 1998). Past escapement estimates indicate that Mill Creek could support up to 3,500 spring-run Chinook and 2,000 steelhead (CH2M Hill 1998). Due to the steep sides of the canyon, human land use impacts are mostly limited to the valley floor portion of the watershed. AFRP and other organizations recognized the importance of Mill Creek for spring-run Chinook and have funded numerous restoration projects over the last 10 years.

Deer Creek

Spawning/ Holding Habitat

Unlike most tributaries in the Sacramento River basin, salmonids can still access the headwater stream habitat because there are no impoundments in Deer Creek (Armentrout et al. 1998). Deer Creek currently supports a self-sustaining population of spring-run Chinook (Lindley et al. 2007). Like Mill and Antelope Creeks, Deer Creek has excellent instream habitat conditions for spring-run Chinook holding, spawning, and rearing (Armentrout and other 1998). Deer Creek is in a long, narrow watershed with moderate to steep slopes. It has approximately 25 miles of spring-run holding habitat from Upper Falls downstream to the confluence with Rock Creek, but most holding occurs in the first 15.5 miles above Ponderosa Way (Armentrout et al. 1998). Based on a survey of the upper 17 miles of the holding habitat, Armentrout et al. (1998) noted the presence of 166 pools—of which 60% were classified as holding pools (depth > 6 feet).

Spring-run spawning extends from Upper Falls downstream nearly 30 miles, but the distribution of spawning can vary based on water temperatures and the amount of runoff (Armentrout et al. 1998). Based on visual observations, Armentrout et al. (1998) noted that the spawning substrate is in good condition with a low amount of fine sediment.

Very little distribution and abundance data are available on steelhead spawning in Deer Creek, but their range is expected to include the range for spring-run and can extend beyond it (Armentrout et al. 1998). Steelhead have access to an additional 13 miles of habitat when the fish ladder at Upper Falls is opened in fall (DWR 2005).

Rearing Habitat

The habitat diversity is high in Deer Creek and provides an abundance of microhabitats to support the needs of juvenile salmonids during their stream residency (Armentrout et al. 1998). Deer Creek also provides the cobble and gravel substrates with open interstitial spaces necessary for overwintering juvenile spring-run Chinook and steelhead (Armentrout et al. 1998). Like Mill Creek, Deer Creek supports a stream-type life history, with a varying proportion of spring-run remaining in the creek and migrating as yearlings. Rearing and outmigration in the lower portion of the Creek has improved after all the diversions were screened to prevent entrainment (Harvey 1997).

Limiting Factors

Water diversions on the valley floor of the creek are physical barriers and reduce springtime flows, which can delay adult spring-run migration into the creek and impact outmigration of juvenile spring-run and steelhead. The five diversions are Stanford-Vina Ranch Diversion Dam, Cone-Kimball Diversion Dam, North Main Diversion Canal, Deer Creek Irrigation Dam, and an unnamed canal on Deer Creek (DWR 2005). The low flows also increase water temperatures in the lower portion of the creek, limiting juvenile rearing in the Valley reach.

The upper watershed is inaccessible for most of its length due to the steep canyon walls, except where Highway 32 parallels the creek, limiting human use. However, the unstable sloughing of soil on the canyon shelves due to roads, landings, and skid trails can affect water quality (DWR 2005). Fishing for spring-run on a catch-and-release basis (with gear restrictions) is permitted from the end of April until November 15 (NMFS 2008). The impacts of fishing on the holding and spawning adults have not been documented, but some inadvertent negative impacts due to anglers disturbing redds are possible (NMFS 2008).

Deer Creek provides relatively good rearing habitat for juvenile salmonids; but flood control activities have reduced channel diversity, riparian habitat, instream cover, and floodplain habitat (NMFS 2008). All of the water diversions have fish screens to reduce mortality, but low flows can impede fish passage (DWR 2005).

Monitoring Activities

CDFG has monitored spring-run escapement in Deer Creek since 1940 using partial weir and ladder counts (1940–1948), spawning area surveys and/or aerial redd counts (1948–1956), electronic fish counters (1963–1964), area surveys (1970–1986), carcass surveys, and snorkel surveys (1987–1991). Since 1992, CDFG staff has conducted a standardized snorkel survey to estimate the annual spawning population by making a single pass during the first week of August between Upper Deer Creek Falls and Dillon Cove. CDFG collects data on the number of salmon observed and the spatial distribution. No annual monitoring is conducted for steelhead on Deer Creek.

Restoration Activities

In 1999, USFWS prepared a draft Programmatic Environmental Assessment of anadromous fish restoration actions in Lower Deer Creek (USFWS 1999). The proposed actions were divided into 10 categories: (1) land conservation; (2) fish screens; (3) fish passage; (4) channel and instream habitat modifications; (5) spawning gravel replenishment; (6) streambank modification; (7) riparian

revegetation; (8) meander belt and floodplain management; (9) agricultural management; and (10) road management.

