Appendix A

Central Valley Watershed Profiles

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CENTRAL VALLEY SALMON AND STEELHEAD RECOVERY PLAN WATERSHED PROFILES

At first glance, California Central Valley's major watersheds might seem very similar in physical characteristics and to have redundant habitat types. However, the Sacramento and San Joaquin River Basins that make up the two main watersheds in the Central Valley are surprisingly diverse. As already mentioned in the Recovery Plan, the Central Valley is made up of four distinct geological zones which create different watershed systems, which in turn are the basis for diverse fisheries.

An example of this is that the large number of historic salmon runs present before the 1850's, were likely a result of the plethora of habitat types and geological formations found in the Central Valley. These varying habitats supported different life history strategies leading to genetically distinct populations of salmon and steelhead. Central Valley salmon and steelhead developed different life history strategies by evolving with habitat factors that reflected differences in these watersheds such as: the availability of cold water, adequate substrate, cover, and flow. Fish ecologists believe that the variability in life history traits was caused by the limitations or availability of habitat features between watersheds, and geographic isolation of populations, which led to genetic separation and to independent salmonid populations within the Central Valley.

With the many habitat changes, and impacts to salmonids discussed in the Recovery Plan, improving habitat quality and availability of different habitats within a watershed and increasing the number of Central Valley watersheds that could support independent or important dependent populations is a cornerstone for salmon and steelhead recovery. Improvement in genetic diversity is and will be a direct result of maintaining and improving habitat complexity within watersheds. Since salmon and steelhead evolve to the habitats that they reside in, the loss of these habitats, or access to these habitats has been one of the primary road blocks to species population differentiation, production, and thus to recovery. Therefore, the relationship of these watersheds to population recovery is one of the primary tasks for planners when tackling restoration actions within watersheds.

The following watershed profiles characterize current watershed conditions, summarize key threats, and identify factors affecting species. The watershed profiles are generally categorized by biogeographic diversity groups based on the Central Valley Technical Recovery Team's (TRT) identification of four groups that Chinook salmon and steelhead historically inhabited in the Central Valley (Figure 1). Diversity groups are intended to capture a wide variety of climatological, hydrological, and geological conditions; and important components of habitat, life history or genetic diversity that contribute to the viability of salmonid ESUs/DPSs (Lindley *et al*. 2007). The diversity groups are as follows:

- The **basalt and porous lava diversity group** composed of the upper Sacramento River and Battle Creek watersheds;
- The **northwestern California diversity group** composed of streams that enter the mainstem Sacramento River from the northwest;
- The **northern Sierra Nevada diversity group** composed of streams tributary to the Sacramento River from the east, and including the Mokelumne River; and
- The **southern Sierra Nevada diversity group** composed of streams tributary to the San Joaquin River from the east.

The basalt and porous lava region comprises the streams that historically supported winter-run Chinook salmon. All of these streams receive large inflows of cold water from springs through the summer, upon which winter-run Chinook salmon depended. This region excludes streams south of Battle Creek, but would include the part of the Upper Sacramento drainage used by winter-run, and part of the Modoc Plateau region. The Northern Sierra Nevada region includes the southern part of the Cascades region (i.e., the drainages of Mill, Deer, and Butte creeks) and extends south including the Mokelumne River. The Southern Sierra Region begins just south of the Mokelumne River and extends south to include the upper San Joaquin River. This split reflects the greater importance of snowmelt runoff in the southern part, and distinguishes tributaries to the Sacramento and San Joaquin Rivers. There are two additional diversity groups within the steelhead DPS (Central Western California and Suisun Bay) which are not described here in the watershed profiles as it is assumed that full recovery of the CV steelhead can be achieved without the presence of populations in those diversity groups.

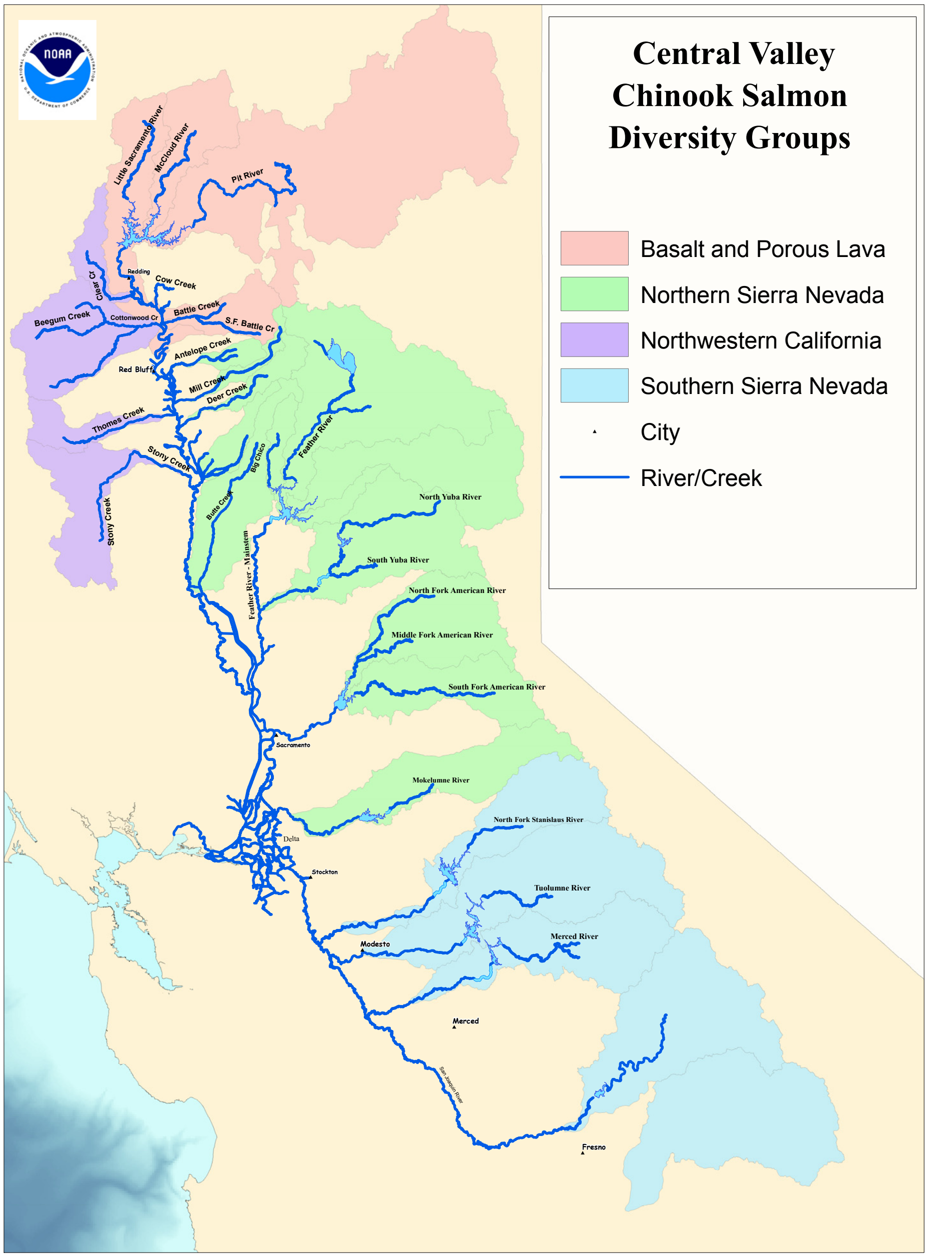

Figure 1. Central Valley Recovery Domain map of diversity groups and watersheds.
Source: Lindley *et al.* 2007

NORTHERN SIERRA NEVADA DIVERSITY GROUP

Cosumnes River Watershed Profile

Listed Species Present in the Watershed

Central Valley steelhead – *Oncorhynchus mykiss*

Species that Historically Occurred in the Watershed

Central Valley steelhead

Diversity Group

Northern Sierra Nevada

Key Stressors

Key stressors to Central Valley steelhead in Cosumnes Creek include, but are not limited to the following:

- Water diversions and groundwater pumping resulting in low flows
- Loss of floodplain habitat, natural river morphology, and riparian habitat and instream cover affecting juveniles
- Predation in the lower intertidal reaches near the confluence with the Mokelumne River

Watershed Description

Originating at an elevation of 7,600 feet, the headwaters of the Cosumnes River flow through the El Dorado National Forest and support native trout fisheries and many other aquatic species. Descending towards the Central Valley, the river passes through blue oak, grassland, and vernal pool communities. The lower reaches of the river provide critical salmon spawning habitat and the broad floodplain of the lower river harbors valley oak riparian forest and freshwater wetlands used by thousands of resident and migratory birds.

Lands within the Cosumnes River Preserve are jointly owned by The Nature Conservancy, The Bureau of Land Management, Ducks Unlimited, the California Department of Fish and Wildlife, State Lands Commission, the California Department of Water Resources, Sacramento County and various private owners. The Preserve is reestablishing riparian forest and perennial grasslands through active and passive restoration efforts. Valley oak, Oregon ash, Fremont's cottonwood, box elder, willow, wild rose, and elderberry are planted to create the diverse understory of trees and shrubs found in mature riparian forest.

The Cosumnes River includes 35 miles river miles of anadromous habitat from Latrobe Falls at an elevation near 400 feet, downstream to the confluence with the Mokelumne River. Because of this low elevation, spawning is only likely to occur in wet water years, and the production of yearling emigrants is unlikely due to warm summer water temperatures. The Cosumnes River may provide important non-natal rearing habitat to CV steelhead from the Mokelumne River or other nearby steelhead-producing rivers. The most valuable portion of this habitat is within the 46,000 acres of the Cosumnes River Preserve, partnership with local landowners, private partners such as the Nature Conservancy, and federal, state and local government agencies. The Cosumnes River preserve is pursuing conservation strategies restore and protect the ecological processes within its boundaries.

Fisheries

The Cosumnes River Barrier Improvement project, funded in 1998, was a collaborative effort by the FFC, Department of Fish and Wildlife (DFG), The Nature Conservancy (TNC), AFRP, CALFED, Rancho Murieta Community Services District (RMCSD), Omochumnes/Hartnell Water district (OHWD), and a private landowner adjacent to the lower Cosumnes River. The focus of the project was fall-run Chinook salmon passage improvement, but is likely to include some ancillary benefits to steelhead, especially in wet years spawning may occur. The objectives of the project as originally proposed were to improve passage conditions at four low-flow barriers; two summer dams and a low flow crossing in the lower river beneath the historic spawning reach and a diversion dam in the middle of the spawning reach. During post project monitoring activities two additional potential barriers were discovered and included in the objectives. In total, improvements were made to six structures from river mile (RM) 6.75 through RM 34.5.

Mokelumne River Watershed Profile

Listed Species Present in the Watershed

Central Valley steelhead

Species that Historically Occurred in the Watershed

Central Valley spring-run Chinook salmon – *Oncorhynchus tshawytscha*
Central Valley steelhead

Diversity Group

Northern Sierra Nevada

Key Stressors

Key stressors to Central Valley steelhead in the Mokelumne River watershed include, but are not limited to the following:

- ❖ Passage impediments/barriers at Camanche Dam and Pardee Reservoir Dam affecting adult immigration and holding
- ❖ Flow conditions (i.e., low flows) associated with attraction, migratory cues, flood flows and the attraction of non-natal fish into the Mokelumne River affecting adult immigration and holding
- ❖ Competition for spawning habitat, physical habitat alteration associated with limited supplies of instream gravel, habitat suitability and spawning habitat availability affecting adult spawning
- ❖ Hatchery effects associated with redd superimposition, competition for habitat, and genetic integrity affecting adult spawning
- ❖ Water temperatures affecting adult spawning and embryo incubation
- ❖ Flow conditions (i.e., flow fluctuations, changes in hydrology) affecting adult spawning, embryo incubation, juvenile rearing and outmigration
- ❖ Flow dependent habitat availability affecting juvenile rearing and outmigration
- ❖ Hatchery effects on juvenile rearing and outmigration

Watershed Description

With its headwaters at 10,000 feet on the crest of the Sierra Nevada mountains, the Mokelumne River drains approximately 661 square miles from four counties (i.e., Amador, Calaveras, Sacramento, and San Joaquin (USFWS and The Trust for Public Land 2009). It is a major tributary to the Sacramento-San Joaquin Delta, entering the lower San Joaquin River northwest of Stockton. The median historical unimpaired runoff is 696 taf, with a range of 129 taf to 1.8 maf (USFWS 1995). The landscape of the Mokelumne River watershed is typical of the lower

Sierra foothills, with rolling terrain interrupted by scattered rock outcrops and moderate to steep hillsides. The vegetation is predominantly grasslands and oak woodlands (EBMUD 2008).

The upper Mokelumne River watershed (upstream of Pardee Reservoir) measures about 570 square miles and is drained by numerous creeks (e.g., Jackson, Tiger and Sutter), feeding into the Mokelumne River (EBMUD 2009).

Chinook salmon and steelhead were once abundant in the Mokelumne River. The building of Comanche Dam, the Woodbridge diversion as well as other structures caused an 85% loss of habitat accessibility by these anadromous fish. Dams, sedimentation from gold mining and loss of habitat access were the main reasons that much of the steelhead and Chinook salmon runs have severely declined since the early 1900's (Reynolds *et al*. 1990 in USFWS 1995). Current efforts include improvements to fish passage and flows such as the recent improvement of passage at the Woodbridge diversion structure.

Recent monitoring in the San Joaquin River watershed has detected self-sustaining populations of steelhead in the Stanislaus, Mokelumne, and Calaveras rivers (McEwan 2001). Additionally, steelhead (and their progeny) from the artificially propagated stocks from the Coleman NFH and the Feather River Hatchery steelhead programs are considered part of the listed CCVS ESU. The Mokelumne River Hatchery uses steelhead stocks that originated from the Feather and Mokelumne River hatcheries and naturally produced Mokelumne River steelhead that enter the fish trap. The last time Nimbus origin eggs were used for the Mokelumne Hatchery program was in 1999-2000. Feather River steelhead eggs were imported from 2001-02 through 2006-07.

It is likely that the abundance of lower Mokelumne River steelhead would increase if water temperatures and flows for juvenile rearing and migration were improved, particularly in dry years. Lindley *et al*. (2007) recommend that in order to assess the risk of extinction or develop effective recovery actions for steelhead in the Central Valley, determining the distribution of steelhead and assessing the relationship between resident and anadromous forms of *O. mykiss* is a fundamental need. Lindley *et al*. (2007) stress that any quantitative assessment of population viability would be inadequate unless the role resident fish play in population maintenance and persistence of *O. mykiss* in the Central Valley is known.

Geology

The topography of the upper watershed varies from the gently sloping plain of the eastern San Joaquin Valley to the gentle and moderately rolling hills and ridges of the western-most Sierra Nevada foothills (EBMUD 2008). Elevations range from 235 feet above mean sea level (msl) to about 700 feet msl on the ridge-crests adjacent to Pardee Dam. Major soil groups in the upper watershed include well-drained stony clays to stony silt loams, well-drained gravelly to cobbly loams, well-drained clays occupying moderate slopes, relatively young overlying soil deposits consisting of well-developed alluvia with resistant hardpans, and unconsolidated to slightly consolidated alluvia. All exposed sedimentary rocks and soils are subject to erosion and transport into the downstream reservoirs (e.g., Pardee and Camanche), largely as a function of slope. Because rainfall in the watershed can mobilize contaminants and sediment in runoff, the presence of vegetation is a major factor in the prevention of erosion. Local sediments are the primary source of inorganic turbidity in Pardee and Camanche reservoirs (EBMUD 2008).

Hydrology

Almost 90 percent of precipitation occurs as rainfall during the months of November through April, and snowfall within the watershed is rare (EBMUD 2008).

Construction of Pardee Dam and Reservoir (1929) and Camanche Dam and Reservoir (1963) altered the hydrologic regime of the Mokelumne River, and the historic 100-year floodplain of the Mokelumne River is now within the area permanently flooded by Pardee and Camanche Reservoirs (EBMUD 2008). Watershed runoff is captured in three major impoundments (Camanche, Pardee, and Salt Springs Reservoirs) operated by East Bay Municipal Utilities District (EBMUD) and PG&E. These impoundments have a combined storage capacity of more than 750 taf. One other small impoundment in the watershed, the Lower Bear River Reservoir, stores 52 taf. Minimum flows below Camanche Dam range from between 100 to 325 cfs, as specified in FERC 2916-029, 1996 (Joint Settlement Agreement) (Reclamation 2008). Minimum flows below the Woodbridge Diversion Dam range from between 25 to 300 cfs (Reclamation 2008).

Land Use

The Mokelumne River watershed is a significant source of water for both consumption and energy production. The major land use in the upper watershed, owned both privately and publicly, is timber management. Much of the privately held land in the drainage area is undeveloped, and is currently left as open space or used for grazing (EBMUD 2008). Additionally, the Mokelumne River has a long history of water development. Within the watershed, East Bay Municipal Utility District (EBMUD) owns about 44 percent of the land area, which includes areas in the upper watershed extending from U.S. Highway 49 westward toward and including the Mokelumne River Day Use Area below Camanche Dam (EBMUD 2008a). Existing developments on the Mokelumne River upstream of Camanche Reservoir include facilities for hydroelectric, irrigation, and municipal use. Downstream of Camanche Reservoir, developments include both hydroelectric and irrigation facilities (USFWS 1995). EBMUD operates Camanche Reservoir together with Pardee Reservoir as part of an integrated system, and water releases are used to meet various demands for downstream users, including storage regulation for flood control and for the Mokelumne River Fish Hatchery, hydroelectric generation, and instream flow requirements for salmon (The Trust for Public Land 2009).

Fisheries and Aquatic Habitat

Five species of anadromous fish are present in the Mokelumne River below Camanche Dam, including fall-run Chinook salmon, steelhead, American shad[1], striped bass and pacific lamprey (USFWS 1995; M. Workman, USFWS, pers. comm. 2009). Fall-run Chinook salmon and steelhead are the primary management focus in the river (EBMUD 2008b).

Steelhead historically occurred in the Mokelumne River (USFWS 1998), but as recently as 2007, native steelhead were believed to be extinct, and were maintained in the river by hatchery plants (Marsh 2007). In the San Joaquin Basin, anadromy in *Oncoryhynchus mykiss* populations may be nonexistent or too low to detect while resident *O. mykiss* populations in the same rivers have remained strong (CDFW 2008). Because resident and anadromous *O. mykiss* juveniles can be difficult to differentiate, monitoring programs in these rivers typically report steelhead/rainbow trout captures as *O. mykiss*, rather than identifying the particular life history strategy of individual fish (CDFW 2008). Given the above considerations, in addition to the relatively recent, but extensive monitoring efforts that have been undertaken since implementation of the Joint Settlement Agreement[2] (1998), detailed findings regarding steelhead populations in the lower Mokelumne River are only beginning to emerge. Consequently, much of the information regarding anadromous salmonids habitat utilization in the Mokelumne River is based upon fall-run Chinook salmon.

Since the early 1900s, Chinook salmon in the lower Mokelumne River were adversely affected by poor water quality associated with winery and mine wastes, fish losses at unscreened diversions, and migration barriers due to dams (DFG 1991 in USFWS 1995). Runs up to 12,000 fish were recorded in the early 1940s (USFWS 1995). Spring-run Chinook salmon were probably present in the Mokelumne River prior to the construction of Pardee Dam in 1929. However, dams, poaching, and sedimentation caused by gold mining eliminated the spring-run Chinook salmon in the Mokelumne River (Reynolds *et al*. 1990 in USFWS 1995).

Wheaton *et al*. (2004) reports that "*the majority of salmonid spawning now takes place in a 14-km reach between Camanche Dam and Elliot Road (Merz and Setka, in press)*". The annual upstream fall-run Chinook salmon migration in the Mokelumne River begins in September, peaks in November and tapers off by early January (EBMUD 2009; (CDFW 1991 in USFWS 1995). Fall-run Chinook salmon spawning generally occurs in late October through January (EBMUD 2009). Myrick (1998 and 2000 in Reclamation 2008) found steelhead from the Mokelumne River preferred water temperatures between 62.5°F and 68°F. However, the

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[1] Distribution is believed to be limited to reaches downstream of Woodbridge Dam (Michele Workman, USFWS, pers. comm. 2009).

[2] The Lower Mokelumne River Joint Settlement Agreement for the Lower Mokelumne River Project, FERC No. 2916, regarding flow and non-flow measures appropriate for the lower Mokelumne River was entered into by and between East Bay Municipal Utilities District, USFWS, and CDFW. The Agreement was intended to resolve: (1) pending FERC Proceeding No. 2916-004; and (2) pending Mokelumne River Water Rights Proceedings before the SWRCB.

condition of the aquatic habitat and the variation of conditions in the lower Mokelumne River have resulted in widely varying population levels of these species (USFWS 1995).

The major barrier to upstream migrating Chinook salmon and steelhead adults on the Mokelumne River is Woodbridge Dam (USFWS 1995). Woodbridge Dam, a flashboard dam constructed on the lower Mokelumne River in 1910, contained no fish ladder until 1925. Fish passage was dependent upon river flows and the length of the irrigation season. Upstream migration of adult Chinook salmon was generally possible only after the flashboards were removed at the end of the irrigation season (October). The fish ladder proved to be ineffective and was reconstructed in 1955. Subsequent analyses of passage conditions indicated that migration of adult Chinook salmon past the dam was potentially impaired by spills that attract fish away from the fish ladder (CDFW 1991 in USFWS 1995). CDFW identified a shallow portion of the Mokelumne River near Thornton as a migration barrier to adult Chinook salmon at flows less than 60 cfs (CDFW 1991 in USFWS 1995). Historically, inadequate attraction and migration flows (generally less than 50 cfs) below Woodbridge Dam during October and November resulted in poor adult returns to the Mokelumne River and the Mokelumne River Fish Facility (USFWS 1995). However, since completion of the Joint Settlement Agreement (1998), flows during the fall do not decrease below 350 cfs in any water year type. The failure of returning adults to detect Mokelumne River outflow also may be exacerbated by diversion of proportionately large volumes of Sacramento River water into the lower Mokelumne River via the Delta Cross Channel (DCC), and reverse flows in the lower San Joaquin River and south Delta channels.

As previously discussed, historic upstream migration of adult Chinook salmon in the Mokelumne River was often delayed due to high water temperatures below Woodbridge Dam, which could persist until early November, even during a normal water year (CDFW 1991 in USFWS 1995). Passage at natural riffles is not as much of a concern for steelhead as it is with Chinook salmon because steelhead are smaller and better swimmers and can better negotiate natural riffles and partial barriers (USFWS 1995). Poor water quality conditions below Camanche Reservoir had the potential to adversely affect Chinook salmon by inhibiting upstream migration of adult Chinook to spawning areas. Water quality problems in the Mokelumne River have been associated with heavy metal pollution from Penn Mine, drought conditions, and Pardee and Camanche Reservoir operations. Past fish kills at the Mokelumne River Fish Facility were attributed to Camanche Reservoir discharges containing toxic levels of copper and zinc, low dissolved oxygen levels, and high concentrations of hydrogen sulfide. These conditions were associated with low inflows from Pardee Reservoir; record low reservoir levels; and hypolimnetic mixing, which may have mobilized sediments during the late summer and fall turnover of the reservoir (CDFW 1991 in USFWS 1995).