Deer Creek was identified as a priority stream in the AFRP Final Restoration Plan (USFWS 2001). In the Restoration Plan, USFWS identified five actions to help increase the natural production of anadromous fish in Deer Creek: (1) acquire water from willing sellers to supplement instream flows in the lower 10 miles of Deer Creek; (2) develop a watershed management plan; (3) improve spawning habitat in lower Deer Creek for fall and late-fall-run Chinook; (4) restore and preserve riparian habitats along Deer Creek; and (5) plan and coordinate flood management activities with least damage to fishery resources and riparian habitat.

AFRP has funded several projects in Deer Creek to protect riparian habitat and reduce erosion. Two projects focused on protecting the riparian corridor in the lower Deer Creek watershed. In 1997, 2.5 miles of riparian corridor was acquired resulting in the protection of 468 acres of riparian habitat; another project, completed in 2004, fenced off two sections of streambank to protect a Nature Conservancy conservation easement (DWR 2005). In addition, an erosion control project was undertaken to identify the highest erosion sites in the Upper Meadows area of Deer Creek and offered engineered solutions to some specific sites (CSUC 2001a).

In August 2007, the Deer Creek Irrigation District (DCID) entered into a long-term agreement with DWR and CDFG to construct, operate, maintain, and monitor a flow enhancement program on lower Deer Creek in order to improve passage for both adult spring-run and juvenile salmonids. The Deer Creek Flow Enhancement Program provides DCID with a supplemental agricultural water supply so that surface water can remain in the creek when needed in spring and early fall to support fish passage. The supplemental supply includes water acquired from new groundwater wells, efficiency improvements to DCID's distribution system, and new water management techniques (DCID et al. 2005). Operation of the program incorporates adaptive management and a comprehensive monitoring program, and fulfills the groundwater protection requirements in the Tehama County AB 3030 Groundwater Management Plan (DCID et al. 2005).

The instream flows are augmented when the flows below the Stanford-Vina Diversion Dam are measured at less than or equal to 50 cfs between April 1 and June 30, and again between October 15 and November 15 (DCID 2008). In that case, DCID bypasses up to 10 cfs of surface water in Deer Creek. CDFG also can request DCID to bypass up to 30 cfs for 1 or 2 consecutive days in order to generate a pulse flow to attract migrating adults (DCID 2008). As part of the agreement, CDFG will conduct a Fish Passage Management Assessment Program to evaluate the effectiveness of the flow actions (DCID 2008). In addition to the Flow Enhancement Program, DWR is working with DCID to improve fish passage at the DCID Diversion Dam (DWR website). DWR is currently developing a detailed topographic survey of the area and will conduct a preliminary engineering investigation (DWR website).

The Stanford-Vina Ranch Irrigation Company (SVRIC) has improved its fish ladder on the Stanford-Vina Ranch Diversion Dam and constructed a holding pool downstream of the dam to improve adult passage (DWR 2005). The SVRIC also has voluntarily bypassed instream flow upon request by CDFG to augment flows during critical migration periods for anadromous salmonids (DWR 2005).

Further downstream, the Deer Creek Watershed Conservancy (DCWC) is working on a Lower Deer Creek Restoration and Flood Management Feasibility Study with funding from the CALFED ERP (Tompkins et al. 2007). The project is intended to implement flood management actions that

provide flood flow conveyance while improving ecosystem health and function (Tompkins et al. 2007). The project includes baseline monitoring, a feasibility study, identifying project elements, conceptual design of those elements, environmental documentation, implementation, monitoring, and adaptive management. As part of the study, Mussetter Engineering et al. (2007) identified two sets of alternatives—one that involves actions downstream of Highway 99 and another that involves actions upstream of Highway 99, two hydraulically disconnected reaches.

Deer Creek, like Antelope and Mill Creeks, is one of few remaining tributaries streams where salmonids have access to the historical headwater stream habitat with a natural hydrograph in the upper watershed (Armentrout et al. 1998). The average natural production has been estimated at 3,260 spring-run Chinook and approximately 1,000 steelhead (CH2M Hill 1998). Due to the steep sides of the canyon, human land use impacts are mostly limited to the valley floor portion of the watershed. Similar to Mill Creek, AFRP and other organizations recognized the importance of Deer Creek for spring-run Chinook and have funded numerous restoration projects over the last 10 years.

Butte Creek

Spawning/ Holding Habitat

Butte Creek currently supports an independent, self-sustaining spring-run Chinook population (Lindley et al. 2007). This population is also the largest remaining population in the Central Valley. Near the headwaters, several small tributaries converge in the Butte Meadows basin then Butte Creek flows through a steep canyon approximately 25 miles in length where it drops into the valley floor near the city of Chico (BCWP 1998). Approximately 6 miles downstream of the Butte Meadows is the first major diversion dam, the Butte Creek Diversion Dam (also referred to as the Butte Creek Head Dam). Downstream of the Butte Creek Diversion Dam is a section with several large waterfalls that is “pool-drop” in nature and is believed to restrict upstream salmonid migration except during periods of extremely high flows (BCWP 1998). Butte Creek continues downstream to the DeSabra Powerhouse where the creek is commingled with water from the West Branch of the Feather River (PG&E 2007b). Just downstream of the DeSabra Powerhouse, Butte Creek is diverted at the Centerville Diversion Dam, which is considered the upper limit for salmonid migration (PG&E 2007b).

During summer, spring-run Chinook use holding pools between a natural barrier (known as the Quartz Bowl) about 1 mile below Centerville Diversion Dam and the Honey Run Covered Bridge, a distance of about 10 miles (BCWP 1998). Most of the spawning occurs in this area, but spring-run also move further downstream near the Parrot-Phelan Diversion (BCWP 1998). In years with higher flows, both spatial and temporal overlap in spawning of fall and spring-run Chinook can occur; in most years, fall-run spawning occurs downstream of the Parrot-Phelan Diversion (CH2M Hill 1998). Imported water from the Feather River may encourage straying by Feather River Hatchery spring-run Chinook into Butte Creek.

Historically, steelhead may have accessed the Butte Meadows, but spawning is now restricted to the area between the Centerville Diversion Dam and Parrot-Phelan Diversion on the mainstem and to tributaries such as Dry Creek, except during periods of extremely high flows (BCWP 1998).

Rearing Habitat

Because spawning occurs at a much lower elevation in Butte Creek compared to Mill and Deer Creeks, the spring-run exhibit more of an ocean-type life history. Most of the fry migrate out of the creek upon emergence while a smaller fraction migrates as juveniles in spring (BCWP 1998). A few spring-run remain and migrate as yearlings the following fall. Steelhead and the remaining spring-run rear below Centerville Diversion Dam where summer flows are generally high enough to keep water temperature below 68 °F (BCWP 1998). The fry that migrate upon emergence use both the lower portion of Butte Creek and the Sutter Bypass for rearing prior to emigration in the late spring (BCWP 1998).

Limiting Factors

Fish passage is a major factor affecting both adult and juvenile salmonids in Butte Creek. Starting from the Sutter Bypass, adult salmonid passage is affected by about 22 major structures—including agricultural diversions, hydroelectric dams, and flood bypasses (DWR 2005). Low flows and the associated increased water temperatures can be problematic for all life stages of salmonids within Butte Creek. Water quality is generally good in the upper watershed, but dissolved oxygen concentrations and water temperatures are the primary water quality issues in the lower portion of Butte Creek (DWR 2005). Agricultural and flood management practices have altered the natural stream processes, reducing the amount of riparian habitat in Butte Creek (DWR 2005). Beneficial uses that can impact salmonid habitat include gravel extraction, mining, recreation, water diversions for waterfowl habitat, and timber harvest (DWR 2005).

Monitoring Activities

Since 1995, CDFG staff has conducted a snorkel survey on Butte Creek in July—from the Quartz Bowl to the Covered Bridge—to estimate the annual escapement of spring-run Chinook and steelhead. CDFG collects data on the number of spawners, age distribution, and spatial distribution. From 1954 to 1990, CDFG estimated spring-run escapement based on expansions from an annual carcass, redd, and live salmon counts survey. In 1991, CDFG switched to the snorkel survey; and the methods were standardized in 1995. PG&E also conducted a snorkel survey in Butte Creek from 1981 to 1994.

Since 1995, CDFG staff also has conducted a carcass survey to estimate spring-run escapement. The survey is conducted between June 15 and December 31 each year between the Quartz Bowl and the Western Canal Siphon. CDFG uses the survey to calculate the annual spring-run escapement along with an estimate of pre-spawn mortality, spatial and temporal distribution, and size and age composition.

Restoration Activities

Formation of the Butte Creek Watershed Conservancy (BCWC) in 1995 brought together landowners; water users; recreational users; conservation groups; and local, state, and federal agencies to protect, restore, and enhance the Butte Creek watershed (BCWC 2000). BCWC enlisted the services of California State University (CSU), Chico to prepare an Existing Conditions Report that was completed in 1998. The Existing Conditions Report was used to support BCWC in preparing a Watershed Management Strategy that was completed in 2000. The Watershed Management

Strategy outlines a series of goals and objectives to provide an adaptive management framework and a list of potential projects and actions (BCWC 2000).

The goals and objectives addressed issues related to education and outreach, recreation, fisheries, fuel load, timber management, road erosion, groundwater and water supply, water quality, and flooding (BCWC 2000). For fisheries, the goal was to help enhance and maintain the native fishery—with emphasis on salmon and steelhead. The objectives included supporting efforts to improve passage; protect and enhance existing riparian habitat by providing outreach, assistance, and incentives to willing landowners; maintain and improve water quality through monitoring and encouraging implementation of best management practices (BCWC 2000). Since then, BCWC has worked on projects to improve fish passage, provided facilities for community cleanups, and supported educational programs within the watershed. Currently, BCWC is completing the education and outreach portions of two grants, the CALFED Rural Roads Grant and the Butte Creek Groundwater Modeling Grant (BCWC website).

Butte Creek was identified as a priority stream in the AFRP Final Restoration Plan (USFWS 2001). In the Restoration Plan, USFWS identified 14 high-priority and 27 medium-priority actions to help increase the natural production of anadromous fish in Butte Creek. The priority actions addressed increasing instream flow, passage and screens at diversions, removing dams, developing a watershed management plan, establishing operational criteria, and evaluating juvenile spring-run Chinook life history (USFWS 2001). Since 2001, AFRP has provided approximately \$2.5 million towards these restoration actions (AFRP website).