Suitable water temperatures for Chinook salmon spawning in the Mokelumne River below Camanche Dam generally have not occurred until early November during a normal water year. Water quality standards have been recommended by CDFW, including water temperatures to protect aquatic resources, including adult Chinook salmon spawners (CDFW 1991 in USFWS 1995). Camanche Dam also prevented the natural recruitment of gravel from upstream sources to spawning areas below the dam. Net losses of spawning gravels and a general increase in the size of streambed materials have reduced the amount of suitable spawning area. In addition, armoring or compaction of spawning substrate has reduced spawning gravel quality (USFWS 1995). Suitable water temperatures for Chinook salmon incubation and emergence in the Mokelumne River below Camanche Dam generally have not occurred until early November during a normal water year. Potential stranding of juvenile salmonids as a result of flow fluctuations were evaluated in several reaches downstream of Camanche Dam based on predicted changes in wet surface area over a range of flows. The stranding potential increased at flows below 400 cfs (USFWS 1995).

As part of the Joint Settlement Agreement, water temperatures in the lower Mokelumne River were to be maintained to meet the life-history needs of aquatic organisms (e.g., fall-run Chinook salmon and steelhead). EBMUD opens the upper level outlet in Camanche Reservoir after lake turnover and closes the upper outlet when temperatures at Woodbridge Dam reach approximately 64°F to maintain the best possible release temperatures to meet the life-history needs of aquatic organisms, including steelhead. Using its best efforts, EBMUD also manages the hypolimnetic volume in Camanche Reservoir so that at the end of October, the volume has exceeded 28,000 acre-feet in every year except 2003. The Mokelumne River watershed received uncharacteristically high precipitation in April and May 2003 and high flood control releases were required which diminished the cold-water pool during 2003 to 16,700 acre-feet (EBMUD *et al*. 2008).

Dry year flows in the lower Mokelumne River below Woodbridge Dam during the spring period are inadequate to effectively convey juvenile salmonids downstream and through the Delta (USFWS 1995). Juvenile Chinook salmon in the Mokelumne River are allowed to migrate naturally to the ocean in wet, normal and above normal water year types, but are trapped at Woodbridge Dam and trucked to Rio Vista or other suitable locations in the Delta during dry or critically dry years. In general, peak adult returns to the Mokelumne River indicate favorable rearing and emigration conditions during preceding wet years. Nearly all Chinook salmon produced at the Mokelumne River Fish Facility are trucked as yearlings to release locations in the western Delta. Major diversions affecting juvenile Chinook salmon emigrants from the Mokelumne River are the Woodbridge Canal diversion and the south Delta SWP and CVP export facilities. The Woodbridge Canal diversion was screened in 1968 and operates from April to October, depending on irrigation demands. The Woodbridge Canal fish screen was identified as not meeting NMFS and CDFW fish screen velocity and design criteria (USFWS 1995). However, as part of the Lower Mokelumne River Restoration Program, one of the project's key elements is to improve the fish screens and the fish bypass system for anadromous salmonids at the Woodbridge Dam (CALFED 2000).

Adult steelhead are likely to encounter the DCC gates in both an open and closed configuration throughout their extended spawning migration. NMFS (2009a) suggests that elevated levels of net negative flow present a risk to emigrating fish that have entered the central Delta through Georgiana Slough or, when the DCC is open, the Mokelumne River system. Closure of the DCC gates from November 1 through May 20 may block or delay adult salmonids that enter the Mokelumne River system and enter through the downstream side of the DCC. However, it is anticipated that closure of the DCC gates during this period will reduce diversion of Sacramento River water into the Central Delta, thereby improving attraction flows for adults in the mainstem Sacramento River (NMFS 2009a).

Steelhead are reported to move out of the Mokelumne River during December and January. Steelhead smolts from the Mokelumne River system enter the Eastern Delta. The Mokelumne River fish can either follow the north or south forks of the Mokelumne River through the Central Delta before entering the San Joaquin River at RM 22. Some fish may enter the San Joaquin River farther upstream if they diverge from the South Fork of the Mokelumne River into Little Potato Slough. Smolts migrating naturally out of the Mokelumne River also are exposed to Delta flow patterns in the central and south Delta (USFWS 1995).

Anadromous salmonids are subject to loss as they cross the Delta during their downstream migration towards the ocean (NMFS 2009a), and steelhead from the Mokelumne River Basin must pass several points of potential entrainment into the south Delta prior to reaching the western Delta (NMFS 2009a). Reverse flows caused by CVP and SWP export pumping in the south Delta contribute to poor survival of juvenile Chinook salmon and steelhead that enter the central Delta from the Mokelumne River or from the Sacramento River via the DCC or Georgiana Slough. Mark-recapture studies indicate that juvenile Chinook salmon released in the lower Mokelumne River experience higher mortality than those released in the Sacramento River below the DCC under dry year conditions (USFWS 1987 in USFWS 1995). As shown by the Burau *et al*. (2007), Perry and Skalski (2008) and Vogel (2008a) studies, individual fish risk entrainment into the channels of Georgiana Slough under all conditions and into the Mokelumne River system when the DCC gates are open as they migrate downstream in the Sacramento River. Estimated average survival is only 33 percent with a range of approximately 10 percent to 80 percent survival (NMFS 2009a). Most of this loss is believed to be associated with predation, but may also include prolonged exposure to adverse water quality conditions represented by temperature or contaminants. Several years of salmonid survival studies utilizing both Coded Wire Tags (CWT) and acoustically tagged fish indicate that survival is low in the interior Delta waterways compared to the mainstem Sacramento River. Likewise, survival in the upper San Joaquin River is substantially lower than survival from Jersey Point to Chipps Island (VAMP studies), indicating that transiting the Delta interior is a risky undertaking for fish exiting from the San Joaquin River Basin or the east side tributaries (Mokelumne River Basin) (NMFS 2009a).

CDFW has determined that the river reaches between Camanche Dam and the confluence with the Delta are of considerable importance for maintenance and restoration of Chinook salmon and steelhead (CDFW 1991). Over the past few years, Mokelumne River studies have used an extensive acoustic receiver array system deployed in the river to track the movement, survival, and habitat use of hatchery origin steelhead smolts, hatchery steelhead kelts and multiple life stages (>160mm) of the wild river population of *O. mykiss (*Workman *et al*. 2008). EBMUD, CDFW and USFWS continue to collaboratively work to improve conditions for the lower Mokelumne River. Restoration objectives have focused on providing additional salmonid spawning gravel, improving intergravel water quality, and increasing floodplain connectivity and providing the energy needed to sustain river rehabilitation in the first 1 mile below Camanche Dam (EBMUD 2009). Spawning gravel augmentation, side channel reconnection, riparian and educational projects have been undertaken. Woodbridge Irrigation District has completed the rebuilding of the dam at Woodbridge with improved fish passage facilities and improved screening at the diversion (USFWS 2008).

Steelhead

Although steelhead historically had sustained annual runs up the Mokelumne River, no information exists on the size of these historic runs (USFWS 1995). The Mokelumne River Fish Hatchery was constructed in 1964 as mitigation for loss of spawning habitat between Camanche and Pardee Dam. The hatchery has received an average of about 500 Chinook salmon adults between 1967 and 1991 (USFWS 1995). The Mokelumne River Fish Hatchery has an annual production goal of 100,000 yearling fish, which are primarily from Feather River and American River stocks (Reclamation 2008). However, NMFS (1998; 1999) does not consider Mokelumne River Fish Installation stocks to be part of the Central Valley ESU. Mokelumne River rainbow trout (hatchery produced and naturally spawned) are genetically most similar to Mount Shasta Hatchery trout, but also show genetic similarity to the Northern California ESU (Nielsen 1997, as cited in NMFS 1997b).

More recently, monitoring has detected small, self-sustaining populations of steelhead (although influenced by the Mokelumne River Hatchery steelhead program) in the Mokelumne River. Since implementation of the Joint Settlement Agreement, East Bay Municipal Utilities District has monitored *O. mykiss* populations in the lower Mokelumne River using video monitoring as the Woodbridge Irrigation District Dam (WIDD) fish ladder, rotary screw traps in the lower Mokelumne River downstream of the WIDD, and conducted seasonal fish surveys from Camanche Dam downstream to WIDD (Table 1) (EBMUD *et al*. 2008). Steelhead redd surveys in the lower Mokelumne River are conducted between Camanche Dam and the Elliott Road Bridge (EBMUD *et al*. 2008).

Table 1. *O. mykiss* observed in the fisheries sampling conducted in the lower Mokelumne River from Camanche Dam downstream to Woodbridge Dam between 1998 and 2008

Year	Period	Community Surveys [1]		Rotary Screw Trap [2]		WID Fish Ladder [3]	
		Hatchery [4]	Wild [5]	Hatchery	Wild	Hatchery	Wild
1998/1999	Oct-Mar		347	620	22		555
1999	Apr-Sep		227	6	191		2
1999/2000	Oct-Mar		24	871	19		941
2000	Apr-Sep		205	31	148	8	3
2000/2001	Oct-Mar		274	487	77	3,067	89
2001	Apr-Sep		245	4	381	9	23
2001/2002	Oct-Mar		253	9	154	593	152
2002	Apr-Sep		213	1	50	357	400
2002/2003	Oct-Mar		196	82	78	1,017	117
2003	Apr-Sep		98	15	78	1,312	380
2003/2004	Oct-Mar		175	61	16	385	105
2004	Apr-Sep		131	9	43	749	439
2004/2005	Oct-Mar		410	28	7	265	70
2005	Apr-Sep		335	4	74	816	42
2005/2006	Oct-Mar		781	61	8	28	10
2006	Apr-Sep		189	6	51	108	22
2006/2007	Oct-Mar	2	324	75	15	337	16
2007	Apr-Sep	6	273	2	136	121	23
2007/2008	Oct-Mar		213	1	31	*	*

1 Includes seasonal electrofishing and seining (January - June)
2 Rotary screw trap(s) immediately below Woodbridge Irrigation District Dam (mid-December through July)
3 Includes video monitoring and trapping in old ladder
4 Fish of hatchery origin (adipose fin clip)
5 Fish of natural origin
* Monitoring system inoperable due to construction of fish screens at WID canal

Source: Reproduced from EBMUD *et al*. 2008.

American River Watershed Profile

Listed Species Present in the Watershed

Central Valley steelhead

Species that Historically Occurred in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Diversity Group

Northern Sierra Nevada

Key Stressors

Key stressors to steelhead in the American River include the following:

- ❖ Nimbus and Folsom Dams (and smaller upstream dams) blocking access to historical spawning habitat;
- ❖ Warm water temperatures, particularly below dams, affecting juvenile rearing and outmigration and adult immigration and holding;
- ❖ Predation of juveniles;
- ❖ Loss of riparian habitat and instream cover affecting juvenile rearing and outmigration;
- ❖ Loss of floodplain habitat affecting juvenile rearing and outmigration;
- ❖ Loss of natural river morphology affecting juvenile rearing and outmigration;
- ❖ Competition for spawning habitat between natural- and hatchery-origin steelhead and the resultant effects on the genetic fitness of the natural population;
- ❖ Flow fluctuations affecting early life stages

Watershed Description

The American River drains a watershed of approximately 1,895 square miles (Reclamation 1996), and is a major tributary entering the Sacramento River and RM 60. The American River watershed drains about 1,900 square miles and ranges in elevation from 23 feet to more than 10,000 feet (SWRI 2001). The American River has historically provided over 125 miles of riverine habitat to anadromous and resident fishes.

Presently, use of the American River by anadromous salmonids is limited to the 23 miles of river below Nimbus Dam (i.e., the lower American River) (Figure 2).

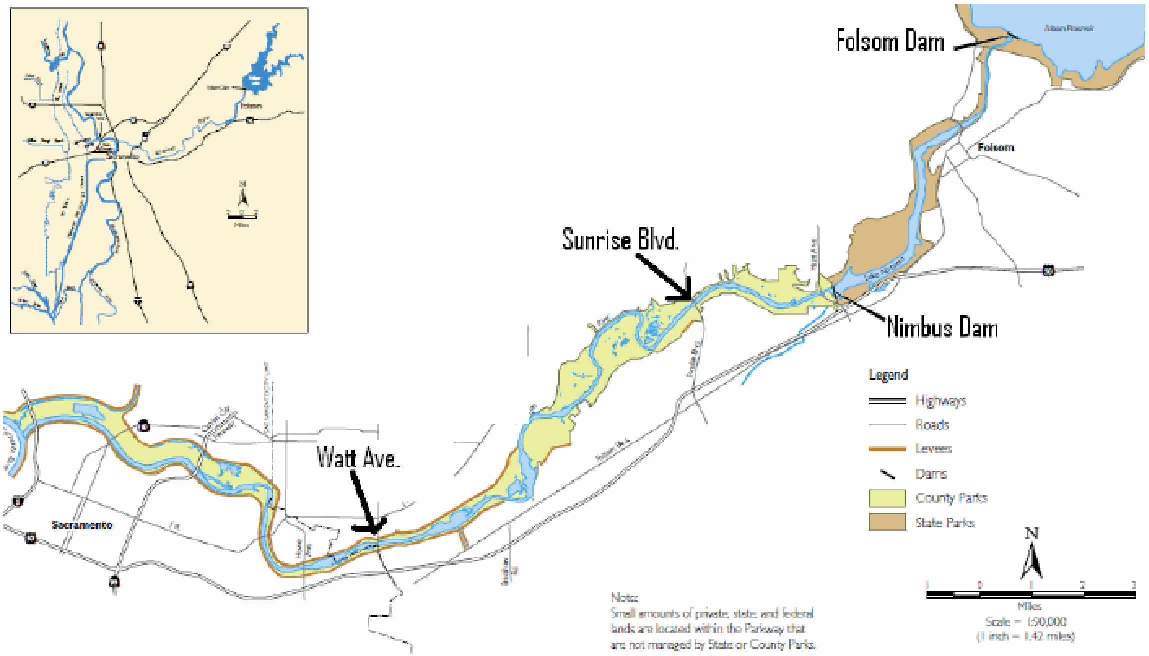

Figure 2. Map of lower American River. Modified from Water Forum (2005).

There is a general consensus in the available literature suggesting that habitat for steelhead in the American River below Nimbus Dam is impaired (Reclamation 2008; NMFS 2009a; Water Forum 2005; Water Forum 2005a; SWRI 2001; CDFW 1991, 2001). Of particular concern are warm water temperatures, flow fluctuations, and limited flow-dependent habitat (e.g., low flows during summer and fall limiting predator refuge habitat for juveniles). It has been suggested that the environmental factor probably most limiting to natural production of steelhead in the lower American River is high water temperatures during the summer and fall (Water Forum 2005; Reclamation 2008). Structural modifications may be needed to alleviate this limiting factor, including, but not limited to enhancing or replacing the shutter system at Folsom Dam, dredging and/or construction of temperature control curtains in Lake Natoma, and installation of a temperature control device at the El Dorado Irrigation District diversion.

Based on general observations of habitat complexity in terms of the distribution and availability of mesohabitat types (e.g., riffles, runs, and pools), with respect to geomorphology, it does not appear that the lower American River is in a highly degraded state, although a specific study addressing this issue is needed. One known concern regarding habitat complexity in the lower American River is that recruitment of large woody debris is limited, primarily because the debris is removed in order to provide safer conditions for rafting and other recreation activities.

The presence of Nimbus and Folsom dams have the most influence on the restoration potential of the American River watershed. Dams produce extensive ecological disruptions, including alteration of flow regimes, sedimentation, and nutrient fluxes, modification of stream-channel morphology, spatial decoupling of rivers and their associated floodplains, disruption of food webs, and fragmentation and loss of habitat (Ligon *et al*. 1995, Levin and Tolimieri 2001). All of these disruptions have occurred in the American River watershed due to the construction of Nimbus and Folsom dams.

Between Folsom Lake and the next upstream fish barrier, approximately 57 miles of riverine habitat exists in the North, Middle, and South forks combined. Within this 57 miles (and in more upstream habitats), evaluations of habitat quality with respect to anadromous salmonid life history requirements are needed. An indication that these riverine habitats above Folsom Dam may still be of sufficient quality to support anadromous salmonids is that populations of resident *O.mykiss* abundant enough to support recreational fisheries occur in all three forks, although the situation in the South Fork is complicated by the influence of stocking. The *O.mykiss* populations in the North and South Forks are entirely composed of wild fish.

Geology

As reported by SWRI (2001), from Folsom Dam to Fair Oaks, the American River floodplain is narrow. At Fair Oaks, the floodplain widens to about 1 to 5 miles, and the steep 125-foot high bluff of the Turlock Lake formation bounds the northern channel margin. Downstream, near Sacramento, the bluff height reduces to less than 10 feet and consists of the Riverbank Formation. The southern channel margin consists of a terrace of Recent-age alluvium that is lower than the northern bluff. The levees that have been constructed along both banks of the lower river are, therefore critical to flood control operations. The bed of the American River is primarily composed of gravel to cobble-sized material. However, gravel size can change seasonally and from year-to-year (SWRI 2001).

Hydrology

As reported by USFWS (1995), the American River accounts for approximately 15% of the total Sacramento River flow. Average annual precipitation over the watershed ranges from 23 inches on the valley floor to 58 inches at the river's headwaters. Snowmelt is the source of approximately 40% of the American River flow. Average historical unimpaired run-off at Folsom Dam, near the border between Sacramento and Placer counties, is 2.8 maf. The median historical unimpaired run-off is 2.5 maf, with a range of 0.3-6.4 maf. The American River has three major branches: the South Fork, the Middle Fork, and the North Fork. Today, 13 major reservoirs exist in the drainage with total storage capacity of 1.9 maf. Folsom Lake, the largest reservoir in the drainage, was constructed in 1956 and has a capacity of 974 taf. Folsom Dam, approximately 30 miles upstream from the mouth, is a major element of the Central Valley Project. The dam is operated by USBR as an integrated system with other Federal and State reservoirs to meet contractual water demands and instream flow and water quality requirements in the Delta (USFWS 1995).

Completion and operation of Folsom and Nimbus dams resulted in higher flows during fall, significantly lower flows during winter and spring, and significantly higher flows during summer.

Land Use

The following discussion on the historical land use in the American River watershed was directly taken from the *Impacts on Lower American River Salmonids and Recommendations Associated with Folsom Reservoir Operations to Meet Delta Water Quality Objectives and Demands* (Water Forum 2005a). Prior to 1849, the riparian vegetation along the river formed extensive, continuous forests in the floodplain, reaching widths of up to 4 miles. Settlement of the lower American River floodplain by non-indigenous peoples and the resulting modifications of the physical processes shaping the river and its floodplain have drastically altered the habitats along the river. Early settlers removed trees and converted riparian areas to agricultural fields. Hydraulic gold mining in the watershed caused deposits of 5-30 feet of sand, silt, and fine gravels on the riverbed of the lower American River. These deposits resulted in extensive sand and gravel bars in the lower river and an overall rising of the river channel and surrounding floodplain. This was later exacerbated by gravel extraction activities. As a result, the floodplain's water table has dropped, reducing the growth and regeneration of the riparian forest (Water Forum 2005a).

Additional habitat impacts resulted from the construction of Folsom and Nimbus Dams. These structures have blocked the main upstream sediment supply to the lower American River. This sediment deficit reduces the amount of material that can deposit into bars and floodplains in the lower reaches, resulting in less substrate for growth of cottonwoods and other riparian vegetation (Stromberg *et al*. 2007). Modification of river flows resulting from the operation of Folsom Dam and Reservoir has likely affected the potential for regeneration of cottonwood. Flows that had historically occurred during the seed dispersal period for cottonwood shifted from the late spring/early summer to late summer or no longer occur. Also, artificial flow fluctuations can cause the stranding of fish in ponds and depressions on the floodplain when high flows recede (Water Forum 2005a).

Since the 1970s, bank erosion, channel degradation and creation of riprap revetments have contributed to the decline of riparian vegetation along the river's edge, loss of soft bank and channel complexity, and reduced amounts of large woody debris in the river that are used by fish and other species. Currently, some of the large woody debris that does still accumulate in the river is removed to provide safer conditions for recreation activities such as swimming and rafting. In addition, there has been a decrease in overhanging bank vegetation called shaded riverine aquatic (SRA) habitat (Water Forum 2005a).

Urbanization throughout the greater Sacramento area has led to a replacement of agricultural land uses within the American River floodplain with urban land uses, and a corresponding increase in urban runoff (SWRI 2001). Based on data from 1992 through 1998 collected by the Ambient Monitoring Program, lower American River water quality exceeded State (California Toxics Rule) or Federal (EPA) criteria with respect to concentrations of four metals – lead, copper, zinc, and cadmium (SWRI 2001). High concentrations of these metals have adverse effects on fish. In particular, studies have demonstrated that fish fed diets contaminated with zinc exhibited reduced survival, growth, and increased incidence of disease (Farag *et al*. 1994, Bowen *et al*. 2006). It should be noted that zinc is easily bioaccumulated in stream invertebrates – an important food source for juvenile salmonids while rearing in freshwater systems (Bowen *et al*. 2006).

Fisheries and Aquatic Habitat

Including the mainstem, and north, middle, and south forks, historically over 125 miles of riverine habitat were available for anadromous salmonids in the American River watershed

(Yoshiyama *et al*. 1996). The construction of Nimbus Dam in 1955 blocked steelhead and spring-run Chinook salmon from all historic spawning habitat in the American River (Lindley *et al*. 2006). Hydrological and ecological changes associated with the construction of the dams contributed to the extirpation of summer steelhead and spring-run Chinook salmon, which were already greatly diminished by the effects of smaller dams (*e.g*., Old Folsom Dam and the North Fork Ditch Company Dam) and mining activities (Yoshiyama *et al*. 1996).

Development of the American River watershed has modified the seasonal flow and water temperature patterns in the lower American River. Operation of the Folsom-Nimbus project significantly altered downstream flow and water temperature regimes. In addition, operation of Sacramento Municipal Utility District's Upper American River Project (UARP) since 1962, as well as Placer County Water Agency's Middle Fork Project (MFP) since 1967, altered inflow patterns to Folsom Reservoir (SWRI 2001).

Seasonal water temperature regimes also have changed with development in the American River watershed, particularly with the construction and operation of Folsom and Nimbus Dams. Prior to the completion of Folsom and Nimbus Dams in 1955, maximum water temperatures during summer frequently reached temperatures as high as 75°F to 80°F in the lower American River (Gerstung 1971). Although summer water temperatures are cooler in the lower river after Folsom Dam was constructed as compared to the pre-dam conditions, prior to habitat elimination resulting from the dam, rearing fish had access to cooler habitats throughout the summer at higher elevations.

Water temperature management for anadromous salmonids is an issue of concern in the lower American River. For example, the occurrence of a bacterial-caused inflammation of the anal vent (commonly referred to as "rosy anus") of American River steelhead has been reported by CDFW to be associated with warm water temperatures. Sampling in the summer of 2004 showed that this vent inflammation was prevalent in steelhead throughout the river and the frequency of its occurrence increased as the duration of exposure to water temperatures over 65°F increased. At one site, the frequency of occurrence of the anal vent inflammation increased from about 10 percent in August, to about 42 percent in September, and finally up to about 66 percent in October (Water Forum 2005a). During the summer, mean daily water temperatures at Watt Avenue often exceed 68°F (NMFS 2009a).

Predators of juvenile steelhead in the lower American River include both native (*e.g*., pikeminnow) and non-native (*e.g*., striped bass) fish as well as avian species. Some striped bass reportedly reside in the lower American River year-round, although their abundance greatly increases in the spring and early summer as they migrate into the river at roughly the same time that steelhead are both emerging from spawning gravels as vulnerable fry and are migrating out of the river as smolts (SWRI 2001). Striped bass are opportunistic feeders, and almost any fish or invertebrate occupying the same habitat eventually appears in their diet (Moyle 2002). Empirical data examining the effect of striped bass predation on steelhead in the American River have not been collected, although one such study was recently conducted in the Delta (CDWR 2008). Results of this study concluded that steelhead of smolt size had a mortality rate within Clifton Court Forebay that ranged from 78 ± 4 percent to 82 ± 3 percent over the various replicates of the study. The primary source of mortality to these steelhead is believed to be predation by striped bass. Although Clifton Court Forebay and the lower American River are dramatically different systems, this study does demonstrate that striped bass are effective predators of relatively large-sized steelhead. Considering that striped bass are abundant in the lower American River during the spring and early summer (SWRI 2001), when much of the steelhead initial rearing and smolt emigration life stages are occurring, striped bass predation on juvenile steelhead is considered to be a very important stressor to this population.