Western Canal District involvement in restoration actions to improve passage in the middle reaches of the mainstem of Butte Creek has resulted in removal of five diversion dams: the Western Canal Main Dam, Western Canal East Channel Dam, Point Four Dam, McGowan Dam, and McPherrin Dam (DWR 2005).

CDFG worked with landowners and other agencies to improve passage in Butte Creek, including installing a new fish screen and a pool and chute ladder at the Parrot-Phelan Diversion Dam (DWR 2005). CDFG is conducting a multi-year study on juvenile spring-run Chinook life history and manages a 285-acre Ecological Preserve along Butte Creek. In 1998, with funding from USFWS, National Fish and Wildlife Foundation, CALFED, and the Wildlife Conservation Board, the CSU, Chico Research Foundation purchased a 93-acre parcel now known as the Butte Creek Ecological Preserve Honey Run unit. The unit is adjacent to the CDFG Butte Creek Canyon Ecological Reserve (CSUC 2001b). The management goals for the Honey Run unit are restoring, protecting, and enhancing habitat for spring-run Chinook and steelhead; improving riparian habitat; and creating a living laboratory and field classroom (CSUC 2001b).

DWR engineered three fish ladders and screen designs. The ladders and screens were constructed in 1997 at Durham Mutual, Adams, and Gorrill Diversion Dams (DWR 2005). In 1999, the Sanborn Slough/Butte Creek Bifurcation Structure was modified to improve flow and fish passage. DWR also is working with Ducks Unlimited and various consulting firms on the multi-faceted Lower Butte Creek Project (DWR 2005). As part of the Lower Butte Creek Project, the Sutter Bypass East Borrow Canal Water Control Structures Project modifies Weir No. 2 and the Willow Slough Weir, including replacing existing fish ladders to improve passage (DWR website).

PG&E is in the process of relicensing the DeSabra-Centerville Project, FERC Project No. 803, with FERC. The current license expires in October 2009. PG&E is proposing to continue operating the

project with no changes to the generation facilities but will adopt resource management measures, remove five stream diversions that are no longer used, and rebuild or refurbish the Centerville Powerhouse (PG&E 2007b). Since 1999, PG&E has worked with CDFG, NMFS, and USFWS to develop an Annual Operations and Maintenance Plan to enhance and protect spring-run Chinook habitat each summer. PG&E releases water from Round Valley and Philbrook Reservoirs to provide additional cool water for spring-run holding from June until mid-September each year (PG&E 2007b). In addition, PG&E increased flows below Lower Centerville Diversion Dam to 60 cfs from late September through February in 2004 to increase spring-run spawning habitat (PG&E 2007b). In following years, PG&E has increased the instream flows from 60 to 75 cfs. In the FERC license application, PG&E proposed additional changes to the minimum instreamflow releases below Lower Centerville Dam based on water-year type in order to continue maximizing the cool water benefits for spring-run Chinook holding, spawning, and rearing (Table 2).

Table 2. Proposed Minimum Instream Flows below Lower Centerville Diversion Dam According to Water-Year Type

Months	Normal Water-Year Type Minimum Instream Flows	Dry Water-Year Type Minimum Instream Flows
Sep 15 – Jan 31	75 cfs	60 cfs
Feb 1 – Apr 30	80 cfs	75 cfs
May 1 – May 31	80 cfs	65 cfs
Jun 1 – Sep 14	40 cfs	40 cfs

Source: Pacific Gas and Electric Company. 2007. DeSabra-Centerville Project: license application. FERC Project No. 803. October. San Francisco, CA.

The spring-run Chinook population in Butte Creek has increased in the last 10 years in part due to the restoration activities taking place (Figure 2). Due to the low elevation of the watershed, years with below-normal precipitation water temperatures can limit spring-run salmon production. High levels of pre-spawn mortality can occur in years when summer water temperatures exceed the tolerance of holding spring-run Chinook. High summer water temperatures also can affect salmonid rearing within Butte Creek. Recent and ongoing improvements in the Sutter Bypass, however, are providing additional salmonid rearing habitat.

Big Chico Creek

Spawning/ Holding Habitat

Historically, Big Chico Creek supported a small run (up to 1,000 fish) of spring-run Chinook, but a viable population is no longer believed to exist (CH2M Hill 1998). Spring-run Chinook have been observed in low numbers in recent years, and water temperatures below Iron Canyon often exceed their tolerance during the summer holding and egg incubation period. Spring-run summer holding and spawning habitat is limited to a 9-mile stretch between Iron Canyon and Higgin's Hole in the foothill reach of Big Chico Creek (BCCWA date unknown). Although passage through Iron Canyon Fish Ladder can be impeded in low-flow years, the habitat in this upper portion of the watershed is relatively pristine (CH2M Hill 1998).

Steelhead also use Big Chico Creek, and spawning occurs in the foothill reach (BCCWA date unknown). Steelhead distribution data are limited due to a lack of species-specific monitoring. Historically, steelhead were observed in Big Chico Creek, and their presence has been detected in recent monitoring by CDFG.

Rearing Habitat

Both the foothill reach, between Higgin's Hole and Iron Canyon, and the valley reach provide salmonid rearing habitat (BCCWA unknown date). Conditions in the foothill reach are suitable for the year-round rearing necessary for steelhead (BCCWA unknown date). Rearing also occurs in Mud and Rock Creeks although habitat in these creeks has been degraded by flood control measures leading to high water temperatures in most years (CH2M Hill 1998).

Limiting Factors

Low flows and high water temperatures are the most limiting factors in Big Chico Creek for spring-run and steelhead. Low flows affect passage for both adults and juveniles. Loss of riparian habitat in the valley reach and diversion by flood control structures also limit salmonid production (BCCWA 2006).

Monitoring Activities

CDFG staff conducts a single snorkel survey on Big Chico Creek each July to estimate the annual escapement of spring-run Chinook and steelhead. CDFG collects data on the number of spawners, age distribution, and spatial distribution. From 1956 to 1985, CDFG estimated spring-run Chinook escapement based on expansions from observational surveys. In 1989, CDFG switched to the snorkel survey; and the methods were standardized in 1995.

Restoration Activities

The Big Chico Creek Watershed Alliance adopted a Watershed Management Strategy in 2006 (BCCWA 2006). The management strategy identifies goals, objectives, and potential actions to protect and enhance both the ecological integrity and economic vitality of the watershed. Several goals related to salmonids include restoring water quality, restoring sustainable populations of native fish, restoring functioning riparian habitat, and eradicating non-native plant species.

Some of the specific actions include reducing agricultural and urban runoff, reducing stream temperatures, improving the Iron Canyon Fish Ladder, improving passage at diversion dams and culverts, enhancing rearing habitat, restoring floodplain and riparian habitats, and eradicating non-native plant species and replanting with native species.

DWR prepared a Preliminary Engineering Technical Report (2002) for the proposed Iron Canyon Fish Ladder repair. Following this technical report, HDR et al. (2006) evaluated the feasibility of the project. HDR et al. (2006) concluded that no physical constraints would preclude construction of the ladder and that performance of the proposed ladder was expected to surpass that of the existing ladder over its 50-year life span. Improvements to the existing ladder would allow passage to existing spawning and holding habitat over a broader range of flows (HDR et al. 2006).

Yuba River

Spawning/ Holding Habitat

Englebright Dam (RM 24) is the upper limit for salmonid migration in the Yuba River (CH2M Hill 1998). The channel below Englebright Dam, referred to as the Lower Yuba River channel, is still strongly influenced by the effects of historical hydraulic mining (ENTRIX and Monroe 2003). The entire Lower Yuba River channel is accessible to both spring and fall-run Chinook for spawning and rearing.

The section just downstream of Englebright Dam to the confluence with Deer Creek does not provide adequate habitat for spring-run spawning due to the bedrock canyon geometry, high velocities, and lack of spawning gravel (Pasternack 2008). This reach is the most heavily impacted, and spring-run were observed clustering in this area where they failed to reproduce (Pasternack 2008).

Below this reach is the Rose Bar reach, as defined by ENTRIX and Monroe(2003), which has a relatively complex stream morphology consisting of deep pools, long riffles and runs, low amounts of fine sediment, and low water temperatures (ENTRIX and Monroe 2003). This reach has good spawning gravel and provides adequate spawning and holding habitat for spring-run Chinook (ENTRIX and Monroe 2003). Pasternack (2008) noted that this section is incising due to a lack of sediment influx but nevertheless is geomorphically self-sustaining, with excellent Chinook salmon spawning habitat and sufficient gravel supplies.

The next reach, Parks Bar, is approximately 6 miles long between the Rose Bar Reach and Daguerre Point Dam. The channel is less sinuous with wide, flat, fluvial terraces and sparse riparian habitat (ENTRIX and Monroe 2003). The upper 2 to 3 miles of the reach are similar to the Rose Bar reach and provide the best spawning and holding habitat in this reach; however, spawning does occur throughout the reach along the cobble bars and the backwater areas of side channels (ENTRIX and Monroe 2003).

Both the Rose Bar and Parks Bar reaches support steelhead spawning, but habitat availability and quality may be more limiting due to the preponderance of larger cobble and small boulders (ENTRIX and Monroe 2003). Pasternack (2008) noted that there are temporary local patches of finer gravel for steelhead spawning.

The Daguerre reach, beginning at the Daguerre Point Dam (RM 11) and ending at the confluence with the Feather River, is used by adult spring-run only as a migration corridor. The river gradient decreases in this stretch and the floodplain widens, with only a few deep pools (ENTRIX and Monroe 2003). Summer water temperatures and the lack of sufficient holding pools make the reach unsuitable for spring-run spawning and holding.

CDFG (1991) calculated that spring flows of 1,000 cfs in April, 2,000 cfs in May, and 1,500 cfs would provide adequate spring-run Chinook attraction and adult migration flows. Flows at 700 cfs would provide adequate conditions for salmonid adult migration and spawning, and would prevent redd dewatering between mid-October and March (CDFG 1991).