Steelhead

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

Estimates of historic run sizes for fall- and winter-run steelhead in the American River were not identified in the available literature. However, all three (summer, fall, and winter) runs of steelhead were likely historically abundant in the American River considering: (1) the extent of available habitat; (2) the historic run size estimates of Chinook salmon before massive habitat degradation occurred; and (3) the reported historic run size estimates for summer-run steelhead in the 1940s which occurred even after extensive habitat degradation and elimination.

The following information on the current status of American River steelhead comes from the Biological Opinion on the Long-Term Central Valley Project and State Water Project Operations Criteria and Plan (NMFS 2009a) and references therein.

The Central Valley steelhead DPS includes naturally-spawned steelhead in the American River but excludes steelhead spawned and reared at Nimbus Fish Hatchery. The current population size of 300 to 400 in-river spawning steelhead (Hannon and Deason 2008) is much lower than estimates (*i.e*., 12,274 -19,583) from the 1970s (Staley 1976), and is primarily composed of fish originating from Nimbus Hatchery. This means that the listed population (*i.e*., naturally-produced fish) in the lower American River is at an abundance level lower than the estimates provided by Hannon and Deason (2008) and is likely on the order of tens.

In addition to small population size, other major factors influencing the status of naturally spawning steelhead in the American River include: (1) a 100 percent loss of historic spawning habitat resulting from the construction of Nimbus and Folsom Dams (Lindley *et al*. 2007), which has obvious and extreme implications for the spatial structure of the population; and (2) the operation of Nimbus Fish Hatchery, which has completely altered the diversity of the population.

Lindley *et al*. (2007) classifies the natural population of American River steelhead at a high risk of extinction because this population is reportedly mostly composed of steelhead originating from Nimbus Fish Hatchery. The small population size and complete loss of historic spawning habitat and genetic composition further support this classification.

Auburn Ravine/Coon Creek Watershed Profile

Listed Species Present in the Watershed

Central Valley steelhead

Species that Historically Occurred in the Watershed

Central Valley steelhead

Diversity Group

Northern Sierra Nevada

Key Stressors

Key stressors to steelhead in Auburn Ravine and Coon Creek include, but are not limited to the following:

- Passage impediments/barriers affecting adult immigration and spawning
- Flow conditions (i.e., low flows, flow fluctuations) associated with attraction and migratory cues into the Auburn Ravine and Coon Creek drainage affecting adult immigration and spawning
- Limited instream gravel supply and habitat availability affecting spawning
- Flow dependent habitat availability affecting juvenile rearing and outmigration
- Water temperature and water quality (e.g., agricultural and urban runoff) into the Auburn Ravine and Coon Creek drainage affecting juvenile rearing and outmigration
- Entrainment at individual diversions in the Auburn Ravine and Coon Creek drainages affecting juvenile rearing and outmigration
- Loss of natural morphology, riparian habitat and instream cover affecting juvenile rearing and outmigration
- Predation associated with non-site specific and structure-related habitats in the Auburn Ravine and Coon Creek drainage affecting juvenile rearing and outmigration

Watershed Description

Auburn Ravine originates north of the City of Auburn and flows 29 miles to its confluence with the East Side Canal, draining an area of approximately 79 square miles. The East Side Canal drains into the Cross Canal, which then drains into the Sacramento River just southeast (downstream) of the Feather River confluence. The elevation of the Auburn Ravine basin ranges from 1,600 to 30 feet above mean sea level (msl) (County of Placer 2002). Primary tributaries to Auburn Ravine include North, Dutch, and George's Ravines (County of Placer 2002).

The Coon Creek watershed originates in the foothills north and east of the City of Auburn, near Clipper Gap. The watershed east of SR 49 is primarily composed of two intermittent tributaries, Dry Creek and Orr Creek, which eventually merge approximately one mile west of SR 49 to form Coon Creek (County of Placer 2002). Primary tributaries to upper Coon Creek include Orr, Dry, and Rock Creeks, and Deadman Canyon. Doty Ravine is the primary tributary of Coon Creek. The Doty Ravine watershed originates in the Bald Hill area north of Newcastle and flows westerly for about 8.5 miles before leaving the upper watershed just east of McCourtney Road. Major tributaries to Doty Ravine include Sailor's Ravine and Caps Ravine (County of Placer 2002).

The limiting factor for steelhead in the Auburn Ravine system is suitable spawning habitat. Due to the current out of basin water imports and related flow regimes, these streams provide spawning and rearing habitats that would otherwise be limited or absent. Rainbow trout are known to spawn here, however, steelhead spawning has not been confirmed. If suitable spawning habitat were to be established, it is possible that there would be more active use of this creek by steelhead.

To facilitate Auburn Ravine water deliveries to users, there are approximately 10 small seasonal diversion dams installed throughout Auburn Ravine. Most of the dams are less than 10 feet high and pond water for diversion into agricultural areas. Larger dams also divert water into major canals. Installation of the seasonal dams during the spring and removal during the fall reportedly can affect the upstream migration of some fish species (e.g., steelhead and fall-run Chinook salmon) (Jones & Stokes Associates 1999).

As reported by SARSAS (2009), Placer Legacy and NID are currently in the process of retrofitting the Lincoln Gaging Station and Hemphill Dam for fish passage. These dams will be retrofitted by the end of Summer 2009. Fish will then be able to reach the base of NID's Gold Hill Diversion Dam. NID has identified retrofitting Gold Hill Dam to facilitate fish passage as a focus for NID once fish are able to reach the dam (SARSAS 2009).

Geology

As reported by North Fork Associates (2003), the area immediately around Auburn consists of Jurassic and Triassic metavolcanic rocks. The remainder of the upper foothills is composed of Mesozoic granitic rocks. Pliocene nonmarine sediments occur between the granitic rocks to the east and Highway 65 between Roseville and Lincoln. These sediments form the Mehrten Formation, which consists of a variety of cemented material and is well known for supporting vernal pools along the east side of the Central Valley. Eocene deposits of he Ione Formation form small pockets associated with the Mehrten Formation. West of Highway 65 is a large amount of Pliocene and Pleistocene nonmarine sediments, which tend to form coarse, well drained soils. Further to the west, more recent alluvial fan deposits form coarse to fine grained soils. Soils in the upper and lower foothills of western Placer County include Auburn, Sobrante, Andregg, Caperton, Sierra, Exchequer, and Inks. The upper foothill soils are shallow to moderately deep and are typically well drained. Therefore, much of the rainfall in this region enters streams either through direct runoff or groundwater discharges. The Exchequer-Inks soils occur over shallow volcanic rock. Inks soils are formed from consolidated or cemented sediments derived from volcanic rock, and is one of the primary Mehrten Formation soils. Valley soils include San Joaquin, Cometa, Fiddyment, Kasberg, Ramona, Kilga, Redding, and Corning Series. Several of these are Alfisols and have dense, subsurface clay layers that impede water percolation. Wetlands are often found on these soils because they tend to hold water, especially in depressions (North Fork Associates 2003).

Hydrology

As reported by County of Placer (2002), water management practices in Auburn Ravine, Coon Creek, and Doty Ravine are different than most small East Side foothill tributary streams. Because these watersheds are relatively small, very little of the stream flow is from natural runoff. Coon Creek's hydrology is similar to Auburn Ravine, except that nearly all irrigation water is diverted out of the channel just downstream of Highway 65 during the irrigation season. Water in the Coon Creek channel downstream of this diversion point is primarily groundwater inflows or agricultural return flows (County of Placer 2002).

Historically, Auburn Ravine flows were ephemeral (Sierra Business Council 2003). Flows gradually declined through the spring, summer, and early fall until the first seasonal storm events occurred. Compared to the historical flow regime, current management practices produce higher flows year-round and more consistent flows during the spring and summer months (Table 2). Most of the instream flow in Auburn Ravine is water imported from the Yuba River, Bear River, and American River watersheds through various means, to meet domestic and agricultural needs in western Placer County and southeastern Sutter County (Sierra Business Council 2003). Discharges from PG&E's Wise Powerhouse dominate instream flows during the irrigation season, which extends from April 15 through October 15. Winter flows are dominated by discharges from wastewater treatment facilities and natural runoff. Current water management practices in Auburn Ravine likely provide cold water habitat for salmonids during time periods which historically lacked cold water habitat (Sierra Business Council 2003).

Table 2. Estimated historic and existing streamflow regimes in Auburn Ravine (cfs)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Historic	70.6	50.9	32.3	20.1	2.4	0.2	0.1	0.0	0.0	4.1	11.7	38.2
Existing	117	120	132	66	88	82	114	99	43	30	39	84
Source: Jones & Stokes Associates 1999												

The relatively cool water discharged from the Wise Powerhouse originates from the Drum-Spaulding Project on the Yuba and Bear rivers. PCWA also discharges up to 50 cfs of water from the North Fork American River into Auburn Ravine during the irrigation season. NID, PCWA, and South Sutter Water District, and their customers, divert water from Auburn Ravine primarily for irrigation purposes. Water temperatures in Auburn Ravine during the irrigation season are heavily influenced by these discharges and diversions.

As reported by County of Placer (2002), the Placer County Wastewater Treatment Plant, discharges treated effluent into Rock Creek. Rock Creek joins Dry Creek about 50 yards downstream of the effluent outfall. Dry Creek continues to flow west to the confluence with Orr Creek, which flows from the northeast. Dry Creek and Orr Creek join together to form Coon Creek, which then flows generally westward to the Cross Canal before entering the Sacramento River. The upper half of the Coon Creek basin is characterized by a complex network of irrigation canals managed by NID to carry water imported from the Bear River (County of Placer 2002).

The maximum elevation of the Auburn Ravine watershed is approximately 1,000 feet above mean sea level (MSL). Therefore, precipitation in the watershed falls nearly exclusively as rainfall. The annual timing of rainfall is fairly consistent, with the majority of a water year's precipitation occurring between November and April. However, the amount of precipitation can vary greatly on an annual basis, and individual storm cells can deliver a large amount of rainfall in a relatively short period, even during drought periods (County of Placer 2002).

Winter flows vary widely between and among the Auburn Ravine and Coon Creek watersheds. Auburn Ravine's winter flow peaks can range from a few hundred cubic feet per second (cfs) to an estimated 100-year flow event exceeding 17,000 cfs. Coon Creek's peak flows can range from several hundred cfs in smaller events to more than 22,000 cfs in a hundred year event (County of Placer 2002). High flow events are not contained within the channel of Coon Creek and extensive overland flow occurs (County of Placer 2002).

The critical low flow period generally occurs in October when irrigation season ends and flows from imported sources cease or greatly diminish. Flows during this period (generally early October until winter rains are sufficient to generate additional natural stream flow) are often only a few cfs, resulting in a substantial decrease in aquatic habitat in the low gradient portions of the Auburn Ravine, Doty Ravine, and Coon Creek watersheds (County of Placer 2002).

Land Use

As reported by Placer of County (2002), portions of Auburn Ravine, Dutch Ravine, Doty Ravine, and Coon Creek were placer mined in the mid-to-late 1800s. This activity resulted in removal of riparian vegetation, excavation of soil, and redeposition of tailings. Large quantities of sediment, generated by hydraulic mining, were washed into stream channels and most of this sediment was deposited on the valley floor. Trees were also removed for firewood, construction materials, and to facilitate grazing and farming. In the western portion of the watersheds, the creeks have been largely confined to narrow channels and the riparian plant community reduced to a narrow band along the banks. In general, the eastern portion of the watersheds are in a more natural state.

Lower elevations, which were once dominated by marshlands, have been largely converted to irrigated agriculture. Stream channels have been converted to irrigation/flood canals, with some riparian vegetation within a generally open grassy levee system. Historic vernal pool grasslands have been largely replaced by farmland. Upstream, streams flow though non-native grassland (often grazed) and agricultural fields, with a thin margin of mixed native and non-native riparian species along the creeks. Grassland areas may include patches of valley oak woodland. Oak woodland and mixed oak woodland and scrub habitats become more predominant in the foothills, transitioning to heavier forested areas in the steeper portions of the watershed. These plant communities are affected significantly by the invasion of exotic plants, including a variety of non-native grasses and weedy species such as mustard, broom, and Himalayan blackberry. These species have largely replaced the native grass and forb habitats of the lower foothills (County of Placer 2002).

Auburn Ravine flows through the middle of the city of Auburn, where it is channelized and passes through a variety of culverts. The land adjacent to this portion of the watershed is highly urbanized. Immediately west of the City of Auburn, the character of the channel changes, adjacent land uses change, and water from various sources is discharged into to the channel (County of Placer 2002).

The primary ecological and land use concern in the Auburn Ravine and Coon Creek watersheds is the conversion of existing land uses from agriculture to urban and suburban development. Stream and riparian zone areas would face further ecological stress due to the conversion of adjacent upland habitats to urban and suburban development. Additionally, it is anticipated that water quality will decline with urbanization of the surrounding watersheds. Sustaining commercial agriculture, with its open space component, is a primary goal of habitat conservation, as planned urban development and uncontrolled annexation of agricultural lands continues (County of Placer 2002).

Urban development is least likely to occur along Coon Creek above Gladding Road due to large parcel sizes, current General Plan designations, a lack of urban services and environmental constraints. Auburn Ravine is experiencing the greatest pressures from urban encroachment with the expansion of housing tracts in the Lincoln area. Development could be a major constraint on fishery restoration as most land in the watershed is in private ownership and has no permanent protection (Bear River Watershed Group Website 2009).

Due to large parcel sizes, particularly along Coon Creek upstream of Gladding Road, blue oak woodlands are relatively intact and unfragmented, thus providing large patch sizes for terrestrial species. The Auburn Ravine's upper watershed is more fragmented due to the predominance of the rural resources land designation. The potential for subdivision development in the upper Coon Creek watershed is generally low under current General Plan designations and is unlikely to occur in the future because of a lack of urban services and environmental constraints. The dominant land use in the portion of the watersheds west of Lincoln is rice farming. This land use drives the current water management practices and the timing and flow volumes of water that is delivered during the spring, summer, and early fall (County of Placer 2002).

Fisheries and Aquatic Habitat

As reported by County of Placer (2002), Auburn Ravine provides a diversity of aquatic habitats, including shallow, fast-water riffles, glides, runs and pools. Near its headwaters in the City of Auburn, Auburn Ravine is highly restricted to its natural channel and passes through several culverts. From the western edge of the City of Auburn to west of Lozanos Road, Auburn Ravine is confined in a narrow canyon and has a steep gradient. Stream habitat units in this reach are primarily cascades and pool-riffle complexes, while the substrate consists of bedrock, sands, and cobbles. Just east of Gold Hill Road, the channel gradient in Auburn Ravine decreases to less than 2 percent and the stream habitat is dominated by pools, riffles, and runs, while the substrate is dominated by sands and gravels. Near the City of Lincoln, the stream gradient decreases to less than one percent and the stream habitat shifts from pool-riffle complexes with mixes of gravels and sands to dune-ripple complexes dominated by coarse sand. The lowermost seven miles of Auburn Ravine are confined within naturally erosion-resistant banks and man-made levees, and are dominated by dune-ripple complexes and a sandy substrate (County of Placer 2002).

Aquatic habitat surveys of Auburn Ravine, within and downstream of the City of Lincoln, indicate that a large percentage of the stream is dominated by sandy and silty substrates. Sandy and silty substrates also dominate the middle reaches of Coon Creek and portions of Doty Ravine. These substrate types are characterized by low instream productivity and low habitat diversity. The sources of these sediment inputs are not apparent, but the small grain size and continuously shifting nature of these substrate types contribute to what are considered low quality fish habitats. These substrate types eliminate, for all practical purposes, the potential for Chinook salmon and steelhead spawning in areas downstream of the Highway 65 Bridge in Lincoln (County of Placer 2002).

Without the water imported into these watersheds, most would be dry, or nearly so, for several months of the year. Due to the current water delivery schedules and flow volumes, there are riparian and aquatic habitats along tens of miles of stream channel length that would otherwise be absent. As a result, these streams may support aquatic species that would not otherwise have found suitable habitat in this region. At the same time, these enhanced flow regimes provide habitat for non-native species; for example, the regular flow regime may enhance conditions for Himalayan blackberry, a non-native species that crowds out native plants (County of Placer 2002).

Flows and water temperatures in Auburn Ravine are influenced by discharges from the Lincoln Wastewater Treatment and Reclamation Facility (WWTRF) and the Auburn Wastewater Treatment Plant (WWTP). These discharges likely are warmer than the receiving waters in Auburn Ravine. Another factor influencing Auburn Ravine water temperature is the amount of overhanging riparian vegetation. The lack of riparian buffers along the downstream reaches of Auburn Ravine likely contributes to elevated water temperatures.

To facilitate Auburn Ravine water deliveries to users, there are approximately 10 small seasonal diversion dams installed throughout Auburn Ravine. Most of the dams are less than 10 feet high and pond water for diversion into agricultural areas. Larger dams also divert water into major canals. Installation of the seasonal dams during the spring and removal during the fall reportedly can affect the upstream migration of some fish species (e.g., steelhead and fall-run Chinook salmon) (Jones & Stokes Associates 1999).

As reported by SARSAS (2009), Placer Legacy and NID are currently in the process of retrofitting the Lincoln Gaging Station and Hemphill Dam for fish passage. These dams will be retrofitted by the end of Summer 2009. Fish will then be able to reach the base of NID's Gold

Hill Diversion Dam. NID has identified retrofitting Gold Hill Dam to facilitate fish passage as a focus for NID once fish are able to reach the dam (SARSAS 2009).

Steelhead

Historically, low elevation streams such as Auburn Ravine likely were essentially dry during the summer and fall, at least in the foothill sections. Therefore, streams such as Auburn Ravine likely were not conducive to supporting significant or consistent steelhead populations. Local area residents have reported that steelhead routinely spawned near Auburn (Jones & Stokes Associates 1999).

Documented evidence of steelhead spawning (e.g., observations of steelhead actively spawning or confirmed steelhead redds) in Auburn Ravine has not been located, however, the presence of juvenile rainbow trout captured during electrofishing surveys and seining suggests that at least rainbow trout successfully spawn in Auburn Ravine (CDFW 2005, unpublished data).

Currently, information regarding steelhead presence and habitat utilization in Auburn Ravine is either limited or not readily available. Steelhead were not collected during the 1997 fish survey, although juvenile fishes were collected in upper reaches during the 1998 and 1999 surveys (Jones & Stokes Associates 1999). The 1998 survey reported that some of the captured juvenile fish exhibited the iridescent silvery sides typical of smolting salmonids (Jones & Stokes Associates 1999); however, it can be difficult to determine whether juvenile fish are anadromous or resident forms of the species. The juvenile fishes collected during the 1999 survey reportedly did not exhibit any obvious visual characteristics of emigration associated with the anadromous form (i.e., steelhead) (Jones & Stokes Associates 1999).

CDFW (2005, unpublished data) conducted two-pass electrofishing surveys on a total of seven reaches in Auburn Ravine during the fall/winter of 2004 and the spring of 2005. During the 2004 fall/winter survey, a total of 689 fish were collected in Auburn Ravine, 309 of which were identified as steelhead/rainbow trout. Of the 674 fish collected during the 2005 survey, 253 were identified as steelhead/rainbow trout. The CDFW survey results indicate that Auburn Ravine may constitute a probable steelhead spawning area given the presence of very small juveniles during spring. Auburn Ravine, both upstream and downstream of the tunnel outlet, may represent a year-round rearing area for juvenile steelhead, given the presence of both YOY and larger juveniles during November, December, and April.

Dry Creek Watershed Profile

Listed Species Present in the Watershed

Central Valley steelhead

Species that Historically Occurred in the Watershed

Central Valley steelhead

Diversity Group

Northern Sierra Nevada

Key Stressors

Key stressors to steelhead in Dry Creek include but are not limited to the following:

- Passage impediments/barriers in the Dry Creek watershed affecting adult immigration and holding
- Elevated water temperatures and water quality (agricultural and urban runoff) affecting adult immigration and holding, spawning and embryo incubation, juvenile rearing and outmigration
- Flow fluctuations affecting spawning
- Physical habitat alteration associated with limited supplies of instream gravel, habitat suitability and spawning habitat availability affecting adult spawning
- Flow dependent habitat availability affecting juvenile rearing and outmigration
- Loss of natural morphology, riparian habitat and instream cover affecting juvenile rearing and outmigration

Watershed Description

The following information on the Dry Creek watershed is summarized from the *Dry Creek Watershed Coordinated Resource Management Plan* (ECORP Consulting 2003).

Dry Creek originates in the Sierra Nevada Foothills, drains approximately 101 square miles, and is approximately 17.6 miles long (ECORP Consulting 2003) and is hydraulically connected to the Sacramento River *via* the Natomas East Main Drainage Canal. The Dry Creek watershed covers a range from just west of Auburn (Placer County) west to Steelhead Creek (north of Sacramento, Sacramento County), and south to Folsom (Sacramento County). The mainstem drainage system is composed of 1.3 miles of intermittent drainage, 20.3 miles of first-order perennial, and 21.6 miles of second-order perennial streams.

Elevations in the Dry Creek watershed ranges from approximately 1,200 feet above mean sea level (msl) down to approximately 30 feet above msl. Below Elverta Road, Dry Creek diverges into two channels (i.e., the Main Fork and the North Fork). The Main Fork lies to the south and contains flow year-round. The North Fork is several feet higher than the Main Fork and functions as an overflow channel (Foothill Associates 2003). Tributaries to Dry Creek include Secret Ravine, Miners Ravine, Strap Ravine, Antelope Creek, Clover Valley Creek, and Linda Creek.

Because of the extensive changes that have happened to Dry Creek's channel morphology, restoration of this creek has potential but will be tricky. Throughout the watershed, reaches have been straightened, floodplain area reduced, reaches dredged, and riparian vegetation removed, resulting in eroding banks, sediment deposition, lack of cover, lack of pools and riffles, lack of riparian vegetation, and barriers to fish passage. Additionally, placer mining in Secret, Strap, and Miners Ravines accelerated stream incision down to the bedrock in the upper reaches. However, Dry Creek does support a relatively healthy riparian corridor upstream of Folsom Road to the confluence with Miners and Secret ravines (ECORP Consulting 2003), and thus, the focus for restoration should be in those areas along that reach that can support stream cover and natural channel processes.

Geology

Soils within the Dry Creek watershed are variable, depending upon landscape position and underlying geology. Most soils are formed from either granitic or volcanic parent material, and often include a clay pan, hard pan, or other consolidated layer that impedes water permeability. Shallow soils and rock outcrops are fairly common at higher elevations. At lower elevations, soils are generally on flatter lands and underlain by a claypan or hardpan, have low permeabilities, finer texture (e.g., silts and clays), low soil strength, and high shrink-swell potential. These soils often require artificial drainage for development or agriculture. Additionally, areas of the watershed are underlain by Mehrten Formation that may present infiltration impediments and support vernal pool ecologies (ECORP Consulting 2003).

Hydrology

The headwaters of three major Dry Creek tributaries, Antelope Creek, Secret Ravine, and Miners Ravine, begin in the foothills of the Sierra Nevada mountain range at 900 to 1200 feet above mean sea level. Secret Ravine converges with Miners Ravine just upstream from Eureka Road in Roseville, CA. Antelope Creek enters Dry Creek just south of Atlantic Boulevard, also in Roseville. Linda Creek and Strap Ravine are lower gradient streams that begin near Granite Bay at a mean sea level elevation of 300 to 500 feet. Linda Creek is tributary to Cirby Creek. Cirby Creek then flows into Dry Creek just downstream of Royer Park in Roseville. The Dry Creek mainstem begins at the confluence of Secret Ravine and Miners Ravine and flows down to about 30 feet above mean sea level into Steelhead Creek (i.e., the Natomas East Main Drainage Canal) in Sacramento County (ECORP Consulting 2003).