Rearing Habitat

All three reaches provide suitable rearing habitat, and the upper reaches provide adequate year-round temperatures to support the spring-run yearling life stage. However, the Daguerre reach may not be as suitable in some years, especially low-flow years, due to higher water temperatures and more predation pressure (ENTRIX and Monroe 2003). Based on an analysis conducted by CDFG (1991), the greatest amount of rearing habitat for fry occurs at flows of 100 cfs and between 150 and 200 cfs for juvenile Chinook. However, CDFG calculated that flows near 700 cfs between mid-October and March did not significantly reduce the amount of fry and juvenile habitat while benefitting early outmigrant spring-run juveniles and spawning adults. The higher spring flows (1,000 to 2,000 cfs) also reduce the amount of fry and juvenile habitat but are necessary for the needs of other life stages (CDFG 1991).

The greatest amount of steelhead fry habitat occurs between 100 and 200 cfs (CDFG 1991). For steelhead, juvenile flows between 200 and 350 cfs maximize the amount of rearing habitat; however, spawning steelhead need flows between 600 and 800 cfs (CDFG 1991). Below Daguerre Point Dam, adequate juvenile steelhead rearing conditions are available when flows are between 250 and 450 cfs, between July and mid-October (CDFG 1991).

Limiting Factors

Englebright Dam is an impassable barrier to spring-run migration into the upper reaches of the watershed, limiting spawning habitat availability. The lack of spawning habitat and gravel in the reach just below Englebright Dam also can affect spring-run production in the Yuba River (Pasternack 2008). In the reach below Daguerre Point Dam, gravel recruitment is limited except when flows are high enough to move gravel from the mined debris along the edge of the riverbank (ENTRIX and Monroe 2003). Because of no spatial separation with fall-run, redd superimposition can occur in the two reaches above Daguerre Point Dam (ENTRIX and Monroe 2003).

Spring-run passage through the fish ladder on Daguerre Point Dam can be delayed when springtime flows are less than 400 cfs or greater than 2,500 cfs (ENTRIX and Monroe 2003). Steelhead passage at Daguerre Point Dam can be delayed when fall flows are greater than 2,000 cfs (ENTRIX and Monroe 2003). When passage is delayed for an extended period, the chance of injury associated with attempting to pass over the dam face is increased; or a loss of condition can affect egg production (ENTRIX and Monroe 2003).

The existing riparian habitat below Daguerre Point Dam only minimally benefits rearing salmonids (CDFG 1991). The loss of riparian habitat reduces nutrient inputs to the river and increases water temperatures, making the lowest portion of the river less suitable for juvenile Chinook and steelhead rearing. Entrainment of juvenile Chinook in agricultural diversions also reduces spring-run Chinook and steelhead production in the Yuba River. There are three major diversions facilities on the Lower Yuba River: Browns Valley Irrigation, Hallwood-Cordua, and South Yuba and Brophy Water Districts (CDFG 1991).

Monitoring Activities

CDFG and USFWS conducted spring-run spawning surveys on the Yuba River between 1999 and 2003; historically, annual surveys were conducted only sporadically starting in 1972 (ENTRIX and Monroe 2003). In 2003, CDFG installed a Vaki River-Watcher system in the fish ladders on Daguerre

Point Dam. The automated fish counters allow for continuous monitoring of adult salmonid passage through the fish ladders and evaluation of the temporal distribution of Chinook salmon and steelhead populations and straying rates of non-native salmonids.

Restoration Activities

The Yuba County Water Agency (YCWA) worked with a coalition of stakeholders and agencies to develop a set of agreements that form the proposed Lower Yuba River Accord (Yuba Accord) (YCWA 2005). The Yuba Accord resolves nearly 15 years of litigation over instream flows requirements for the Lower Yuba River (YCWA 2005) that were recommended in the CDFG Lower Yuba River Fisheries Management Plan. The Yuba Accord has three separate proposed agreements: a Fisheries Agreement, a Water Purchase Agreement, and a Conjunctive Use Agreement (YCWA 2005).

The Fisheries Agreement establishes new instream flow requirements based on the water-year type (YCWA 2005). The higher flows will improve instream habitat conditions during summer and fall months in part for spring-run holding and spawning, and juvenile steelhead rearing. The agreement also provides funding for long-term scientific fisheries monitoring, studies, and enhancement projects (YCWA 2005). Implementation of the instream flows was started on an interim basis in 2006, with full implementation to begin in 2008. The final environmental impact report/environmental impact statement for the Yuba Accord was completed in October 2007.

The Daguerre Point Dam Fish Passage Improvement Project was initiated, with DWR and the U.S. Army Corps of Engineers (USACE) as lead agencies, to address the fish passage problem identified at Daguerre Point Dam (Wood Rodgers 2003). The goal of the project is to improve upstream and downstream passage for salmonids while keeping water interests whole and not increasing the risk of flood (Wood Rodgers 2003). Wood Rodgers (2003) evaluated the benefits, limitations, and estimated cost of the alternative projects identified by the Yuba River Technical Working Group. The alternatives include: (1) no action; (2) build new fish passage facilities at either the existing location or at a new location or low-head weirs; (3) notch the dam; (4) construct either a short or long reach natural channel around the dam; and (5) remove the dam and construct new fish screens and pump stations at the existing location or 3 miles upstream (Wood Rodgers 2003).

In November 2007, University of California, Davis, USFWS, and USACE implemented an experimental gravel injection project just below Englebright Dam to evaluate its use as a habitat enhancement tool for spring-run Chinook (Pasternack 2008). Because flows were not sufficiently high in winter 2008 to mobilize the gravel, the results from the project are not yet available. However, modeling efforts conducted as part of the project demonstrated constriction of the upper part of the Englebright reach, which limits the potential for gravel deposition (Pasternack 2008). Pasternack (2008) concluded that this reach is not geomorphically self-sustaining like the reach below, scour is focused on the center of the channel preventing cross-channel gravel riffles from forming, and gravel deposition would occur only along channel margins and recirculation zones. In addition, shot rock has replaced a large point bar, composed of spawning gravel, and is taking up potential deposition space (Pasternack 2008).

The Upper Yuba River Studies Program Study Team (Study Team) prepared a watershed habitat assessment of the Upper Yuba River for DWR in 2007. The purpose of the assessment was to determine the biological, environmental, and socioeconomic feasibility of introducing Chinook salmon and steelhead into the watershed above Englebright Dam (UYRSPST 2007). The assessment focused on the Middle and South Yuba River because the North Yuba River is blocked by New

Bullards Bar Dam (UYRSPST 2007). Water temperatures could potentially limit the use of both forks by Chinook and steelhead. Field studies conducted in 2003 suggested that water temperatures were problematic; however, further analysis conducted in 2004 found that temperatures were thermally suitable for holding on a portion of the Middle Yuba River (UYRSPST 2007).

Approximately 5.6 miles of habitat on the Middle Yuba River were thermally suitable, and 0.5 mile was within the optimal range for spring-run Chinook holding and spawning below a natural barrier (UYRSPST 2007). The Study Team (UYRSPST 2007) estimated that combined habitat would support approximately 600 spring-run Chinook. An increase in flow would extend the habitat by an additional 11.7 miles and support a total of 1,650 spring-run Chinook. The increased flow also would provide 14 miles of steelhead spawning habitat supporting approximately 2,640 adults (UYRSPST 2007). Under 2004 operations, conditions were suitable for fall-run Chinook; therefore, hybridization and redd superimposition could reduce spring-run production on the Middle Yuba River (UYRSPST 2007).

2004 operations provided suitable habitat and thermal conditions to support other life stages of both spring-run Chinook and steelhead on the Middle Yuba River. Given the results, the Study Team determined that the upper watershed is capable of supporting salmonids and that increased flow would lengthen the amount of thermally suitable habitat for both spring-run Chinook and steelhead on the Middle Yuba River (UYRSPST 2007). The South Yuba River did not have suitable thermal conditions under 2004 operations, but operational changes could lower water temperatures to support spring-run Chinook and steelhead spawning (UYRSPST 2007).

NMFS recently issued a contract for a watershed-based habitat suitability assessment and conceptual plans for engineered fish passage design alternatives to allow fish passage through or around Englebright Dam (Edmondson pers. comm.). The contract is scheduled for completion by the end of the fiscal year 2009. The plan will, in part, identify potential habitat, facilities, and conceptual-level operation procedures and will clarify the hydropower regulatory environment among the multiple licensees and agencies (Edmondson pers. comm.).

The lower Yuba River does not have a self-sustaining, independent population of spring-run Chinook; however, it does have a small spring-run population that is supported by Feather River Hatchery operations (DWR 2007, Lindley et al. 2007). The lower Yuba River has a relatively naturalized flow regime and substantial sediment storage that will support reach-scale rehabilitation (Pasternack 2008). Therefore, this small population could benefit from restoration activities. However, the Yuba River continues to experience hybridization between spring-run and fall-run Chinook due to the lack of spatial and temporal separation (Yoshiyama et al. 2001). Fish passage around Englebright Dam could be managed to provide access to spawning, holding, and rearing habitat for both spring-run Chinook and steelhead and could provide spatial separation between spring-run and fall-run Chinook.

American River

Spawning/ Holding Habitat

By 1955, with the completion of Folsom and Nimbus Dams, spring-run Chinook were extirpated from the American River. No suitable habitat for spring-run exists in the lower American River.

Steelhead are currently limited to the lower 23 miles of the American River at the confluence with the Sacramento River to Nimbus. The upper portion of lower American River from Nimbus Dam to Goethe Park (RM 14) provides a diversity of aquatic habitat unrestricted by levees, while the section downstream from Goethe Park is bordered by levees resulting in a reduction in river meander and a deeper channel (SWRI 2001).

Snider and Beak Consultants, Inc. (1992) developed a geomorphically based habitat classification system for the lower American River that divided the lower river into three reaches. Reach 1, from the confluence to Paradise Beach Recreation Area, is approximately 5 miles long and characterized by a very low channel gradient and tidal fluctuations (SWRI 2001). The reach is dominated with long uniform flatwater stretches along with bar complexes consisting of glide and pool habitats only (SWRI 2001). Reach 2, from Paradise Beach Recreation Area to the Gristmill Dam Recreation Area, is approximately 7 miles long and is characterized by a predominately sand-bed channel dominated with flatwater areas (SWRI 2001). However, Reach 2 also has eight off-channel features and bar complexes with all four habitat types (riffle, run, glide, and pool) (SWRI 2001). Reach 3, from Gristmill Dam Recreation Area to Nimbus Dam, is approximately 11 miles long and is characterized by a relatively high gradient, gravel bed channel. Reach 3 has less flatwater area than the other two reaches, five off-channel features, and various bar complexes with all four habitat types (SWRI 2001).