Numerous canals, aqueducts, siphons, reservoirs, ponds, dams, pipelines, and other natural and non-natural water features significantly influence local hydrology within the Dry Creek watershed. Modification of the watershed's hydrology is compounded by modification of the instream configuration by channelization, levees, dredging, and reduced floodplain area. These modifications also result in altered stream flow where flow is faster in some areas (i.e., channelized conveyances), contributing to erosion and faster peak flow timing, but slower in other areas (i.e., behind dams and other impeding structures), contributing to flooding and sediment deposition.

Several historically intermittent drainages (e.g., Strap Ravine, upper portions of many tributaries) are currently perennial drainages due to nuisance flows (e.g., flows from artificial outfalls, irrigation runoff, and irrigation drainage). These flows may contribute to water quality degradation through associated pollutants and higher water temperatures.

A major facility discharging into the Dry Creek mainstem is the Roseville Wastewater Treatment Plant (Roseville WWTP). Discharges from the Roseville WWTP have minimal impacts to Dry Creek during wet months, however, they can compose a high proportion of flows during dry months (i.e., greater than 50% of total flow at the Vernon Street Bridge). As development continues to expand within this region, treated effluent discharges will likely increase. A new regional wastewater treatment plant is being built outside of the Dry Creek watershed by the City of Roseville. It is estimated that approximately 15,000 Roseville WTP customers will be transferred to the new facility.

From 1997 through 2008, the highest peak flow on Dry Creek at the Vernon Street Bridge was 7,950 cfs, occurring on Jan 22, 1997 (USGS Website 2009). From 2000 through 2008, annual daily mean flows at the Vernon Street Bridge ranged from 48.8 cfs in 2007 to 131.3 cfs in 2006 (USGS Website 2009).

The climate in which the Dry Creek watershed is located is considered a Mediterranean climate with a warm, dry season during April through October; and a wet, mild season from November through March. Annual precipitation is approximately 20 to 25 inches per year, with peak rainfall occurring during December through February. Summer stream flows are generally composed of flow from springs and urban runoff, and irrigation drainage and effluent from wastewater treatment systems.

Land Use

Various land uses in the Dry Creek Watershed over the past 150 years have resulted in direct and indirect impacts to channel morphology. Historical land uses include placer mining, quarry development, agricultural development, and urbanization. Dramatic levels of urbanization have occurred since the 1950s, particularly in the Roseville and Rocklin areas. Many roads traverse the stream valleys, modifying floodplain areas and channels where bridges and culverts have been installed for crossings. Streams have been channelized, moved or straightened to fit floodplain developments and riparian vegetation has been removed mechanically or by use of herbicides, resulting in bank instability and erosion (ECORP Consulting 2003).

Generally, the middle portion of the Dry Creek watershed has been subject to extreme development pressure by relatively recent growth, primarily within the cities of Roseville and

Rocklin. The upper and lower portions of the watershed are anticipated to experience similar growth in the coming years. Such development generally has been perceived to have exacerbated normal historical flooding conditions lower in the watershed, particularly in Sacramento County, by contributing greater and faster flood flows during storm events. In addition, water quality concerns have arisen, due to the perceived increase in sedimentation and potential contamination from non-point sources.

Within the Dry Creek Watershed, much of the native vegetation has been removed and either replaced with non-native species (e.g., landscaping, agriculture), developed, or left bare. The reduction in native vegetation has contributed to significant degradation of the watershed water resources. Reduction of riparian habitat and/or replacement with non-native species (e.g., ornamentals) occurs within all tributaries of the watershed. This has contributed to bank destabilization and erosion, higher water temperatures, and reduction in suitable habitat for aquatic life.

Historically, livestock traffic compaction and off-road recreational vehicle activities have contributed to bank destruction. In many areas, channels have been deepened, straightened, and/or re-located to accommodate roads, to create agricultural land, for sewage treatment ponds, to convey flows, and for other developments. This channelization and reconfiguration has resulted in reduced area for overbank flow and reduced channel meandering. Whether by erosive processes, historical placer mining or channel reconfiguration, these deepened channels have lowered the shallow groundwater table, particularly in the upper tributary reaches (ECORP Consulting 2003).

Fisheries and Aquatic Habitat

As discussed above, land use impacts have affected the form and function of stream channels throughout the Dry Creek Watershed, which in turn have impacted riparian and aquatic communities. Much of the focus of these impacts have been in the middle and lower reaches of the watershed, particularly Secret Ravine, Miners Ravine, and the mainstem of Dry Creek, due to their importance in sustaining salmonid populations and riparian habitat (ECORP Consulting 2003). Throughout the watershed, reaches have been straightened, floodplain area reduced, reaches dredged, and riparian vegetation removed, resulting in eroding banks, sediment deposition, lack of cover, lack of pools and riffles, lack of riparian vegetation, and barriers to fish passage. Additionally, placer mining in Secret, Strap, and Miners Ravines accelerated stream incision down to the bedrock in the upper reaches. However, Dry Creek does support a relatively healthy riparian corridor upstream of Folsom Road to the confluence with Miners and Secret ravines (ECORP Consulting 2003).

Below the confluence with Secret and Miners ravines, aquatic habitat is characterized by low gradient, slow moving water, dominated by sand/silt substrate. Water temperatures appear to be 5.6 ^{o}C (10 °F) warmer than upstream of the confluence. Available fish habitat is limited to undercut banks, overhanging vegetation, and some instream woody debris. Habitat is much more complex in Secret Ravine, with an abundance of pool habitat, large woody debris, and suitable spawning habitat.

Preliminary water temperature data collected by CDFW in 1999 and 2000 indicate that mean daily summer water temperatures above the confluence never reached 21.1 °C (70°F). This is in contrast to mean daily summer water temperatures below the confluence, which peaked at over 26.7 °C (80°F) in 1999. The Roseville WWTP has recorded mean daily water temperatures of greater than 31 °C in the mainstem of Dry Creek during the summer (period of record was 1998 through June 2003) (ECORP Consulting 2003).

Tributaries within the Dry Creek Watershed are known to support anadromous salmonids and other areas likely historically supported anadromous salmonids, but now either have passage barriers or severely degraded habitat. The mainstem of Dry Creek is not suitable fish habitat, but is considered to be a migratory corridor for anadromous salmonids. Linda Creek has two sites that might be suitable for spawning and rearing, however, most of the habitat is generally degraded with steep eroding banks and high summer water temperatures. Cirby Creek is heavily urbanized and likely no longer supports salmonids. Antelope Creek has two potential spawning areas, but these areas also are degraded. Rock dams and beaver dams act as barriers to fish passage in Antelope Creek, although a few fish have been found in this tributary. Miners Ravine still supports salmonids, however many reaches are heavily degraded. Secret Ravine also still supports salmonids and has the highest quality fisheries habitat in the Dry Creek watershed (ECORP Consulting 2003).

Given the increase in summer streamflows compared to historical conditions, the potential for improvement of existing juvenile steelhead rearing habitat exists, but primarily only within the uppermost portions of Dry Creek (i.e., Secret Ravine) (ECORP Consulting 2003). Several studies and projects have been implemented to improve fish passage and restore aquatic life habitat in Miners Ravine, Secret Ravine, and Cirby/Linda Creek. For example, riparian trees have been planted along Dry Creek by the City of Roseville in association with the Dry Creek Reforestation Project.

Steelhead

General information on the historical presence of anadromous salmonids in Dry Creek is available through many small-scale inventory surveys and anecdotal information. A review of this information suggests that suitable salmonid habitat is available at select sites (Sierra Business Council 2003), and that the system currently hosts a self-sustaining population of steelhead (Ayres *et al*. 2003; Sierra Business Council 2003). All spawning habitat and accounts of spawning anadromous salmonids have been reported to be located upstream of the Dry Creek WWTP.

The CDFW Native Anadromous Fish and Watershed Branch initiated a reconnaissance-level assessment of steelhead distribution and abundance, relative to stream habitat conditions, in 1998 and 1999. At that time, steelhead escapement to the upper Dry Creek watershed was estimated at a few hundred fish, with the most suitable spawning and rearing habitat in Secret Ravine and to a lesser extent, Miners Ravine. Monitoring of juvenile salmonid emigration also was conducted by CDFW during 1999 and 2000. During both years, juvenile steelhead (and Chinook salmon) were collected in rotary screw traps located immediately downstream of the confluence of Secret and Miners ravines (ECORP Consulting 2003).

During the fall/winter of 2004 and the spring of 2005, CDFW conducted two-pass electrofishing surveys on a total of seven reaches in Dry Creek, as well as in several reaches in Miners and Secret ravines. During the 2004 fall/winter survey, no steelhead/rainbow trout were captured in Dry Creek or Miners Ravine. However, 41 steelhead/rainbow trout were captured in Secret Ravine. During the 2005 spring survey, no steelhead/rainbow trout were identified in Dry Creek or Miners Ravine, but 95 steelhead/rainbow trout were captured in Secret Ravine (CDFW 2005, unpublished data). During the 2005 spring survey in Secret Ravine, five pit-tagged steelhead/rainbow trout were re-captured from the 2004 fall/winter survey. All of these fish were re-captured in the same reach of Secret Ravine as when they were originally captured and tagged during the 2004 fall/winter survey. Growth rates for these fish were quite variable, as shown in Table 3.

Table 3. Steelhead/rainbow trout growth in Secret Ravine

Length at Capture (mm)	Time to Re-capture (days)	Length at Re-capture (mm)	Growth (mm)
91	187	168	77
95	204	155	60
88	204	154	66
90	204	188	98
79	204	143	64

Source: CDFW 2005, unpublished data

Based on analysis of data from the 2004/2005 surveys conducted by CDFW, the findings are consistent with previous studies and anecdotal information suggesting that Dry Creek is utilized as a migratory corridor for anadromous salmonid passage upstream to spawning and rearing habitat in the upstream tributaries (Secret Ravine and Miners Ravine) (CDFW 1998). Catch data also is consistent with information presented in the Dry Creek Watershed Coordinated Resource Management Plan (ECORP Consulting 2003), which states that the mainstem of Dry Creek is not suitable anadromous salmonid habitat and is considered only as a migratory corridor to upstream areas containing suitable spawning and rearing habitat.

Feather River Watershed Profile

Species Present in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Species that Historically Occurred in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Diversity Group

Northern Sierra Nevada

Key Stressors

Key stressors to Central Valley spring-run Chinook salmon and steelhead in the Feather River include, but are not limited to the following:

- ❖ Passage impediments/barriers at the Fish Barrier Dam and at the Oroville Dam affecting adult immigration and holding
- ❖ Flow conditions (i.e., low flows) associated with attraction and migratory cues into the Feather River affecting adult immigration and holding
- ❖ Water temperatures affecting adult immigration and holding, spawning, juvenile rearing and outmigration
- ❖ Passage impediments/barriers and hatchery effects related to redd superimposition, competition for habitat, hybridization/genetic integrity affecting spawning
- ❖ Physical habitat alteration associated with limited supplies of instream gravel, habitat suitability and spawning habitat availability affecting adult spawning
- ❖ Loss of natural river morphology, loss of riparian habitat and instream cover affecting juvenile rearing and outmigration
- ❖ Predation effects on juvenile rearing and outmigration

Watershed Description

The Feather River Watershed is located at the north end of the Sierra Nevada and encompasses an area of about 5,900 square miles (DWR 2007). The upper Feather River Watershed above Oroville Dam is approximately 3,600 square miles, and comprises approximately 68 percent of the Feather River Basin. Downstream of Oroville Dam, the watershed extends south and includes the drainage of the Yuba and Bear rivers (Figure 3). The Yuba River flows into the Feather River near the City of Marysville, 39 river miles downstream of the City of Oroville. The Bear River flows into the Feather River about 55 river miles downstream of the City of Oroville.

Approximately 67 miles downstream of the City of Oroville, the Feather River flows into the Sacramento River near the town of Verona (DWR 2007).

Geology

The watershed is bounded by the volcanic Cascade Range to the north, the Great Basin on the east, the Sacramento Valley on the west, and higher elevation portions of the Sierra Nevada on the south (DWR 2007). Downstream of Oroville Reservoir, the Feather River emerges from the Sierra Nevada and enters the Sacramento Valley. The Feather River below Thermalito Diversion Dam to Verona is mostly an alluvial stream flowing across its own sedimentary deposits of clay, silt, sand, and gravel. By far, historic hydraulic mining of Eocene gold-bearing gravel deposits caused the largest impact on the Feather River channel. Massive amounts of erosional debris, including cobbles, gravel, sand, silt, and clay, were washed into the river. Mining debris still profoundly affects the present-day Feather River. Both the human-modified cobble banks and clay rich slickens have increased bank stability. Between the cities of Oroville and Gridley, cobbles and coarse gravel dredge tailings constitute most of the banks, slowing the bank erosion process. Between Honcut Creek and the mouth of the Feather River, the meandering process has slowed, and the river is wide and shallow, with low sinuosity and a sand bed. Most of the reach is mapped as glides or long pools, with low mesohabitat variability. The lower Feather River meander belt (Figure 3) consists of recent alluvium and stream channel deposits. Of the two, the alluvium is older, but both consist of river deposits, including floodplain deposits, point bar deposits, channel fill, oxbow lake deposits, tributary delta deposits, and hydraulic mining debris. The deposits range in size from clay, silt, and sand to gravel, cobbles, and boulders. Coarse deposits predominate near the City of Oroville and fine deposits predominate from Gridley downstream to the mouth of the Feather River. Older alluvial deposits not directly linked to the present Feather River form terraces on both sides of the active stream channel. These deposits are typically higher in elevation, more resistant to erosion and define the boundaries of the active meander belt (DWR 2007).

The most common parent material for the soils downstream of Oroville Dam is river alluvium, with some soils derived from debris deposited during the hydraulic mining period. The predominant soil types or textures in the 100-year floodplain are characterized as fine sandy loam, loamy sand, and loam to silt loam. Minor soil types are clay, clay loam, sandy clay loam, sandy loam, silt loam, silty clay, sand and gravel, and river wash. Many of the soils are further divided by occurrence of flooding, such as occasionally flooded to frequently flooded. The soils range from shallow to very deep, with most being moderately deep to very deep. Floodplain soils are conducive to agriculture and many areas of riparian floodplain and fluvial terraces have been converted to irrigated crops and orchards (DWR 2007).

Hydrology

Climate in the region follows a Mediterranean pattern, with cool wet winters and hot dry summers. Air temperatures range from below zero to above 100 degrees Fahrenheit (ºF). Approximately 95 percent of the annual precipitation occurs during the winter months. Precipitation ranges from more than 90 inches at the orographic (i.e., mountain) crest near Bucks Lake, 33 inches at the City of Oroville, to less than 20 inches in the eastern headwaters.

Precipitation above 5,000 feet occurs primarily as snow, which regularly accumulates in excess of 5 to 10 feet during winter. There are infrequent summer thunderstorms, predominantly in the eastern third of the watershed. These storms can produce significant rainfall of short duration over a relatively small area (DWR 2007).

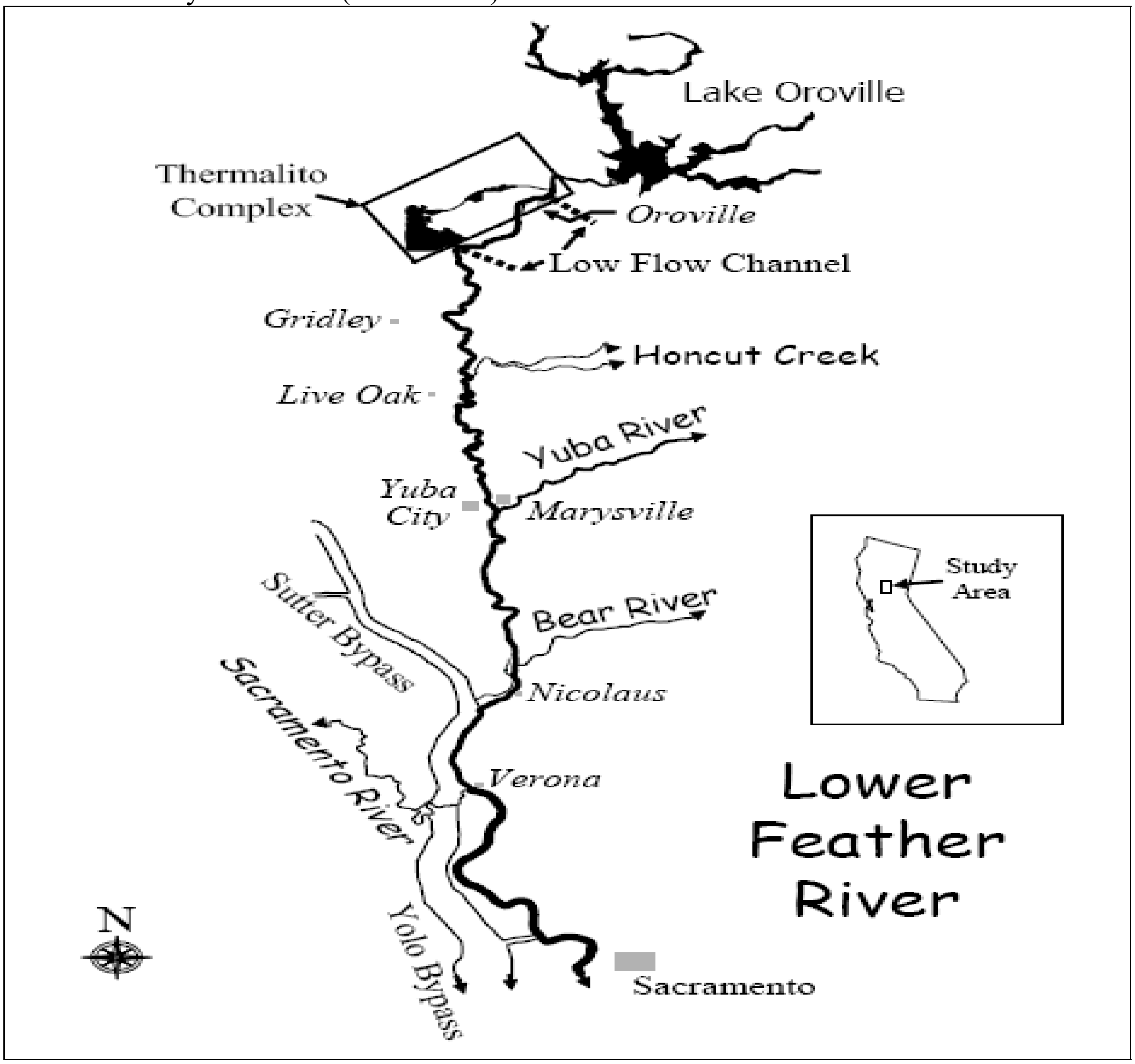

Figure 3. The Lower Feather River Source: DWR 2006

The Feather River is considered to be a major tributary to the Sacramento River and provides about 25 percent of the flow[3] in the Sacramento River (DWR 2007). The average annual yield of the upstream Feather River Basin at Oroville is about 4.2 million acre-feet (maf), with runoff generally occurring between January and June. Summer inflows into Oroville Reservoir are sustained at about 1,000 cfs by snowmelt and accretions from springs and groundwater in the upper watershed. Due to several diversions upstream, actual annual inflow into Oroville

[3] As measured at Oroville Dam.

Reservoir is about 4.0 maf. Annual flows are variable and depend upon precipitation. From 1979 to 1999, annual inflows ranged from a minimum of 1.7 maf to as high as 10 maf (DWR 2007).

Feather River flows are altered by hydroelectric, water storage, and diversion projects upstream of the Oroville Facilities[4], Oroville Reservoir operations, and by diversions from the Thermalito Afterbay to meet service area entitlements (DWR 2007). Upstream projects alter Feather River flows through operation of storage facilities and by diversions from the river and its tributaries. Water diversions to meet service area entitlements occur primarily during the irrigation months, April to October. Water also is required during all months of the year to meet State Water Project (SWP) water contractors' requests, with the highest requests typically occurring from June through August, and the lowest occurring during January. Water available for delivery varies depending on hydrologic conditions and operating requirements (DWR 2007).

Oroville Reservoir, operated by the California Department of Water Resources (DWR) and the keystone of the SWP, is the lowermost reservoir on the Feather River and the upstream limit for anadromous fish (USFWS 1995). With a storage capacity of more than 3.5 maf, Oroville Reservoir is located at the confluence of the West Branch and the North, Middle, and South Forks of the Feather River, upstream from the Yuba and Bear River tributaries at an elevation of 900 feet above msl (YCWA and Reclamation 2007). Water is released from Oroville Dam through a multilevel outlet to provide appropriate water temperatures for the operation of the Feather River Hatchery and to protect downstream fisheries. Approximately 5 miles downstream of Oroville Dam, water is diverted at the Thermalito Diversion Dam into the Thermalito Power Canal, thence to the Thermalito Forebay and another powerhouse, and finally into the Thermalito Afterbay. Water can be pumped from the Thermalito Diversion Pool back into Oroville Reservoir to generate peaking power. The Oroville-Thermalito complex (Figure 4), completed in 1968, provides water conservation, hydroelectric power, recreation, flood control, and fisheries benefits. The other major impoundment in the watershed is Lake Almanor, with a storage capacity of more than 1.1 maf. A number of other small- to moderate-sized impoundments, including Mountain Meadows Reservoir, Bucks Lake, Little Grass Valley Reservoir, Lake Davis, Frenchman Lake, Butt Valley Reservoir, Sly Creek Reservoir, and Antelope Lake, store an additional 450 taf or more (USFWS 1995).

[4] The Oroville Facilities were developed as part of the State Water Project (SWP), a water storage and delivery system of reservoirs, aqueducts, power plants, and pumping plants. The Federal Power Act (FPA) license for the Oroville Facilities (issued by the FERC, on February 11, 1957) expired on January 31, 2007. The California Department of Water Resources (DWR) sought a new federal license to continue generating hydroelectric power while continuing to meet existing commitments and comply with regulations pertaining to water supply, flood control, the environment, and recreational opportunities. FERC issued an annual license to DWR for Project No. 2100 for a period effective February 1, 2007 through January 31, 2008, or until the issuance of a new license for the project or other disposition under the FPA, whichever came first. If issuance of a new license (or other disposition) did not take place on or before January 31, 2008, pursuant to 18 C.F.R. 16.18(c), an annual license under section 15(a)(1) of the FPA will be renewed automatically without further order or notice by FERC, unless FERC orders otherwise (FERC 2007).

Under an agreement with the CDFW, Feather River flows between the Thermalito Diversion Dam and the Thermalito Afterbay outlet are regulated at 600 cfs, except during flood events when flows have been as high as 150,000 cfs (DWR 1983). This section is often referred to as the "low-flow" river section. Water is released through a powerhouse, then through the Fish Barrier Dam to the Feather River Hatchery, and finally into the low-flow section of the Feather River. Thermalito Afterbay has a dual purpose as an afterbay for upstream peaking power releases to ensure constant river and irrigation canal flows, and as a warming basin for irrigation water being diverted to rice fields. Thus, water temperatures in the approximately 14 miles of salmon spawning area from the Thermalito Afterbay outlet to the mouth of Honcut Creek (referred to as the "high-flow" section) are always higher than those in the 8 miles of the low-flow section (USFWS 1995).

Land Use

Human activity over time has resulted in decreased vegetative cover from logging and grazing, channel clearing, levee construction and water diversions. These activities have contributed to the increased sediment load in the Feather River Watershed (Plumas County Flood Control and Water Conservation District 2004). Current land use patterns within the watershed are diverse, but the principal land use activities include recreation, agriculture, timber production, hydropower generation, and livestock grazing. About 4 percent (i.e., approximately 70 square miles) of all land in Butte County consists of urban uses (DWR 2007).

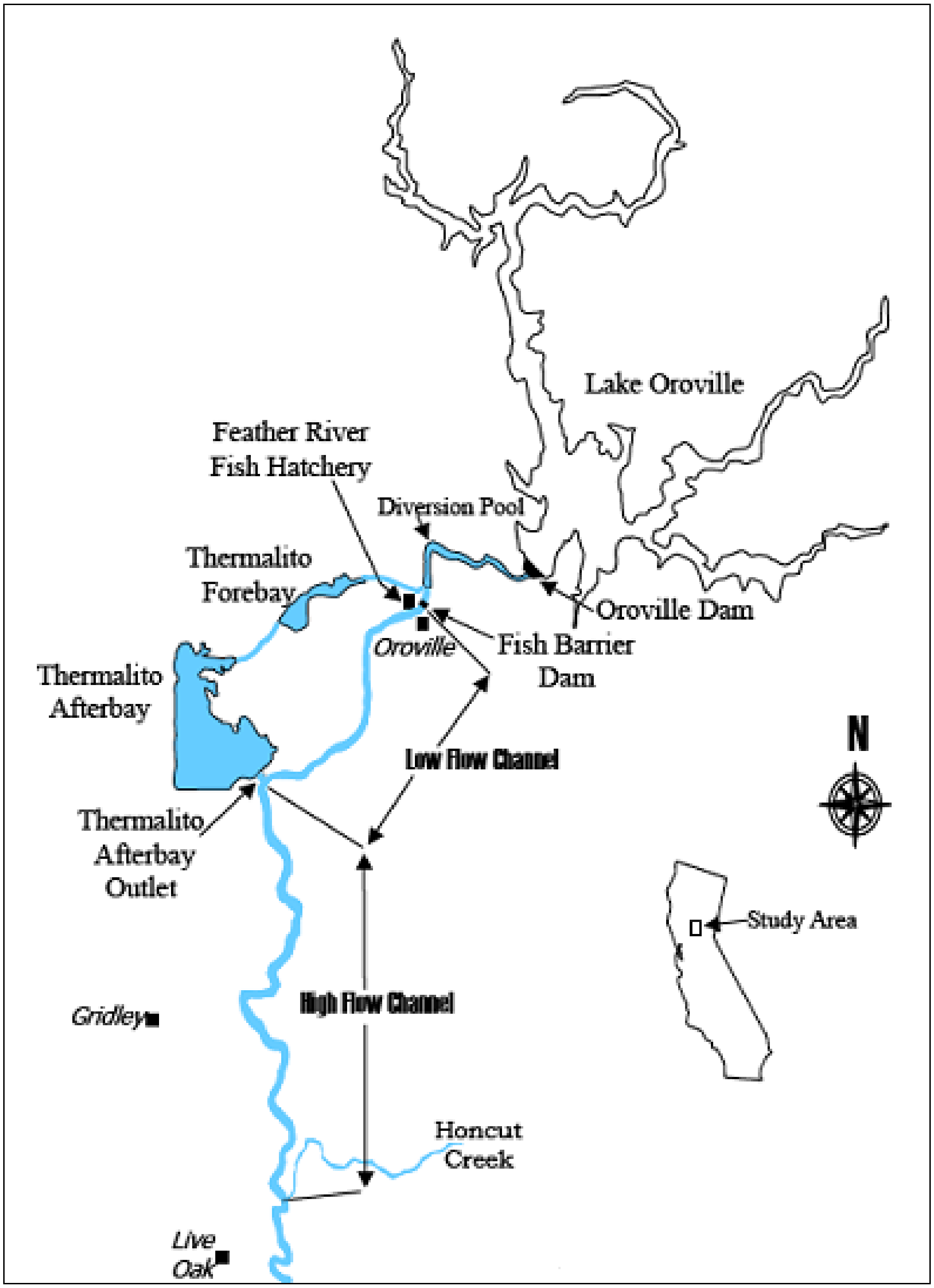

Figure 4. Oroville-Thermalito complex Source: Modified from DWR 2006

Fisheries and Aquatic Habitat

The Feather River Watershed is reported to have contained about 211 miles of historic anadromous fish habitat, and currently contains about 64 miles of habitat for Chinook salmon and steelhead (USFWS 2009). Spring-run historically ascended to the very highest elevation headwaters of the Feather River watershed prior to the construction of numerous hydroelectric power projects and diversions (Clark 1929). Spring-run Chinook salmon were reported to have occurred in the West Branch Feather up to Stirling City, and the North Fork past the present day site of Lake Almanor. In the Middle Fork, spring-run Chinook salmon were reported as far upstream as the natural barrier at Bald Rock, and potentially to Feather Falls located on the Fall River, a tributary to the Middle Fork (CDFW 1998). Spring-run may have ascended to the vicinity of Forbestown on the South Fork (Yoshiyama *et al.* (1996).

Based on broad-scale mesohabitat surveys, the major tributaries in the upper Feather River—the West Branch of the North Fork Feather River (West Branch), the North Fork Feather River (North Fork), the Middle Fork Feather River (Middle Fork), and the South Fork Feather River (South Fork)—generally provide suitable habitat for all life stages of Chinook salmon and steelhead (DWR 2005). For both Chinook salmon and steelhead, spawning and embryo incubation is the life stage for which the smallest amount of suitable habitat is available in the upper Feather River. The greatest amount of suitable habitat is available for the following life stages: (1) Chinook salmon juvenile rearing and downstream movement; (2) steelhead adult immigration and holding; (3) steelhead fry and fingerling rearing and downstream movement; and (4) steelhead smolt emigration. Overall, the North Fork appears to be the most suitable for occupancy of anadromous salmonids, while the South Fork appears to be the least suitable (DWR 2005). Water temperatures, at the locations for which water temperature data were available, approached or exceeded potentially stressful levels generally from May through October (DWR 2005). However, water temperature data loggers were generally located at low elevations near the tributary/reservoir boundary, which is the location within tributaries that is typically believed to experience the highest water temperatures (DWR 2005). In general, the upper Feather River appears to be suitable for migratory Chinook salmon and steelhead based on available mesohabitat data, water temperature profiles, and the current distribution of resident rainbow trout populations (DWR 2005). However, if these upper tributaries become accessible to anadromous salmonids in the future, additional data is required to definitively determine the suitability of habitat in the upper Feather River (DWR 2005).

The lower Feather River commences at the Low Flow Channel (LFC), which extends eight miles from the Fish Barrier Dam (RM 67) to the Thermalito Afterbay Outlet (RM 59) (Figure 5). As described above, flows in this reach of the river are generally regulated at 600 cfs (DWR 1983). Average monthly water temperatures typically range from about 47°F in winter to about 65°F in summer. The majority of the LFC flows through a single channel contained by stabilized levees. Side-channel or secondary channel habitat is extremely limited, occurring primarily in the Steep Riffle and Eye Riffle areas between RM 60 and 61. The channel banks and streambed consist of armored cobble as a result of periodic flood flows and the absence of gravel recruitment. However, there are nine major riffles with suitable spawning size gravel, and approximately 75 percent of the Chinook salmon spawning takes place in this upper reach (Sommer *et al*. 2001). Releases are made from the coldwater pool in Oroville Reservoir and this cold water generally provides suitable water temperatures for spawning in the LFC (DWR 2001).

The lower reach extends 15 miles from the Thermalito Afterbay Outlet (RM 59) to Honcut Creek (RM 44) (Figure 5). Releases from the outlet vary according to operational requirements. In a normal year, total flow in the lower reach ranges from 1,750 cfs in fall to 5,000-8,000 cfs in spring. Water temperature in winter is similar to the Low Flow Channel but increases to 74°F in summer. Higher flows dramatically increase the channel width in this reach. Numerous mid-channel bars and islands braid the river channel, creating side-channel and backwater habitat. The channel is not as heavily armored and long sections of riverbanks are actively eroding. In comparison to the LFC, there is a greater amount of available spawning areas, which are isolated by longer and deeper pools (DWR 2001).

For currently occupied habitats below Oroville Dam, it is unlikely that habitats can be restored to pre-dam conditions, but many of the processes and conditions that are necessary to support a population of CV spring-run Chinook and CV steelhead can be improved and sustained with extensive long-term human intervention, including improvements to water temperature management, habitat availability, spatial distribution and separation of spring- and fall-run Chinook salmon as part of hatchery management. Implementation of the Settlement Agreement for the Oroville FERC license is expected to help address these factors and improve the habitat in the lower Feather River.

CV spring-run Chinook salmon and CV steelhead are produced by the Feather River Hatchery, but also spawn in the river downstream from the Fish Barrier Dam approximately 8 miles to the Thermalito Afterbay Outlet. The majority of the spawning occurs in the upper three miles of river downstream from the Feather River Hatchery. CWT information from these hatchery returns indicates substantial introgression has occurred between fall-run and spring-run Chinook salmon populations within the Feather River system due to hatchery practices which have compromised the genetic integrity of spring-run Chinook salmon. Lindley *et al.* (2007) characterized CV spring-run Chinook salmon and CV steelhead populations in the Feather River as data deficient. However, the existing spring-run Chinook population in the Feather River, including the hatchery fish, may be the only remaining representatives of this important ESU component and that the Feather River hatchery spring-run Chinook stock may play an important role in the recovery of spring-run Chinook in the Feather River Basin.

This is primarily based on the presence of hatchery supported populations that are known to reproduce naturally in the Low Flow Channel between river mile 59 and 67. The Settlement Agreement for Licensing of the Oroville Facilities (March 2006) includes the Lower Feather River Habitat Improvement Plan, which requires the development and implementation of numerous programs and projects that will improve the ecological condition of the Lower Feather River, in a manner that is expected to improve the quality and quantity of CV spring-run Chinook salmon and CV steelhead habitat for the next 50 years. Most significantly, the Settlement Agreement includes measures to improve the short- and long-term genetic management of the Feather River Hatchery, measures to physically separate and isolate CV spring-run Chinook salmon from CV fall-run Chinook salmon, and measures that will increase the spatial availability of spawning habitat for CV steelhead.

Spring-run Chinook Salmon

NMFS (2009a) reports that four independent populations of spring-run Chinook salmon historically occurred in the upper tributaries (*i.e.*, North, Middle and South forks, and the West Branch) of the Feather River Watershed, but they are now extinct. However, a hatchery population currently occurs in the lower Feather River below Oroville Dam (see below).

A naturally-spawning dependent population of spring-run Chinook salmon currently is restricted to accessible reaches of the lower Feather River (CDFW 1998). Approximately two-thirds of the natural Chinook salmon spawning in the Feather River occurs between the Fish Barrier Dam and the Thermalito Afterbay Outlet (RM 67 to 59), and one-third of the spawning occurs between the Thermalito Afterbay Outlet and Honcut Creek (RM 59 to 44) (DWR 2007).

Chinook spawning typically occurs from September through December. Spring-run Chinook salmon spawning may occur a few weeks earlier than fall-run spawning, but currently there is no clear distinction between the two, because of the disruption of spatial segregation by Oroville Dam. Thus, the spawning and embryo incubation life stage of spring-run Chinook salmon in the Feather River generally occurs during the same months (i.e., September through February) as fall-run Chinook salmon spawning and embryo incubation (Moyle 2002). Because of hatchery overproduction and the inability to physically separate spring-run and fall-run Chinook salmon adults, significant redd superimposition occurs in the lower Feather River and this concurrent spawning has led to hybridization between the spring- and fall-run Chinook salmon in the Feather River.

Most juvenile Chinook salmon emigrate from the lower Feather River within a few months of emergence, and 95 percent of the juvenile Chinook have typically emigrated from the Oroville Facilities project area by the end of May (DWR 2007). However, spring-run Chinook salmon juveniles reportedly can rear in their natal streams for up to 15 months (Moyle 2002). Adult Chinook salmon exhibiting the typical life history of the spring-run are found holding at the Thermalito Afterbay Outlet and the Fish Barrier Dam as early as April (DWR 2007).

Over the past several decades, Chinook salmon are reported to be the most numerous fish species in the lower Feather River, and between 30,000 and 170,000 Chinook salmon spawn in the lower Feather River annually (DWR 2007). Significant numbers of spring-run Chinook salmon, as identified by run timing, return to the Feather River Fish Hatchery (FRFH). Between 1967 and 2008, the highest annual hatchery spring-run Chinook salmon escapement was 8,662, occurring in 2003 (CDFW 2009). From 1986 to 2007, the average number of spring-run returning to the FRFH was 3,992, compared to an average of 12,888 spring-run returning to the entire Sacramento River Basin. More recently, FRFH spring-run Chinook salmon escapement from 2005 through 2008 was 1,774, 2,061, 2,674, and 1,418, respectively (CDFW 2009). Coded Wire Tag (CWT) information from hatchery returns indicates substantial introgression has occurred between spring-run and fall-run populations within the Feather River system due to hatchery practices. Because Chinook salmon have not always been temporally separated in the hatchery, spring- and fall-run Chinook salmon have been spawned together, thus compromising the genetic integrity of the spring-run and early fall-run stocks. The number of naturally spawning spring-run in the Feather River has been estimated only periodically since the 1960s, with estimates ranging from 2 fish in 1978 to 2,908 in 1964. However, the genetic integrity of this population is questionable because of the significant temporal and spatial overlap between spawning populations of spring-run and fall-run Chinook salmon (Good *et al*. 2005). Spring-run Chinook salmon escapement estimates for the Feather River Hatchery are available from 1962 through 2011 (Table 4).

Table 4. Adult spring-run Chinook salmon population estimates for the Feather River Hatchery from 1963 to 2011. Estimates are not available for all years.

Year	Adult Estimate	Year	Adult Estimate	Year	Adult Estimate
1963	600	**1980**	669	**1997**	3653
1964	2908	**1981**	1000	**1998**	6746
1965	738	**1982**	2000	**1999**	3731
1966	297	**1983**	1702	**2000**	3657
1967	146	**1984**	1562	**2001**	4135
1968	208	**1985**	1632	**2002**	4189
1969	348	**1986**	1433	**2003**	8662
1970	235	**1987**	1213	**2004**	4212
1971	481	**1988**	6833	**2005**	1774
1972	256	**1989**	5078	**2006**	2061
1973	205	**1990**	1893	**2007**	2674
1974	198	**1991**	4303	**2008**	1418
1975	691	**1992**	1497	**2009**	989
1976	699	**1993**	4672	**2010**	1661
1977	185	**1994**	3641	**2011**	1900
1978	204	**1995**	5414		
1979	250	**1996**	6381		

Sources: CDFW Grandtab; personal communications with CDFW and USFWS biologists.

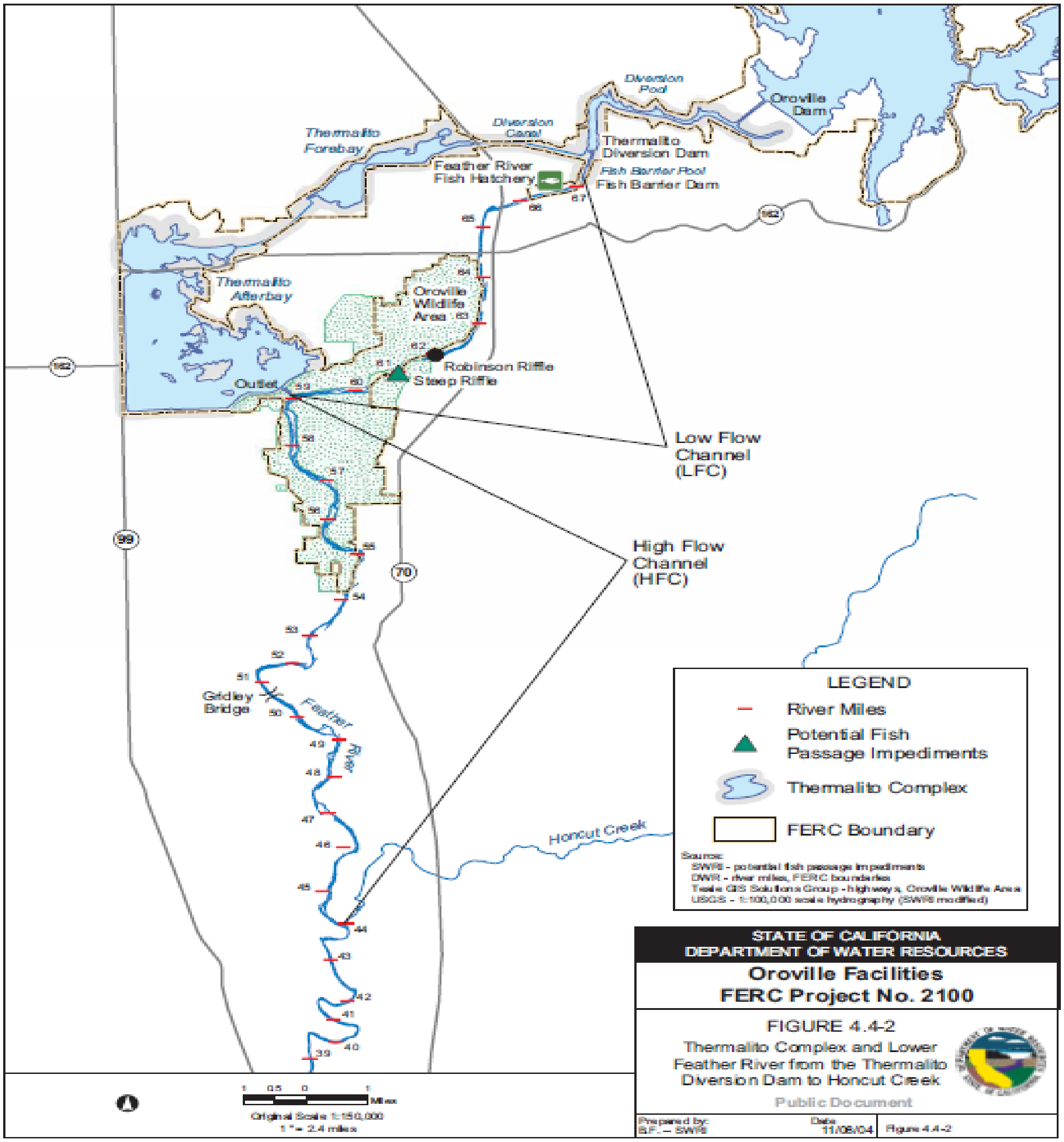

Figure 5. Thermalito complex and lower Feather River from Thermalito Diversion Dam to Honcut Creek Source: DWR 2007

Steelhead

NMFS (2009a) reports that existing wild steelhead stocks in the Central Valley are mostly confined to the upper Sacramento River and its tributaries (e.g., Antelope, Deer, and Mill creeks and the Yuba River). However, some wild steelhead are produced in the Feather River (McEwan and Jackson 1996).

Most of the natural steelhead spawning in the Feather River occurs in the LFC, particularly in the upper reaches near Hatchery Ditch, a side channel located between RM 66 and RM 67 (DWR

2007). Adult steelhead typically ascend the Feather River from September through April (Busby *et al*. 1996; Cavallo 2004 pers. comm.; McEwan 2001; Moyle 2002); spawning occurs during the winter and early spring. The majority of the steelhead spawning and embryo incubation life stage in the Feather River generally lasts from December through May (Busby *et al.* 1996; Cavallo 2004 pers. comm.; McEwan 2001; Moyle 2002). The residence time of adult steelhead in the Feather River after spawning and the extent of adult steelhead post-spawning mortality is currently unknown. It appears that most of the natural steelhead spawning in the Feather River occurs in the LFC, particularly in the upper reaches near Hatchery Ditch. Limited steelhead spawning also occurs below the Thermalito Afterbay Outlet (DWR 2007). After emerging from the gravel, a moderate percentage of the fry appear to emigrate (DWR 2007). The remainder of the population rears in the river for at least six months to two years (McEwan 2001; Moyle 2002), then reportedly emigrate from January through June (Cavallo 2004 pers. comm.,). Studies have confirmed that juvenile rearing (and probably adult spawning) is most concentrated in small secondary channels within the LFC. The smaller substrate size and greater amount of cover (compared to the main river channel) likely make these side channels more suitable for juvenile steelhead rearing. Currently, this type of habitat comprises less than 1 percent of the available habitat in the LFC (DWR 2001 in DWR 2007).

Since 2001, DWR has conducted redd dewatering and juvenile salmonid stranding surveys to assess the impact of water operations on the population of juvenile salmonids in the lower Feather River. Objectives of this long-term study are to determine the number of redds dewatered by reductions in flow; identify potential ponding areas; determine the relative abundance of stranded salmonids; and determine the biological significance of redd dewatering and juvenile stranding (DWR 2006).

Between January 6 and April 3, 2003, a total of 13 weekly redd surveys were conducted and 108 steelhead and 75 redds were observed during this sampling period (DWR 2005). Redd construction likely began sometime in late December, peaked in late January, and was essentially complete by the end of March. During January, February, and March, steelhead constructed, at minimum, 45, 26, and 4 redds, respectively. The surveys revealed that nearly half (48 percent) of all redds were constructed in the uppermost reach of the lower Feather River (between RM 66 and RM 67), between the Table Mountain Bicycle Bridge and Lower Auditorium Riffle. This section of river maintained 36 redds per mile, more than 10 times more than any other reach surveyed. Hatchery Ditch alone had 26 redds constructed within it, 5 times more redds than were constructed in any other location (DWR 2005). Attempts were not made to estimate the number of adult steelhead spawning (DWR 2005). Difficulties associated with identifying all steelhead redds indicated only the minimum number of spawning steelhead for the 2002–2003 spawning period. Assuming one female per redd and a male-to-female ratio of 1.2:1, the minimum number of males and females expected to have spawned was 88 and 75, respectively, for a total of 163 steelhead (DWR 2005). Physical characteristics of constructed redds in both the High Flow Channel and LFC appeared suitable for successful spawning and egg incubation. High flows in the High Flow Channel during three weeks in February may have reduced spawning in the High Flow Channel or forced steelhead to spawn near the river margin. There was no evidence that any redds were dewatered after the flow reduction. It is unknown whether a flow of 8,000 cfs (experienced on February 20, 21, and 22) would scour recently constructed redds in the High Flow Channel (DWR 2005).

Steelhead returns to the Feather River Fish Hatchery have decreased substantially in recent years with only 679, 312, and 86 fish returning in 2008, 2009 and 2010, respectively (Figure 6) (NMFS 2011). Because almost all of the returning fish are of hatchery origin and stocking levels have remained fairly constant over the years, the data suggest that adverse freshwater and/or ocean survival conditions have caused or at least contribute to these declining hatchery returns. The Central Valley experienced three consecutive years of drought (2007-2009) which would likely have impacted parr and smolt growth and survival and poor ocean conditions are known to have occurred in at least 2005 and 2006 which impacted Chinook populations in the Central Valley and may well have also impacted steelhead populations.