Most spawning occurs in the upper 3 miles of the lower American River (NMFS 2004). The total spawning area peaks at flows of 2,400 cfs, but the availability varies only slightly between 1,000 and 4,000 cfs (NMFS 2004).

Rearing Habitat

Conditions from Watt Avenue (RM 9) to Nimbus Dam are generally suitable for the year-round rearing necessary for steelhead. Steelhead occasionally can be found rearing slightly lower in the river between Paradise Beach (RM 5) and Watt Avenue, depending on water temperatures (SWRI 2001).

Limiting Factors

High water temperature between July and September is probably the primary factor limiting steelhead production in the lower American River (SWRI 2001). NMFS set the temperature objective at a daily mean temperature of 65 °F at Watt Avenue for juvenile rearing but can adjust this objective depending on the size of the coldwater pool in Folsom Reservoir each year (NMFS 2004). In years with a low coldwater pool, water temperatures can exceed 65 °F between May and October; temperatures can reach 75 °F in July and August (NMFS 2004).

Flood control releases in spring can cause redd scouring, and the flow reductions following the releases can cause redd dewatering or stranding of fry and juveniles (NMFS 2004). In addition, harvest impacts (angling), hatchery practices, loss of riparian habitat, and predation may limit steelhead production in the lower American River (SWRI 2001).

Monitoring Activities

Since 2001, CDFG has conducted redd surveys and live adult counts for steelhead to estimate the number of in-river spawners, spawning distribution and time, and the percent of hatchery to wild

spawners. CDFG staff surveys every 2 weeks from December 20 through the first week in April, from Nimbus Dam (RM 23) to Paradise Beach (RM 5). The surveys are conducted by jet boat, walking, or snorkeling.

Restoration Activities

Reclamation operates Folsom and Nimbus Dams as part of the CVP; flows are managed on the lower American River to provide flood protection, water supplies, hydropower, recreational opportunities, and water quality control in the Delta (Water Forum 2005). Reclamation also manages flows to protect fish and wildlife downstream of Nimbus Dam. The American River Operations Work Group (AROG) meets once or twice a month to focus on real-time flow and water temperature management on the lower American River and provides operational recommendations to Reclamation (Water Forum 2005).

In the 1980s, the lower American River was designated as a “Recreational River” under both the California Wild and Scenic Rivers Act and the National Wild and Scenic Rivers Act. This designation provides additional protection to the scenic, wildlife, historic, cultural, and recreational value of the river (Water Forum 2005).

In 1994, the Water Forum was formed of a diverse group of business and agricultural leaders, citizen groups, environmental groups, water managers, and local governments in Sacramento County. Its purpose is to guide development of a regional solution in order to provide a reliable and safe water supply and to preserve the fishery, wildlife, recreational, and aesthetic values of the lower American River. A Memorandum of Understanding for the Water Forum Agreement that was signed in 2000 allows the region to meet its needs in a balanced way through year 2030 (Water Forum 2000).

In 2002, the Lower American River River Corridor Management Plan (RCMP) was developed by the Lower American River Task Force, with support from Sacramento Area Flood Control Agency (SAFCA), the Water Forum, and Sacramento County (Water Forum 2005). The RCMP sets goals, objectives, and actions for four distinct elements: fisheries and in-stream habitat management, vegetation and wildlife management, flood management, and recreation management. The Fisheries and Instream Habitat (FISH) Workgroup of the Lower American River Task Force developed a FISH Plan that works as a single blueprint to identify and prioritize opportunities to improve the fish and aquatic habitats in the lower American River; this plan serves as the habitat management element of the RCMP (Water Forum 2005). The goals of the FISH Plan is to increase and maintain viable populations of naturally spawning fall-run Chinook salmon, steelhead, and splittail; restore and maintain an appropriate distribution and abundance of other native species; and sustain American shad and striped bass fisheries consistent with restoring native species.

The three key areas in managing the river to protect fall-run Chinook and steelhead involve improving water temperatures and flow; restoring, maintaining, and improving fish habitat; and reducing the impact of water supply diversions (Water Forum 2005). Recent improvements related to the FISH Plan include improving and updating the flow management standards, minimizing flow fluctuations, constructing and operating a temperature control device on Folsom Dam to improve cool water pool management, implementing the Discovery Park floodplain habitat enhancement project, reducing surface water diversions, removing non-native invasive plants, and increasing riparian habitat (Water Forum 2005).

Reclamation, through CVPIA projects, has placed approximately 6,000 tons of gravel in the three sites on the lower American River to improve spawning habitat (Reclamation and USFWS 2009). In addition, several AFRP projects totaling \$501,000 have been completed including an instream flow study and a temperature reduction modeling project.

Construction of Folsom and Nimbus Dams completely blocked access to spawning habitat for both spring-run Chinook and steelhead in the American River. While no suitable habitat exists in the lower American River for spring-run, a small population of steelhead remains. Water temperatures in summer and fall, flow fluctuations, and limited spawning habitat limit the potential recovery for steelhead in the American River basin.

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