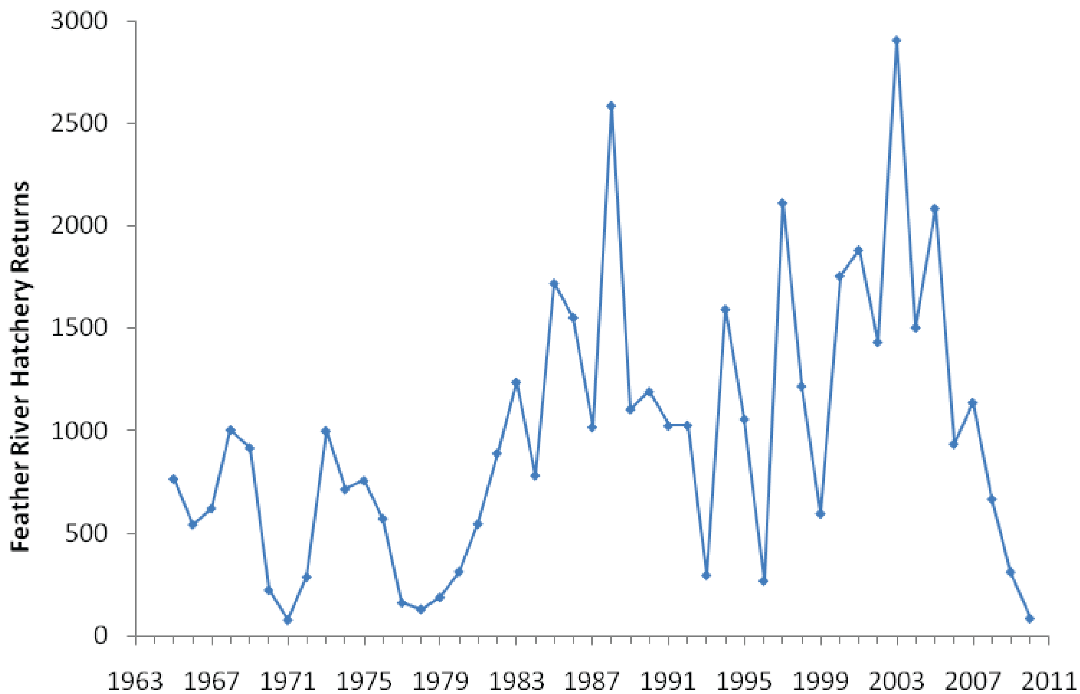

Figure 6. Steelhead Returns to Feather River Fish Hatchery 1965-2010 Source: NMFS 2011

Bear River Watershed Profile

Listed Species Present in the Watershed

Central Valley steelhead

Listed Species that Historically Occurred in the Watershed

Central Valley steelhead

Diversity Group

Northern Sierra Nevada Diversity Group

Key Stressors

Key stressors to Central Valley steelhead in the Bear River include, but are not limited to the following:

- Loss of natural river morphology, riparian habitat, floodplain habitat and instream cover affecting juvenile rearing and outmigration
- Flow conditions (i.e., low flows and flow fluctuations) associated with attraction and migratory cues in the Bear River affecting adult immigration and holding, spawning, embryo incubation, juvenile rearing and outmigration
- Water temperature affecting adult immigration and holding, embryo incubation
- Physical habitat alternation associated with limited supplies of instream gravel, and suitability of available habitat affecting adult spawning
- Water quality affecting embryo incubation, juvenile rearing and outmigration
- Flow dependent habitat availability affecting juvenile rearing and outmigration
- Entrainment at individual diversions affecting juvenile rearing and outmigration

Watershed Description

As reported by the Bear River Watershed Group Website (2009), the Bear River rises on the west side of the Sierra Nevada just below Lake Spaulding at an elevation of 5,500 feet. From there it flows southwest about 65 miles to its confluence with the Feather River at RM 12 of the Feather River, draining portions of Nevada, Placer, Sutter and Yuba counties. The 292 square mile Bear River watershed includes over 990 miles of streams, creeks, and rivers, and reaches 20 miles across at its greatest width. It can be divided into three major reaches, the upper Bear River, middle Bear River and lower Bear River (Bear River Watershed Group Website 2009).

The Upper Bear River extends from its headwaters above Bear Valley to Rollins Lake at approximately 3,300 feet elevation. The middle Bear River extends from Rollins Dam about 15 miles downstream at 2,100 foot elevation; then another 10 miles to Lake Combie at 1,600 foot elevation; then another 17 miles to New Camp Far West Reservoir at the 300 foot elevation. The lower Bear River extends from New Camp Far West Reservoir 16 miles to its confluence with the Feather River at 23 foot elevation (Bear River Watershed Group Website 2009).

The upstream limit of anadromous fish access in the Bear River is the South Sutter Irrigation District's diversion dam, approximately 15 miles above the confluence with the lower Feather River (USFWS 1995).

The lower Bear River continues to support remnant and/or "stray" wild and/or hatchery-sustained salmon, and in the past it supported both steelhead and sturgeon as well (Bear River Watershed Group Website 2009). Inadequate streamflow in the Bear River prevents the establishment of a self-sustaining steelhead population (JSA 2004).

Geology

The Bear River is an example of an "underfit" stream—a stream whose channel was formed by a larger flow than presently existed (Johnson 2002). The deep V-shaped canyon of the Bear River reflects the work of a much larger river at some point in the past. Researchers have studied glacial stratigraphy of the Bear River, and the features indicate that at least two and probably three glacial advances occupied both the South Yuba and Bear valleys (Johnson 2002). These advances are believed to have ground through a narrow ridge separating the South Fork of the Yuba River from the Bear River, just downstream of what is now Lake Spaulding. Water from the upper watershed of the Bear River then began to flow into the Yuba River drainage (James 1995). Outwash deposits extend downstream from Bear Valley and grade into coarse channel lag gravel and boulders upstream of the Drum Powerhouse (NID 2008). This capture reflects a structural advantage to the Yuba River drainage, such as a lower base level and softer material that is less resistant to erosion (Johnson 2002). The Bear River contains surface basin deposits, which are composed of stream channel and floodplain deposits, and dredger tailings. These deposits consist of highly permeable boulders, gravels, cobbles and sands (Onsoy *et al*. 2005). The Bear River contains an estimated 125 million cubic meters (160 million cubic yards) of mining sediment, which, in combination with restricting levees, has caused the lower Bear River to change from wide and shallow to deeply incised (Sierra Club Website 2007). In addition, mercury imported from the Coastal Ranges is found in sediments within the historic gold mining areas downstream of Spaulding Reservoir on both the Yuba and Bear rivers (May *et al*. 2000).

Hydrology

The main tributaries of the Bear River include Steephollow and Greenhorn creeks above Rollins Lake, and Wolf and Little Wolf creeks between Lake Combie and Camp Far West Reservoir (Bear River Watershed Group Website 2009). Rock Creek drains into Camp Far West Reservoir. Dry Creek runs through the Spenceville Wildlife Area and into the Bear River below Wheatland. Yankee Slough, from the south, and Best Slough, from the north, enter the Bear just below the confluence with Dry Creek (Bear River Watershed Group Website 2009).

The largest impoundment in the Bear River watershed, Camp Far West Reservoir, is operated by the South Sutter Water District and has a storage capacity of 104 thousand acre-feet (taf). Other small impoundments in the watershed include Rollins Lake and Lake Combie, which store an additional 70 taf or more (USFWS 1995).

The Bear River watershed is one of the most heavily managed watersheds in California for water conveyance. By the late 1800's, hydraulic mining had largely given way to inter-basin water and hydropower development which served agricultural water supply and power generation needs throughout the western foothills region and beyond. By the turn of the 20th century, much of the region's contemporary water infrastructure was in place. Flows are currently largely controlled by the Nevada Irrigation System and PG&E (Bear River Watershed Group Website 2009).

In the 1960's, when growth in the foothills area increased, some of the original water and hydropower infrastructure was replaced or expanded while several new dams, powerhouses, and conveyance works were added. Throughout this period, the Bear River became the region's hydraulic workhorse, conveying water for consumption and energy generation from the upper Yuba, upper American, and its own headwaters and tributaries into the middle and lower Bear, the lower American, and the associated foothill creek-ravine region (Bear River Watershed Group Website 2009). The drainage pattern of the middle and lower reaches of the Bear River is illustrated in Figure 7.

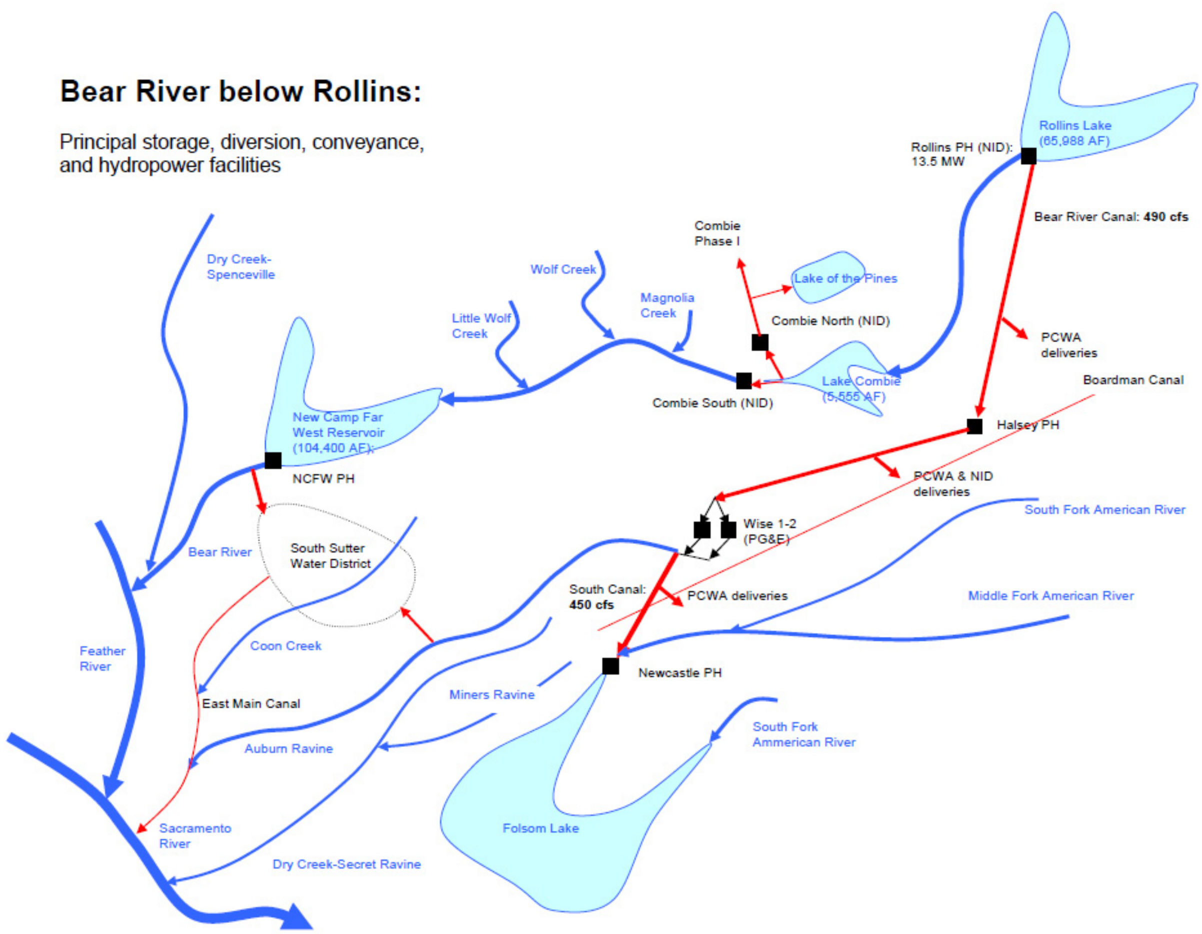

Figure 7. Schematic of the Middle and Lower Reaches of the Bear River
Source: Bear River Watershed Group Website 2009

Land Use

Much of the lower Bear River is under private ownership. While the condition of riparian habitat has not been investigated, it is likely that some riparian habitat has been degraded due to agricultural encroachment into the riparian zone. The upper Bear River includes approximately eight miles of relatively undeveloped river from its spring-fed headwaters above Bear Valley to Rollins Lake (Bear River Watershed Group Website 2009).

The Bear River was far more heavily impacted by hydrologic mining than the Yuba or American rivers and, unlike the Yuba or American rivers, contains a large volume of mining sediment stored in its main channel which is subjected to continual erosion. As mentioned above, it is estimated that 125 million cubic meters (160 million cubic yards) of mining sediment is stored in the lower Bear River. The high volume of mining sediment, in combination with restricting levees, has caused the lower Bear River to change from wide and shallow to deeply incised (Sierra Club Website 2007).

Fisheries and Aquatic Habitat

The upstream limit of anadromous fish access in the Bear River is the South Sutter Irrigation District's diversion dam, approximately 15 miles above the confluence with the lower Feather River (USFWS 1995).

The lower Bear River continues to support remnant and/or “stray” wild and/or hatchery-sustained salmon, and in the past it supported both steelhead and sturgeon as well (Bear River Watershed Group Website 2009). Inadequate streamflow in the Bear River prevents the establishment of a self-sustaining steelhead population (JSA 2004). Minimum releases below Rollins Lake (10 cfs) and Lake Combie (5 cfs) from approximately June to November result in warm water temperatures that are suitable only for bass or other warm water species (Bear River Watershed Group Website 2009). However, during periods of high flows, steelhead are known to utilize the river for limited spawning (JSA 2004). Because environmental conditions do not support a self-sustaining population of steelhead in the Bear River, those steelhead that do spawn during high flow years have likely originated from the Feather River Fish Hatchery. The present system of diversions results in abnormal flow fluctuations, in contrast to historical natural seasonal flow variations.

In addition to inadequate flows, due to the past accumulation of mining sediments and the presence of overly-constrictive levees, the lower reach has become narrow and incised and will likely require physical remediation as part of any flow-related restoration effort, in addition to eradication of invasive plant species such as Giant arundo (Bear River Watershed Group Website 2009). Downstream gravel recruitment has been limited for many years and also would have to be actively supplemented to provide suitable habitat conditions for anadramous fish. In addition, New Camp Far West Reservoir is both shallow and warm and may not be able to provide releases or through-flows when needed (i.e., during late summer and early fall) at water temperatures that are suitable to salmonids downstream; the result will depend upon the

particular reservoir storage and mixing, as well as the volume, timing, source, and temperature of any upstream flow improvements (Bear River Watershed Group Website 2009).
Continued high levels of mercury in present day river sediments indicate that the majority of the estimated 2.5 million pounds of the heavy metal that were lost in the Bear River Watershed during 32 years of hydraulic mining are still present, trapped in the 1.5 billion cubic yards of sediment stripped from hillsides (Bear River Watershed Group Website 2009).

Steelhead

As discussed above, the Bear River does not support a self-sustaining population of steelhead; steelhead that do spawn in the Bear River, during favorable environmental conditions, likely originated from the Feather River Fish Hatchery.

Yuba River Watershed Profile

Listed Species Present in the Watershed

Central Valley Spring-run Chinook Salmon (ESU)
Central Valley Steelhead (DPS)

Listed Species that Historically Occurred in the Watershed

Central Valley Spring-run Chinook Salmon (ESU)
Central Valley Steelhead (DPS)

Diversity Group

Northern Sierra Nevada Diversity Group

Background

The Yuba River supports a persistent population of steelhead and historically supported the largest, naturally-reproducing population of steelhead in the Central Valley (CDFW 1996). Adult Chinook salmon expressing the phenotypic timing of adult immigration associated with spring-run Chinook salmon also persist and spawn in the lower Yuba River below the U.S. Army Corps of Engineers' (Corps) Englebright Dam (Lindley *et al.* 2007). The lower Yuba River is among the last Central Valley floor tributaries supporting populations of naturally-spawning spring-run Chinook salmon and steelhead. There is no hatchery located on the lower Yuba River, although substantial straying of Feather River Hatchery spring- and fall-run Chinook salmon into the Yuba River does occur (Corps 2012, Kormos *et al*. 2012).

Analysis of VAKI Riverwatcher data (Corps 2012) and of coded-wire tag recovery data from Chinook salmon (Kormos *et al*. 2012) indicates that hatchery influence in the Yuba River can be high, particularly when the proportion of Yuba River flow to Feather River flow is high (Corps 2012). Corps (2012) reported that the contribution of hatchery-origin spring-run Chinook salmon to the annual total number of spring-run Chinook salmon returning to the Yuba River ranged from 2.9% in 2008 to 63.0% in 2010. Kormos *et al*. (2012) reported that 71% of Chinook salmon returning to the Yuba River were of hatchery origin. One option being discussed to minimize the impacts of hatchery Chinook salmon (and wild fall-run Chinook salmon) on wild spring-run Chinook salmon in the Yuba river is to utilize a barrier to exclude hatchery Chinook salmon (and wild fall-run Chinook salmon) from wild spring-run Chinook salmon spawning areas.

In recent years, major factors (directly flow-related) influencing the status of naturally-spawning spring-run Chinook salmon and steelhead in the Yuba River include: (1) restricted flow-dependent habitat availability; (2) limited habitat complexity and diversity; (3) elevated water temperatures; and (4) flow fluctuations (YCWA *et al.* 2007; CALFED and YCWA 2005).

In 2003, the SWRCB issued RD-1644 which prescribed minimum instream flow requirements for the lower Yuba River. However, RD-1644 was the subject of legal challenges from both the YCWA and environmental interests. To resolve this controversy, the litigants - YCWA, the South Yuba River Citizens League, Trout Unlimited, the Bay Institute and Friends of the River - along with CDFW, USFWS, NMFS, DWR and Reclamation, developed the comprehensive flow proposal contained in the Fisheries Agreement component of the Proposed Lower Yuba River Accord (Yuba Accord). The Yuba Accord (through the Fisheries Agreement) proposed new instream flow requirements in the lower Yuba River to substantially increase protection for the fisheries resources.

Parties to the Yuba Accord that also are parties to litigation related to RD-1644 were granted a stay in the California Superior Court so that the parties and other participants in the Yuba Accord process could complete environmental documentation and review of the Yuba Accord. After two one-year pilot programs in 2006 and 2007, on March 18, 2008, the SWRCB approved the consensus-based, comprehensive Yuba Accord to protect and enhance 24 miles of aquatic habitat in the lower Yuba River extending from Englebright Dam downstream to the river's confluence with the Feather River near Marysville. The Yuba Accord will be in effect at least until 2016. In addition, the SWRCB ordered that studies be conducted to further evaluate flow fluctuations and potential effects on redd dewatering and juvenile isolation and fry stranding. These studies continue to be conducted. Since the issuance of the SWRCB Yuba Accord Decision, a full-flow bypass structure has been installed on the Narrows II hydropower facility which will essentially eliminate the potential for flow fluctuations to occur in the lower Yuba River associated with maintenance and operation of the Narrows II facility.

Implementation of the flow schedules specified in the Fisheries Agreement of the Yuba Accord is expected to address the flow-related major stressors including flow-dependent habitat availability, flow-related habitat complexity and diversity, and water temperatures. In fact, water temperature evaluations conducted for the Yuba Accord EIR/EIS indicate that Yuba River water temperatures generally would remain suitable for all life stages of spring-run Chinook salmon and steelhead. In general, water temperatures would remain below 58 °F year-round (including summer months) at Smartville, below 60 °F year-round at Daguerre Point Dam and, at Marysville, below 60 °F from October through May, and below 65 °F from June through September (YCWA *et al.* 2007).

Major factors (not directly flow-related) influencing the status of naturally-spawning spring-run Chinook salmon and steelhead in the Yuba River include: (1) blockage of historic spawning habitat resulting from the construction of the Corps' Englebright Dam in 1941, which has implications for the spatial structure of the populations; (2) impaired adult upstream passage at Daguerre Point Dam; (3) high hatchery influence; (4) unsuitable spawning substrate in the uppermost area (i.e., Englebright Dam to the Narrows) of the lower Yuba River; (5) limited riparian habitats, riverine aquatic habitats for salmonid rearing, and natural river function and morphology; and (6) impaired juvenile downstream passage at Daguerre Point Dam (CALFED and YCWA 2005).

NMFS has prioritized the upper Yuba River (upstream of Englebright Dam) as a primary area to re-establish viable populations of spring-run Chinook salmon and steelhead for four main reasons. First, spring-run Chinook salmon and steelhead historically occurred there (Lindley *et al*. 2004, Yoshiyama *et al*. 1996) and studies suggest that multiple areas in the upper river would currently still support those species (DWR 2007; Stillwater Sciences 2012). Second, evidence suggests that significant amounts of summer holding habitat in the upper Yuba River are expected to remain thermally suitable for spring-run Chinook salmon throughout the 21st century even if the climate warms by as much as 5°C (Lindley *et al*. 2007). That expectation of thermally suitable habitat in the upper Yuba River watershed in the face of climate change is based on a simple analysis of air temperatures and did not account for the presence of New Bullard's Bar Reservoir, a deep, steep-sloped reservoir with ample coldwater pool reserves that could be used to provide suitable flows and water temperatures in the upper watershed downstream of the reservoir in perpetuity. The coldwater pool in New Bullards Bar Reservoir has never been depleted, even during the most extreme critically dry year on record (1977) (YCWA 2010). Third, there is considerable distance between the Yuba River watershed and the cluster of watersheds in the diversity group that currently support wild spring-run Chinook salmon. This spatial isolation is important because if one or more spring-run Chinook salmon populations were established in the upper Yuba River watershed, those populations would not be at risk if there was a volcanic eruption at Mt. Lassen, a volcano that the USGS views as highly dangerous. In contrast, all three extant independent populations (Mill, Deer, and Butte creeks) of spring-run Chinook salmon are in basins whose headwaters occur within the debris and pyroclastic flow radii of Mt. Lassen. Even wildfires, which are of much smaller scale than large volcanic eruptions, pose a significant threat to the spring-run Chinook salmon ESU in its current configuration. A fire large enough to burn the headwaters of Mill, Deer and Butte creeks simultaneously, has roughly a 10% chance of occurring somewhere in the Central Valley each year (Lindley *et al*. 2007). Lastly, the Yuba River watershed has an ample supply of water to support spring-run Chinook salmon and steelhead with one of the highest annual discharges (~2,300,000 acre-feet/year) in the Central Valley (Lindley *et al*. 2004).

In February 2010, the Yuba Salmon Forum was initiated by NMFS as a means for multiple stakeholders, including hydropower operators, local, State, and Federal agencies, and conservation organizations, to explore voluntary options for addressing the complex hydropower, water management, and natural resource management issues in the Yuba watershed. There are three hydroelectric projects licensed by the Federal Energy Regulatory Commission (FERC) in the upper Yuba watershed: (1) Nevada Irrigation District's Yuba-Bear Hydroelectric Project (FERC Project No. 2266), which controls water releases into the Middle Yuba River; (2) Pacific Gas and Electric Company's Drum-Spaulding Project (FERC No. 2310), which controls water releases into the South Yuba River; and (3) Yuba County Water Agency's Yuba River Development Project (FERC No. 2246), which controls releases into the North Yuba River downstream of New Bullard's Bar Dam. Each of these companies is currently engaged in regulatory proceedings with FERC to obtain a new license to operate their projects, and each relicensing proceeding has the potential to impact spring-run Chinook salmon and steelhead reintroduction efforts in the Yuba River Basin. The specific purpose of the Yuba Salmon Forum is to seek to implement actions to establish viable salmonid populations in the Yuba River watershed, while also considering other beneficial uses of water resources and habitat values in neighboring watersheds. The Yuba Salmon Forum is not the only collaborative effort looking at options to reintroduce salmon and steelhead into the upper Yuba River watershed.

In November 2010, a diverse group of local, State and Federal agencies and conservation organizations began exploring options to voluntarily reintroduce salmon and steelhead into the North Yuba River, upstream of New Bullards Bar Dam. This North Yuba Reintroduction Initiative would include a fish passage program around the Army Corps of Engineers' Englebright Dam on the lower Yuba River and Yuba County Water Agency's New Bullard's Bar Dam, farther upstream, which would allow fish to access as much as 45 miles of additional historic habitat.

The potential to improve both adult upstream and juvenile downstream passage at Daguerre Point Dam has been the subject of previous studies, including: (1) Daguerre Point Dam Fish Passage Improvement Project Alternative Concepts Evaluation (DWR and Corps 2003); (2) Daguerre Point Dam Fish Passage Improvement Project 2002 Fisheries Studies – Analysis of Potential Benefits to Salmon and Steelhead from Improved Fish Passage at Daguerre Point Dam (DWR and Corps 2003a); and (3) Daguerre Point Dam Fish Passage Improvement 2002 Water Resources Studies (DWR and Corps 2003b). In November 2007 NMFS issued a biological opinion (NMFS 2007) on the operation of Corps facilities on the Yuba River, including Daguerre Point Dam and Englebright Dam. A new biological opinion on the Corps' operations of these facilities was issued in 2012; as of April 2013, the Corps is in the process of re-initiating ESA consultation.

Programs to improve spawning substrate conditions in the lower Yuba River from Englebright Dam to the Narrows have recently been undertaken. With the assistance of the University of California, Davis, the Corps completed a pilot gravel injection project on November 30, 2007 which involved placing 500 tons of gravel approximately 200 yards downstream of Englebright Dam. Additionally, the Corps began injecting gravel into the reach of the Yuba River below Englebright Dam, just downstream of the PG&E's Narrows I power plant, on November 20, 2010. Due to high river flows, the injection was suspended from December 20, 2010 to January 4, 2011, and then was resumed and the injection of 5,000 tons of gravel was completed on January 13, 2011. As part of the gravel injection project, the Corps is implementing a monitoring program to track gravel movement and document the occurrence of salmonid redds in the newly injected gravel. The 2012 Biological Opinion on the Corps operations of Englebright and Daguerre Point Dams requires the Corps to implement a gravel augmentation program, which includes adding 15,000 short tons of graded and washed gravel and cobble into the Englebright Dam Reach annually (NMFS 2012).

The Fisheries Agreement of the Yuba Accord established a River Management Fund. A portion of the River Management Fund is dedicated to a restoration projects account, which includes addressing restoration actions such as riparian habitat establishment and instream aquatic habitat improvement. Such considerations are subject to the recommendation and approval of the Yuba Accord River Management Team, and are expected to be addressed within the next few years.

Implementing the Yuba River actions described in Chapter 5 of this recovery plan is expected to result in viable populations of spring-run Chinook salmon and steelhead, which would directly contribute to meeting the recovery criteria for those species. In the long-term, the Yuba River has high potential for maintaining suitable anadromous salmonid habitat, despite the expected long-term climate warming. Under the expected climate warming scenario of about 5 °C by the year 2100, substantial salmonid habitat would be lost in the Central Valley, with the Yuba River being one of the only Central Valley tributaries with significant amounts of habitat remaining (Lindley *et al.* 2007).

Key Stressors

Key stressors to Central Valley spring-run Chinook salmon and steelhead in the Yuba River watershed include, but are not limited to the following:

- Passage barrier at Englebright Dam blocking access to all historic spawning habitat, and blocking gravel and wood recruitment to the lower river
- High hatchery influence
- Loss of riparian habitat, instream cover, and floodplain habitat affecting juvenile rearing and outmigration
- Passage impediment at Daguerre Point Dam affecting adult immigration, and juvenile outmigration
- Predation of juveniles
- Unsuitable spawning substrate conditions in the reach extending from Englebright Dam to the Narrows

Additional stressors are presented in Appendix A of the Recovery Plan.

Watershed Description

The Yuba River Watershed drains 1,339 square miles of the western slope of the Sierra Nevada and includes portions of Sierra, Placer, Yuba, and Nevada counties (YCWA *et al.* 2007). The watershed is comprised of the North, Middle and South Forks of the Yuba River. There also are several other small- to medium-sized impoundments in the watershed, including Lake Spaulding, Bowman Lake, Jackson Meadows Reservoir, Englebright Reservoir, Lake Fordyce, and Scotts Flat Reservoir. The North Fork of the Yuba River flows into New Bullards Bar Reservoir and is joined by the Middle Fork about 5 miles downstream from the 645-foot New Bullards Bar Dam. The South Yuba begins with runoff near Donner Pass high in the Sierra Nevada, and its source is Lake Angela at 7,190 feet. The South Yuba River extends for 64 miles before joining the other two forks at Englebright Dam and Reservoir to form the main stem of the lower Yuba River (SYRCL 2009). The main stem of the lower Yuba River is a tributary of the Feather River, which drains into the Sacramento River. The lower Yuba River consists of the approximately 24-mile stretch of river extending from Englebright Dam, the first impassible fish barrier along the river, downstream to the confluence with the Feather River near Marysville, California.

Geology

The Yuba River watershed rises from an elevation of about 88 feet msl at its mouth to about 8,590 feet msl at its headwaters, and is bordered by the basins of the Feather River to the north, the Truckee River to the east, and the Bear River and American River to the south (SYRCL 2009). Above 6,000 feet, ponderosa pine, sugar pine, Douglas fir, white fir, and incense cedar are abundant. Precipitation in the watershed can range from 50 to 70 inches annually (SYRCL 2009). The upper Yuba River tributaries (North Yuba, Middle Yuba, and South Yuba rivers) are steep, mountain drainages that flow through narrow, deeply incised canyons alternating between bedrock and alluvial reaches. Alluvial reaches store considerable volumes of sediment in the channel bed, active bars, and infrequent well-vegetated floodplains and terraces (Curtis *et al.* 2005). Bedrock reaches have minimal channel storage, although patchy alluvium may be found in deep pools or behind bedrock constrictions or large boulders (Curtis *et al.* 2006). A stratum of serpentine traverses the Yuba River Watershed in a direction generally parallel with the crest of the Sierras. This stratum is generally softer and more easily eroded than adjoining strata (Department of Agriculture 1901).

Large volumes of sediment, derived from past upstream hydraulic-mining activities, are currently stored in several upland tributaries that flow into the Middle Yuba and South Yuba rivers. A significant part of the Yuba River sediment load is deposited in New Bullards Bar Reservoir (Brown and Thorpe 1947; Dendy and Champion 1978), in Englebright Reservoir (Childs *et al.* 2003; Snyder *et al.* 2004; Snyder *et al.* 2004a), and behind Log Cabin Dam and Our House Dam (YCWA 1989).

Hydrology

New Bullards Bar Reservoir, located on the North Yuba River, is operated by the Yuba County Water Agency (YCWA) and is the principal storage facility of YCWA's Yuba River Development Project (Yuba Project). The reservoir has a total storage capacity of 966 TAF with a minimum pool of 234 TAF (as required by YCWA's FERC license), thus leaving 732 TAF of capacity that can be regulated. A portion of this regulated capacity, 170 TAF, normally must be held empty from September through April for flood control (YCWA *et al.* 2007).

Englebright Dam and Reservoir were constructed in 1941 to capture sediment produced by upstream hydraulic mining activities, and are located downstream of New Bullards Bar Dam at the confluence of the Middle and South Yuba rivers. With a storage capacity of approximately 70 TAF, Englebright Dam and Reservoir essentially serves as a re-regulating afterbay for New Bullards Bar Reservoir and fluctuates on a frequent basis. Most of the water from Englebright Dam is released through the Narrows I and II powerhouses for hydroelectric power generation (USFWS 1995). The 0.2-mile reach of river between the dam and the two powerhouses typically does not contain much water except when the reservoir is spilling. Deer Creek flows into the Yuba River at approximately RM 22.7. The 0.7-mile reach of river downstream of the Narrows I and II powerhouses to the mouth of Deer Creek is characterized by steep rock walls, long deep pools, and short rapids. Below this area, the river cuts through 1.3 miles of sheer rock gorge called the Narrows, where the river forms a large, deep, boulder-strewn pool (USFWS 1995). YCWA and PG&E coordinate the operations of Narrows I and II for hydropower efficiency and to maintain relatively constant flows in the lower Yuba River. The Narrows I Powerhouse typically is used for low-flow reservoir releases, or to supplement the Narrows II Powerhouse capacity during high flow reservoir releases. Because of the recreational and power generation needs, the storage level within the reservoir seldom drops below 50 TAF (YCWA *et al.* 2007).

The river canyon opens into a wide floodplain at the downstream end of the Narrows where large quantities of hydraulic mining debris have been deposited during past gold mining operations. This 18.5-mile section is typified as open valley plain. Dry Creek flows into the Yuba River at RM 13.6, approximately two miles upstream of Daguerre Point Dam (YCWA *et al.* 2007). Daguerre Point Dam, located 12.5 miles downstream from Englebright Dam, is the major diversion point on the lower river. The open valley plain continues 7.8 miles below Daguerre Point Dam to beyond the downstream terminus of the Yuba Goldfields. This section is composed primarily of alternating pools, runs, and riffles with a gravel and cobble substrate. The remaining 3.5 miles of the lower Yuba River extending to the confluence with the Feather River is bordered by levees and is subject to backwater influence of the Feather River (USFWS 1995).

Operations of New Bullards Bar Reservoir can be described in terms of: (1) water management operations (i.e., baseflow operations), (2) storm runoff operations, and (3) flood control operations. Baseflow operations describe normal reservoir operations when system flows are controlled through storage regulation. These operations occur outside periods of flood control operations, spilling, bypassing uncontrolled flows into Englebright Reservoir, or outside periods of high unregulated inflows from tributary streams downstream from Englebright Dam. Storm runoff operations occur during the storm season, typically between October and May. Storm runoff operations target Englebright Reservoir operations, because it is the downstream control point for releasing water into the lower Yuba River. Storm runoff operations guidelines for Englebright Reservoir specify target storage levels and release rates. During flood control operations, the seasonal flood pool specified in the Corps flood operation manual for New Bullards Bar Reservoir is kept evacuated for flood protection, and to avoid unnecessary flood control releases. Reservoir releases may be required to maintain flood control space between September 15 and June 1 (YCWA *et al.* 2007).

Instream flow requirements are specified for the lower Yuba River at the Smartville Gage (RM 23.6), located approximately 2,000 feet downstream from Englebright Dam, and at the Marysville Gage (RM 6.2). The annual unimpaired flow at the Smartville Gage on the lower Yuba River has ranged from a high of 4.93 MAF in 1982 to a low of 0.37 MAF in 1977, with an average of about 2.37 MAF per year (1901 to 2005).[5] In general, runoff is nearly equally divided between runoff from rainfall during October through March and runoff from snowmelt during April through September. Below the Smartville Gage, accretions, local inflow, and runoff contribute, on average, approximately 200 TAF per year to the lower Yuba River.

[5] The forecasted seasonal unimpaired flow at Smartville is estimated each year by DWR and reported monthly in Bulletin 120, *Water Conditions in California*. The unimpaired flow at Smartville controls YCWA contractual delivery obligations to senior water right holders on the lower Yuba River, and is used to calculate the Yuba River Index (YRI), defined in RD-1644, and the North Yuba Index (NYI), defined in the Yuba Accord (YCWA *et al.* 2007).

Land Use

The upper basins of the Middle Yuba and South Yuba rivers have been extensively developed for hydroelectric power generation and consumptive uses by Nevada Irrigation District (NID) and PG&E. Total storage capacity of about 307 TAF on the Middle Yuba and South Yuba rivers and associated diversion facilities enable both NID and PG&E to export an average of approximately 410 TAF per year from the Yuba River Basin to the Bear River and American River basins. In addition, the South Feather Water and Power Agency exports an average of about 70 TAF per year from Slate Creek (a tributary to the North Yuba River) to the Feather River Basin. The operations in these upper basins can significantly reduce the water supply available to the lower Yuba River, particularly during dry and critical water years (YCWA *et al.* 2007).

The Corps and YCWA both own storage facilities in the Yuba Region. Englebright Dam and Daguerre Point Dam were originally constructed by the California Debris Commission, a unit of the Corps, for debris control and now are operated and maintained by the Corps. Englebright Reservoir is used extensively for recreation. The Yuba River Development Project, constructed and operated by YCWA, is a multiple-use project that provides flood control, power generation, irrigation, recreation, and protection and enhancement of fish and wildlife. It includes New Bullards Bar Dam and Reservoir, New Colgate Powerhouse, and Narrows II Powerhouse. Englebright Dam and Reservoir and Daguerre Point Dam are not part of the Yuba River Development Project. However, Englebright Dam and Reservoir are used to regulate power peaking releases from the New Colgate Powerhouse, and Daguerre Point Dam is used by YCWA to divert water to its Member Units. Water projects operated by PG&E, NID, and South Feather River Water and Power Agency export up to approximately 530 TAF of water per year into adjacent basins. Once exported, this water is not available to the lower Yuba River.

Fisheries and Aquatic Habitat

The lower Yuba River consists of the approximately 24-mile stretch of river extending from Englebright Dam, the first impassible fish barrier along the river, downstream to the confluence with the Feather River near Marysville. The vast amounts of hydraulic mining debris deposited in the lower Yuba River's channel and floodplain a century ago, and the lack of gravel recruitment caused by the construction of Englebright Dam, continue to have a dominant influence on the geomorphic character and processes of the lower Yuba River. High winter flows continue to cause extensive channel migration and erosion of bars and dredger tailings throughout much of the lower Yuba River because of the large quantities of unconsolidated cobbles and gravels, the lack of extensive riparian forests, and confinement of much of the active river corridor by dredger tailings (CALFED and YCWA 2005).

Daguerre Point Dam was constructed to create a retention basin for hydraulic mining debris transported downstream from upper reaches of the Yuba River watershed. Because mercury was used as an amalgam for the extraction of gold in the mining process, the sediments stored in the pool formed by the dam may contain elevated concentrations of mercury in its elemental and methylated forms (CALFED and YCWA 2005). The Central Valley Regional Water Quality

Control Board (CVRWQCB) detected elevated levels of mercury in the Yuba River in 1986 (CALFED and YCWA 2005). Ongoing research by the University of California, Davis, has confirmed the upper reach of the Yuba River above Englebright Reservoir as among those with the highest levels of bioavailable mercury, as measured with instream bioindicator organisms. A survey conducted in 1997 by the USGS National Water Quality Assessment Program confirmed that elevated concentrations of bioavailable mercury were still present in the sediments of the upper and lower Yuba River (Corps 2000).

Shaded riverine aquatic (SRA) habitat generally occurs in the lower Yuba River as scattered, short strips of low-growing woody species (e.g., *Salix sp*.) adjacent to the shoreline (CALFED and YCWA 2005). The most extensive and continuous segments of SRA habitat occur along bars where recent channel migrations or avulsions have cut new channels through relatively large, dense stands of riparian vegetation (Beak 1989). Due to a lack of riparian vegetation throughout much of the lower stream, instream woody material also is limited in the lower Yuba River (CALFED and YCWA 2005).

CALFED and YCWA (2005) used previously developed delineations and descriptions for the various reaches in the lower Yuba River. The Narrows Reach of the lower Yuba River is steep and consists of a series of rapids and deep pools confined by a bedrock canyon, and is dominated by deep pool habitat (CALFED and YCWA 2005). Habitats classified as moderate gradient riffles are found only in this reach of the lower Yuba River (CALFED and YCWA 2005). Salmonid spawning gravels are scarce in the Narrows Reach due to the truncation of gravel recruitment resulting from the construction of Englebright Dam and the high-energy hydraulic nature of this reach. Furthermore, the quantity and quality of salmonid spawning substrate in this reach has been significantly reduced by the deposition of large, consolidated rock fragments (i.e. "shotrock") in the vicinity of Englebright Dam. Although montane hardwoods occupy much of the Narrows Reach, the steep-walled canyons preclude immediate riparian growth, thereby limiting the potential for positively affecting the instream aquatic habitat (CALFED and YCWA 2005).

With the exception of moderate gradient riffles, the proportion of mesohabitat compositions of the Garcia Gravel Pit Reach and Daguerre Point Dam Reach are more evenly distributed than in the Narrows Reach, with run and glide habitats comprising the largest proportion of habitat types (CALFED and YCWA 2005). The Simpson Lane Reach is dominated by deep pools and has lower proportions of the remaining habitat types. Spawning gravels are abundant and generally of high quality throughout both the Garcia Gravel Pit and Daguerre Point Dam reaches (YCWA *et al.* 2000). Spawning gravels have been supplied to the river largely from local sources including deposition of hydraulic mining debris in the riverbed between the mid-1800s and 1941 (Beak 1989) and gravel recruitment from Deer Creek. The quality of gravels in the Garcia Gravel Pit and Daguerre Point Dam reaches is considered excellent for Chinook salmon spawning (CDFW 1991). The occurrence of fine interstitial sediments increases in the downstream portions of the Simpson Lane Reach, rendering the habitat less suitable for salmonid spawning (CDFW 1991). In the vicinity of Daguerre Point Dam, the Yuba River is largely devoid of sufficient riparian vegetation to provide suitable juvenile salmonid rearing habitat conditions (CALFED and YCWA 2005).

The Yuba Goldfields area, comprised of approximately 11,000 acres of land adjoining the Yuba River near Daguerre Point Dam, is the result of intensive gold dredging in the late 1800s and early 1900s when up to 27 gold dredges along the river and floodplain worked the area at one time (Smith 1990). One large gold dredge continues to work the area (CALFED and YCWA 2005). A dewatering channel, dug to lower the water level in the Yuba Goldfield area south and west of Daguerre Point Dam, collects subsurface and surface flows and empties them into the Yuba River approximately one mile downstream of the Yuba Goldfields (CALFED and YCWA 2005). The Yuba Goldfields section near Daguerre Point Dam is largely devoid of any streamside vegetation. Land use in the Simpson Lane Reach is comprised primarily of agricultural activities (e.g., orchards, grasslands, rice cultivation) and provides little shading to this portion of the lower Yuba River. In addition, Simpson Lane Reach is bordered by levees and is subject to backwater influence of the Feather River, further restricting the establishment of riparian vegetation in this area (CALFED and YCWA 2005).

Spring-run Chinook Salmon

Historical accounts of the spring-run Chinook salmon population in the Yuba River prior to the impacts associated with gold mining, dam construction, and water diversions, indicate that large numbers of spring-run Chinook salmon were taken by miners and Native Americans as far upstream as Downieville on the North Yuba River, and that during the construction of the original Bullards Bar Dam (1921 - 1924), the number of salmon that congregated and died below the dam was so large, the salmon had to be burned (Yoshiyama *et al.* 1996). Due to their presence high in the watershed, Yoshiyama concluded that these fish were spring-run Chinook salmon (NMFS 2007).

Prior to 2001, when CDFW conducted a study to quantify the number of adult spring-run Chinook salmon immigrating into the Yuba River by trapping fish in the fish ladder at Daguerre Point Dam, there was almost no specific information on the run timing and size of the population in the Yuba River. In the 2001 CDFW study, which involved limited sampling of fish ascending the north ladder, a total of 108 adult Chinook salmon were estimated to have passed the dam between March 1, 2001, and July 31, 2001 (CDFW 2002).

Infrared-imaging technology has been used to monitor fish passage at Daguerre Point Dam in the lower Yuba River since 2003 using VAKI Riverwatcher systems. VAKI Riverwatcher systems are located at both the north and south ladder of Daguerre Point Dam to record and identify the timing and magnitude of passage for Chinook salmon at Daguerre Point Dam during most temporal periods, however system failures predominantly caused by low-voltage disconnections, system maintenance or unknown malfunctions reduced the ability of the equipment to document ladder use during some months. As a result, prior to conducting any temporal modalities analysis for the 7 annual time series of Chinook salmon VAKI daily counts, an estimation procedure of the annual daily count series of each ladder was applied to account for days when the VAKI Riverwatcher systems were not fully operational (Corps 2012). The procedural methodology for this estimation procedure is detailed in Appendix B to Corps (2012).

Corps (2012) indicate that the time series of Chinook salmon moving daily upstream of Daguerre Point Dam for the 2004 to the 2010 biological years (March 1 through February 28) were inspected to identify modes that could be useful in the separation of spring-run Chinook salmon counts from those of fall-run Chinook salmon. Corps (2012) reports that although the combined annual time series displayed considerably daily variability, at least two main groups of fish were identified. One group, presumably spring-run Chinook salmon, is present primarily during May, June and early July, and the other group, presumably fall-run Chinook salmon, is present from mid-August through January.

Corps (2012) reports that for the period (2004-2010) during which VAKI Riverwatcher data are available, the annual number of spring-run Chinook salmon estimated to have passed upstream of Daguerre Point Dam ranged from 285 in 2007 to 2,998 in 2005, with an average of 1,279. For the past four years, the abundance of in-river spawning spring-run Chinook salmon has steadily increased. For the last three consecutive years, an estimated total of 4,130 spring-run Chinook salmon have passed upstream of Daguerre Point Dam, with an average of 1,377 fish per year. As previously described by NMFS (2011), populations with a low risk of extinction (less than 5% chance of extinction in 100 years) are those with a minimum total escapement of 2,500 spawners in 3 consecutive years (mean of 833 fish per year).

Corps (2012) also indicates that the abundance of spring-run Chinook salmon in the lower Yuba River has exhibited a very slight increase over the seven years examined, although the trend is not statistically significant. Nonetheless, the relationship indicates that the population over this time period is at least stable, and did not exhibit a declining trend.

The detection of adipose fin clips on some of these fish indicates that they were hatchery strays, most likely from the Feather River Fish Hatchery. Corps (2012) estimated the annual number of non-hatchery origin spring-run Chinook salmon to have passed upstream of Daguerre Point Dam during the 2004-2010 period ranged from 246 in 2007 to 2,339 in 2005, with an annual average of 866 fish. For the last three consecutive years, an estimated total of 2,080 non-hatchery origin spring-run Chinook salmon have passed upstream of Daguerre Point Dam, with an average of 693 fish per year. Corps (2012) demonstrates a slightly decreasing trend in the abundance of spring-run Chinook salmon of non-hatchery origin in the lower Yuba River over the 7 years examined, although not statistically significant. Corps (2012) also reports a slightly increasing trend in the abundance of spring-run Chinook salmon of hatchery origin in the lower Yuba River over the 7 years examined, although not statistically significant. Table 1 summarizes the results of the separation of the annual VAKI counts of Chinook salmon passing upstream of Daguerre Point Dam into spring-run Chinook salmon, and into spring-run Chinook salmon of hatchery origin for 2004 through 2010. The lowest contribution of spring-run Chinook salmon of hatchery origin to the annual total number of lower Yuba River spring-run Chinook salmon occurred in 2008 (2.9%). The highest contribution of hatchery fish occurred in 2010 (63.0%).

Table 5. Separation of annual VAKI Riverwatcher counts identified as Chinook salmon passing upstream of Daguerre Point Dam into spring-run Chinook salmon, and into spring-run Chinook salmon of hatchery origin (adipose clipped fish) for 2004 through 2010. Percentages indicate the annual percent contributions of spring-run Chinook salmon counts to Chinook salmon, and the annual percent contributions of spring-run Chinook salmon of hatchery origin to spring-run of both hatchery and natural origin.

Year	Chinook Salmon Passing Upstream DPD (Vaki RiverWatcher)				
	Chinook Salmon	Spring-run Chinook Salmon[1]			
		Hatchery + Natural Origin		Hatchery Origin[2]	
	(No. Fish)	(No. Fish)	(%)	(No. Fish)	(%)
2004	5,927	738	(12.5 %)	75	(10.2 %)
2005	11,374	2,998	(26.4 %)	659	(22.0 %)
2006	5,203	803	(15.4 %)	67	(8.3 %)
2007	1,394	285	(20.4 %)	39	(13.7 %)
2008	2,533	521	(20.6 %)	15	(2.9 %)
2009	5,378	723	(13.4 %)	217	(30.0 %)
2010	6,469	2,886	(44.6 %)	1,818	(63.0 %)

[1] For each biological year (March 1 - February 28), all daily Chinook salmon Vaki counts occurring before an annually variable demarcation date were classified as spring-run Chinook salmon counts.

[2] For each biological year, all daily Ad-clipped Chinook salmon Vaki counts occurring before an annually variable demarcation date, multiplied by the average of the production expansion factors corresponding to the CWTs of spring-run Chinook salmon released by the hatcheries and were recovered as carcasses during the annual Yuba River escapement surveys, were classified as spring-run Chinook salmon of hatchery origin.

Source: Corps 2012

In the lower Yuba River, spring-run Chinook salmon adult immigration and holding primarily extends from March through October (YCWA *et al.* 2007). Spring-run Chinook salmon are reported to hold over during the summer in the deep pools and cool water downstream of the Narrows I and Narrows II powerhouses, or further downstream in the Narrows Reach (CDFW 1991; SWRCB 2003), where water depths can exceed 40 feet (YCWA *et al.* 2007). Congregations of adult Chinook salmon (approximately 30 to 100 fish) have been observed in the outlet pool at the base of the Narrows II Powerhouse, generally during late August or September when the powerhouse is shut down for maintenance. During this time period the pool becomes clear enough to see the fish (Michael Tucker, NMFS, pers. obs., September, 2003; Steve Onken, YCWA, pers. comm., April, 2004). While it is impossible to visually distinguish spring-run from fall-run Chinook salmon in this situation, the fact that these fish are congregated this far up the river at this time of year indicates that some of them are likely to be spring-run Chinook salmon (NMFS 2007).

The spring-run Chinook salmon spawning period extends from September through November, while the embryo incubation life stage generally extends from September to March (YCWA *et al.* 2007). Redd surveys conducted by CDFW during late August and September have detected spawning activities beginning during the first or second week of September. They have not detected a bimodal distribution of spawning activities (i.e., a distinct spring-run spawning period followed by a distinct fall-run Chinook salmon spawning period) but instead have detected a slow build-up of spawning activities starting in early September and transitioning into the main fall-run spawning period. The earliest spawning generally occurs in the upper reaches of the highest quality spawning habitat (i.e., below the Narrows pool) and progressively moves downstream throughout the spawning season (NMFS 2007).

Some spring-run Chinook salmon juveniles emigrate as YOY, while others rear in the lower Yuba River year-round. In general, juvenile Chinook salmon have been observed throughout the lower Yuba River, but with higher abundances above Daguerre Point Dam. This may be due to larger numbers of spawners, greater amounts of more complex, high-quality cover, and lower densities of predators such as striped bass and American shad, which reportedly are restricted to areas below Daguerre Point Dam (YCWA *et al.* 2007).

The spring-run Chinook salmon smolt emigration period is believed to extend from November through June, although based on CDFW's run-specific determinations, the vast majority (approximately 94 percent) of spring-run Chinook salmon were captured as post-emergent fry during November and December, with a relatively small percentage (nearly 6 percent) of individuals remaining in the lower Yuba River and captured as YOY from January through March. Only 0.6 percent of the juvenile Chinook salmon identified as spring-run were captured during April, 0.1 percent during May, and none were captured during June (YCWA *et al.* 2007).

Steelhead

CDFW estimated a steelhead spawning population of only about 200 fish annually prior to 1969. Prior to construction of Englebright Dam, CDFW fisheries biologists stated that they observed large numbers of steelhead spawning in the uppermost reaches of the Yuba River and its tributaries (CDFW 1998; Yoshiyama *et al.* 1996). During the 1970s, CDFW annually stocked hatchery steelhead from Coleman National Fish Hatchery into the lower Yuba River, and by 1975 CDFW estimated a run size of about 2,000 fish (CDFW 1991). CDFW stopped stocking steelhead into the lower Yuba River in 1979, and currently manages the river to protect natural steelhead through strict "catch-and release" fishing regulations (NMFS 2007).

Ongoing monitoring of the adult steelhead population in the lower Yuba River has been conducted since 2003 with VAKI Riverwatcher systems at Daguerre Point Dam. For the assessment of steelhead in the lower Yuba River, Corps (2012) examined silhouettes and corresponding photographs for species identification and categorization using methodology similar to that for spring-run Chinook salmon. However, by contrast to the identification of Chinook salmon which may be conducted with a single attribute, the identification of steelhead becomes more problematic with the absence of a defining silhouette or a clear digital photograph (Corps 2012). The methodology to estimate the annual number of steelhead passing upstream of Daguerre Point Dam is provided in Corps (2012).

For the period between 2003 to 2011 Corps (2012) reportedly used the daily counts of adult steelhead passing upstream at Daguerre Point Dam to represent the abundance of steelhead, with the understanding that the resultant estimates were minimal numbers, and in most of the survey years considerably underestimate the potential number of steelhead because the annual estimates: (1) do not include periods of VAKI Riverwatcher system non-operation; and (2) do not consider the fact that not all steelhead migrate past Daguerre Point Dam, and some spawn in the lower Yuba River below Daguerre Point Dam. Corps (2012) states that although the VAKI Riverwatcher systems have been in place since June of 2003, reliable estimates of the number of adult steelhead passing upstream at Daguerre Point Dam are essentially restricted to the last year of available data (2010/2011). VAKI Riverwater data are presently available through February 2011, which represents only a portion of the annual upstream migration. Nonetheless, from August through February of 2010/2011, an estimated 446 adult steelhead passed upstream of Daguerre Point Dam.

Steelhead adult immigration and holding in the lower Yuba River extends from August through March (Corps 2012; YCWA *et al.* 2007). Spawning generally extends from January through April, primarily occurring in reaches upstream of Daguerre Point Dam (CALFED and YCWA 2005; CDFW 1991a; Corps 2012; YCWA *et al*. 2007). The embryo incubation life stage generally extends from January through May (CALFED and YCWA 2005; SWRI 2002). Juvenile steelhead are believed to rear in the lower Yuba River year-round. The steelhead smolt emigration period is believed to extend from October through May (CALFED and YCWA 2005; SWRI 2002; YCWA *et al.* 2007).

The primary rearing habitat for juvenile steelhead/rainbow trout is upstream of Daguerre Point Dam. Juvenile trout (age 0 and 1+) abundances were substantially higher upstream of Daguerre Point Dam, with decreasing abundance downstream of Daguerre Point Dam. Large juveniles and resident trout up to 18 inches long also have been commonly observed in the lower Yuba River upstream and downstream of Daguerre Point Dam (SWRI *et al.* 2000).

Butte Creek Watershed Profile

Listed Species Present in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Listed Species that Historically Occurred in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Diversity Group

Northern Sierra Nevada

Key Stressors

Key stressors to spring-run Chinook salmon and steelhead in Butte Creek include, but are not limited to the following:

- Water temperatures affecting adult immigration and holding and embryo incubation
- Passage impediments/barriers affecting adult immigration and holding
- Predation of juveniles in the Butte Sink and Sutter Bypass
- Flow fluctuations and turbidity affecting spawning and embryo incubation
- Summer instream recreation activities stressing holding adults
- Loss of natural river morphology, riparian habitat and instream cover affecting juvenile rearing and outmigration
- Lack of certainty regarding a long-term flow agreement with irrigation districts (T. Parker, USFWS, pers. comm. 2009)
- Upper watershed condition and fire risk

Watershed Description

The following information on the Butte Creek watershed is generally summarized from the *Butte Creek Watershed Project: Existing Conditions Report* (Butte Creek Watershed Conservancy 1999).

Butte Creek originates in the Jonesville Basin, Lassen National Forest, on the western slope of the Sierra Nevada Mountains, and drains about 800 square miles in the northeast portion of Butte County. The Butte Creek Watershed encompasses approximately 510,000 acres and lies predominantly in Butte County with smaller portions in Tehama, Glenn, Colusa and Sutter Counties. Butte Creek enters the Sacramento Valley southeast of Chico and meanders in a southwesterly direction to the initial point of entry into the Sacramento River at Butte Slough. Butte Creek also enters the Sacramento River through the Sutter Bypass and Sacramento Slough.

In addition to Butte Creek and its tributaries, the watershed includes a series of dams, diversions and canals mostly located in the valley portion of the watershed and in the middle and lower canyon portions of Butte Creek. The Sutter Bypass section of Butte Creek begins downstream of the Butte Slough Outfall. Butte Creek (named Butte Slough in this section) splits into two channels, known as the East and West Borrow Canals, as it enters the Sutter Bypass near Highway 20. Generally, Butte Creek enters the Sacramento River via Sacramento Slough immediately upstream of the mouth of the Feather River near Verona.

Butte Creek historically supported a self-sustaining population of spring-run Chinook salmon despite being at somewhat low elevation (all spawning occurs below 300 m) and having rather warm summer water temperatures (exceeding 20_C in 2002 in the uppermost and coolest reach) (Lindley *et al*. 2004). In recent years, inflows to Butte Creek from the upper West Branch Feather River deliver cold water that help support CV spring-run Chinook salmon. The cold water import from the West Branch Feather River helps spring-run Chinook salmon to oversummer, spawn and successfully occupy Butte Creek.

The success of numerous restoration efforts that have been undertaken on Butte Creek are illustrated by the abundance of CV spring-run Chinook salmon that have been observed since 1998. Once impaired by numerous dams with poor fish passage facilities, no dedicated fish flows, and unscreened diversions, Butte Creek now provides state-of-the-art fish ladders and screens, and dedicated instream flows. Water temperatures continue to pose threats to holding adult spring-run Chinook salmon and may limit habitat availability for steelhead.

Because the Butte Creek spring-run fish population is now considered persistent and viable, the watershed is considered a conservation stronghold for all life stages of spring-run Chinook salmon. Butte Creek is one of the most productive spring-run Chinook salmon streams in the Sacramento Valley (DWR 2005), and is one of only three streams (in addition to Deer and Mill creeks) that harbor a genetically distinct, sustaining population of spring-run Chinook salmon (CDFW 1998, as cited in CDFW 2008). Therefore, the viability of the Central Valley spring-run Chinook salmon ESU is reliant upon sustaining the Butte Creek spring-run Chinook salmon population. Lindley *et al*., (2007) characterized the Butte Creek population as being at a low risk of extinction due to the abundance of the population, positive production trends, and a very low hatchery influence. Recent years have seen a sharp reduction in adult abundance, but the population still remains strong and should still be considered at moderate to low risk of extinction.

In addition, due to the low elevation habitat available to spring-run Chinook salmon in Butte Creek, climate change and potentially warmer water temperatures in the future may become a key threat to their recovery. If summer water temperatures warm even by one or two degrees (°C), it is unlikely that Butte Creek spring-run Chinook salmon would persist (Williams 2006). With a rise in air temperatures of 2 °C, the 25°C isotherm might just rise to the upper limit of the historical distribution of spring-run Chinook salmon in Butte Creek (Lindley *et al*. 2007). These threats currently are being evaluated and will be addressed over the next five years through the issuance of a new FERC license of the operation of the DeSabla-Centerville Hydroelectric project. Water temperature improvements are expected to reduce maximum water temperatures by as much as 1 to 2 degrees Celsius and reduce the frequency of heat events that trigger adult mortality.

The status of steelhead in Butte Creek is unknown. Although water temperatures are adequate to support summer rearing, and *O. mykiss* are present in high densities through the reach between lower Centerville Diversion Dam and the Centerville Powerhouse, high quality spawning and rearing habitat is essentially limited to only about 5 miles of stream. Further monitoring of steelhead in the system, as well as, studying the habitat use and needs of steelhead for Butte Creek is needed to develop a recovery strategy for this Creek. However, given that spring-run Chinook salmon are productive in Butte Creek, the potential to support a viable steelhead population appears to moderate at the least.

Geology

The following information on geology in the Butte Creek watershed was taken from or summarized from the *Butte Creek Watershed Project: Existing Conditions Report* (Butte Creek Watershed Conservancy 1999).

The geology of the headwaters area in the Butte Meadows Basin is composed of volcanic rocks, associated with the Pliocene volcano Mt. Yana. The area contains andesitic rocks, basaltic rocks, and pyroclastic formations (Tuscan Formation).

As Butte Creek leaves the Butte Meadows area, it begins to incise into the Pre-Cretaceous metavolcanic and (older) Paleozoic marine sedimentary and metasedimentary geologic structures, known as the Sierra Nevada Basement Series or Basement Complex. These rocks underlie the volcanic structures that dominate the drainage basin. This formation is composed of massive greenstones, tuffaceous schists, dark schistose metasedimentary and metavolcanic rocks of the “Calaveras Formation”, slates, dark phyllite, quartzite, serpentine, and greywacke. It is in this area that the interface between the Tuscan (mudflow) Formation and the underlying Basement Series geology, in part containing the "Tertiary Auriferous gravels", begins to become exposed. The Tertiary Auriferous gravels are ancient, gold-bearing (auriferous) stream deposits, with their deposition occurring in the Tertiary period of the geologic time scale. Cape Horn, a geologic feature that dominates the canyon landscape, is visible 3/4 of a mile downstream of the Inskip Creek confluence. This outcropping of more resistant metavolcanic material has forced Butte Creek to flow around the rock outcrop, while the Butte Creek Canal, some 180 feet above the creek, enters a tunnel through the rock itself.

The middle section of the Butte Creek canyon downstream of the confluence with Clear Creek, is an area of extensive faulting of the Basement Series, where mining activity and settlement concentrated during the Gold Rush. There are many mines in the area, identified on USGS 7.5' quadrangles (Dix, Royal Drift, Black Diamond, etc.). The natural topography of the inner gorge of Butte Creek Canyon in the area around the Forks of Butte (the confluence with the West Branch of Butte Creek) has been modified by the mining of the stream and terrace gravel in the area of the confluence itself. Tailing piles and old sluice channels are scattered along the banks. The interface between the Tuscan and Basement Series rocks was exploited extensively on the Platte Ravine, off the West Branch of Butte Creek, accounting for headcuts and some hardrock tunneling in this area. Although many of the cutbanks in the area now have 100+ year old trees growing out of them, the landscape is still visibly altered.

The predominant geologic unit in the watershed, the Tuscan Formation, covers all other geologic formations in the mid-section of the watershed and effectively "caps" the landscape. Its estimated 300 cubic miles of material are spread out over a range of 2,000 square miles, covering an area from Oroville to Red Bluff. This formation was created by a mudflow deposit of late Pliocene age and is composed of angular to surrounded volcanic and metamorphic fragments, up to 3 meters in diameter, in a matrix of gray-tan volcanic mudstone. Downstream of the Centerville Diversion Dam, Butte Creek is entrenched in the metamorphic and igneous rocks that comprise the Basement complex of the Sierra Nevada. The sides of the creek show signs of past mining, with tailings piles and tunnels through bedrock banks.

The geologic character of Butte Creek changes markedly about 1.25 miles upstream of Helltown Bridge. At this location the Sierran Basement geology is covered by the Chico Formation (a unit of Cretaceous age associated with the inland seas of the Sacramento Valley). The Chico Formation is composed of fossiliferous marine sandstone. Gravel bars begin to form on the insides of meander bends, and the banks are covered with vegetation as roots more easily penetrate the softer sandstone. Due to a large landslide sometime within the last 11,000 years, the creek is forced up against the west side of the canyon just downstream of Helltown Bridge, cutting deeply into the Chico Formation, leaving well-exposed tan sandstone cliffs. Directly below this landslide area begins a unit known as the Modesto Formation, composed of gravel, sand, silt and clay derived from the Tuscan and Chico Formations. The Modesto Formation is perched atop the Chico Formation along Butte Creek, and is prevalent along the canyon bottom, leading to the Sacramento Valley. Although mining debris are visible further upstream, the Modesto Formation area reveals the first obvious signs of dredge tailings. These tailings, consisting of cobble-sized and larger rocks, sit in piles where they were left after being sluiced through by gold miners. The tailings continue down the canyon along Butte Creek.

Hydrology

The following information on hydrology in the Butte Creek watershed was taken from or summarized from the *Butte Creek Watershed Project: Existing Conditions Report* (Butte Creek Watershed Conservancy 1999).

The hydrology of Butte Creek has been extensively modified and developed. It contains multiple hydropower diversions and imports water from other watersheds. Figure 8 displays the main hydrologic features (e.g., streams, diversions, powerhouses) within the Butte Creek watershed. There are three main sections of Butte Creek (upper, middle and lower).

Upper Butte Creek (i.e., Butte Meadows)

After Butte Creek flows through the Butte Meadows Basin, it transitions through the steep Butte Creek Canyon some 25 miles to the point where it enters the valley floor near Chico. In this section Butte Creek flows in a north-northeast to south-southwest direction, and is characterized by numerous small tributaries and springs, and deep, shaded pools interspersed throughout the upper section of the canyon above Centerville with flora dominated by pine and fir. The creek averages a drop of over 100 feet per mile in this section. The canyon section below Centerville has a shallower gradient and a riparian canopy of alder, oak, sycamore and willow. PG&E owns and operates two hydroelectric power generation dams (Butte Creek Head Dam and Centerville Head Dam) in the canyon.

Middle Butte Creek (i.e., Butte Canyon)

After Butte Creek leaves the canyon near Chico, it flows through a portion of the Sacramento Valley known as the Butte Creek Valley Section that extends to the Butte Slough Outfall, where Butte Creek first enters the Sacramento River. Four dams and numerous diversions in the valley section remove water to irrigate rice fields and orchards. The upstream-most diversion, Parrott-Phelan, diverts water year-round, but most diversions operate during April through September. Dams also impound and divert water for wildlife and agricultural uses in the lower portion of the section (Butte Sink). These dams include: Sanborn Slough, White Mallard Dam, East-West Diversion weir, and weirs number 1 through 5.

Lower Butte Creek (i.e., Butte Valley)

The Sutter Bypass section of Butte Creek, also known as Butte Basin, extends downstream of the Butte Slough Outfall for approximately 40 miles. Butte Creek (named Butte Slough in this section) splits into two channels, known as the East and West borrow pits, as it enters the Sutter Bypass near Highway 20.
The tributaries that enter each of the three Butte Creek reaches (*i.e*., Butte Meadows, Butte Creek Canyon and Butte Creek Valley Section) are listed in an upstream-downstream order in Table 4.

Land Use

As described in the *Butte Creek Watershed Project: Existing Conditions Report* (Butte Creek Watershed Conservancy 1999), the diversity in the terrain encompassed by the Butte Creek Watershed has resulted in very diverse landownership and land uses. The land use map displayed in Figure 9 identifies the general land uses present in the Butte Creek Watershed as of 1997. The map displays broad land use designations and presents numerous generalizations; consequently, it should be only used in a broad or regional context. The areas assigned to each of the 13 land use categories in Figure 9 are quantified in terms of acreage and percent of the total watershed area in Table 2. Most of the lands in the Butte Creek watershed were allocated to grazing and agricultural use (64%), with the remaining lands almost equally split between commercial, industrial and residential use (13.1%) and forest related uses (13%). It is likely that in the recent 10 years these percentages may have changed somewhat due to the increase in residential development at the expense of grazing and agricultural use.

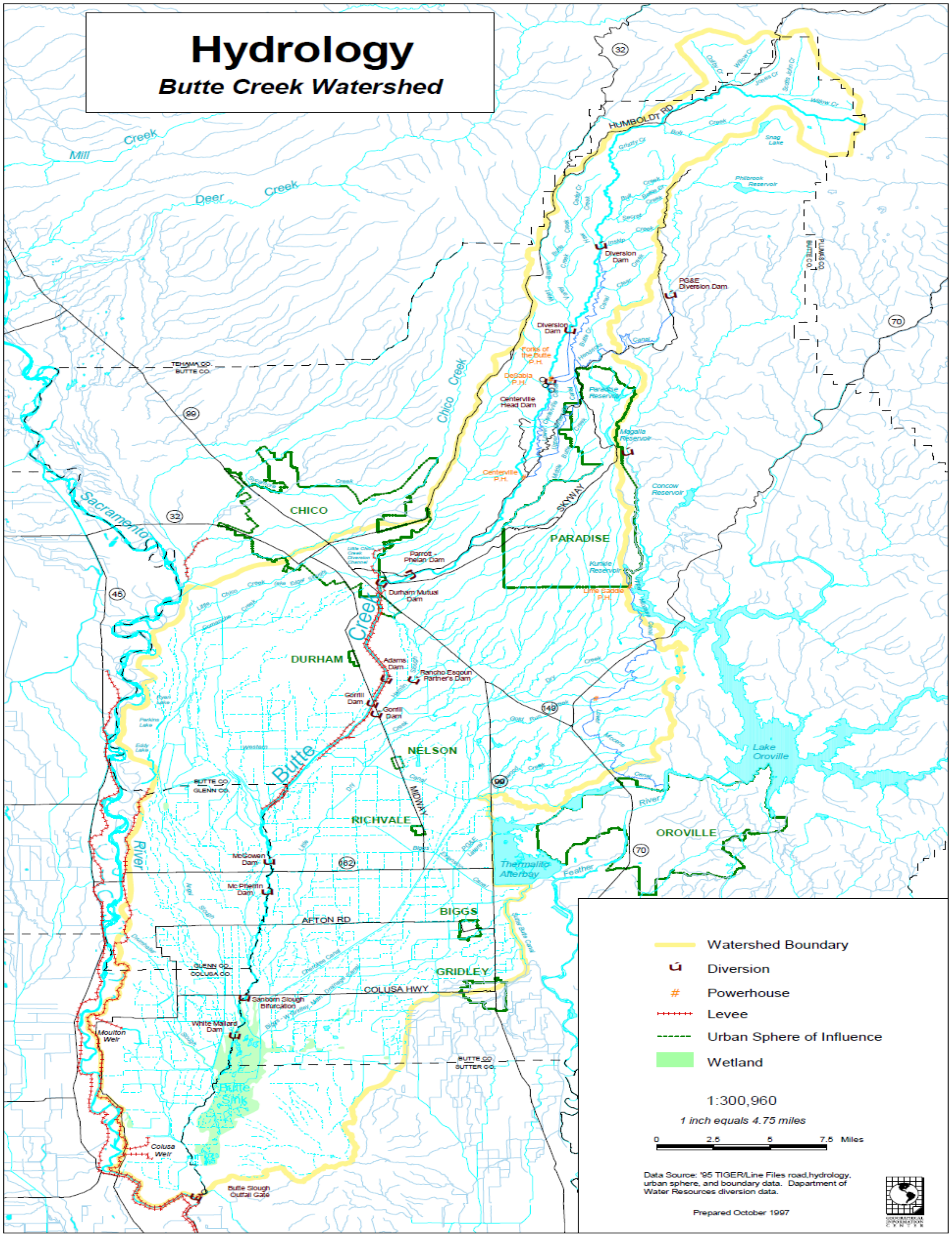

Figure 8. Hydrologic Features within the Butte Creek Watershed
Source: Butte Creek Watershed Conservancy 1999

Table 6. Butte Creek Tributaries

Watershed Section	Tributaries to Butte Creek	
	Butte Creek Left Bank	Butte Creek Right Bank
Butte Meadows	Unnamed Creek Unnamed Creek Bolt Creek Grizzly Creek	Willow Creek Scotts John Creek Jones Creek (joined by another Willow Creek) Colby Creek
Butte Canyon	Three unnamed creeks Bull Creek (joined by Bottle Creek and Secret Creek) Unnamed Creek Inskip Creek Two unnamed creeks Clear Creek (joined by Kanaka Creek) Numerous unnamed small, spring-fed creeks Four unnamed small creeks Little Butte Creek (joined by Middle Butte Creek)	Haw Creek Numerous unnamed small, spring-fed creeks West Branch Butte Creek (joined by Cedar Creek and later Varey Creek) Three unnamed small creeks
Butte Valley	Hamlin Slough Biggs-West Gridley Main Drain joined to Cherokee Canal (result of consolidating Cottonwood Creek, Clear Creek, Gold Run Creek and Dry Creek)	Little Butte Creek Angel Slough Drumheller Slough

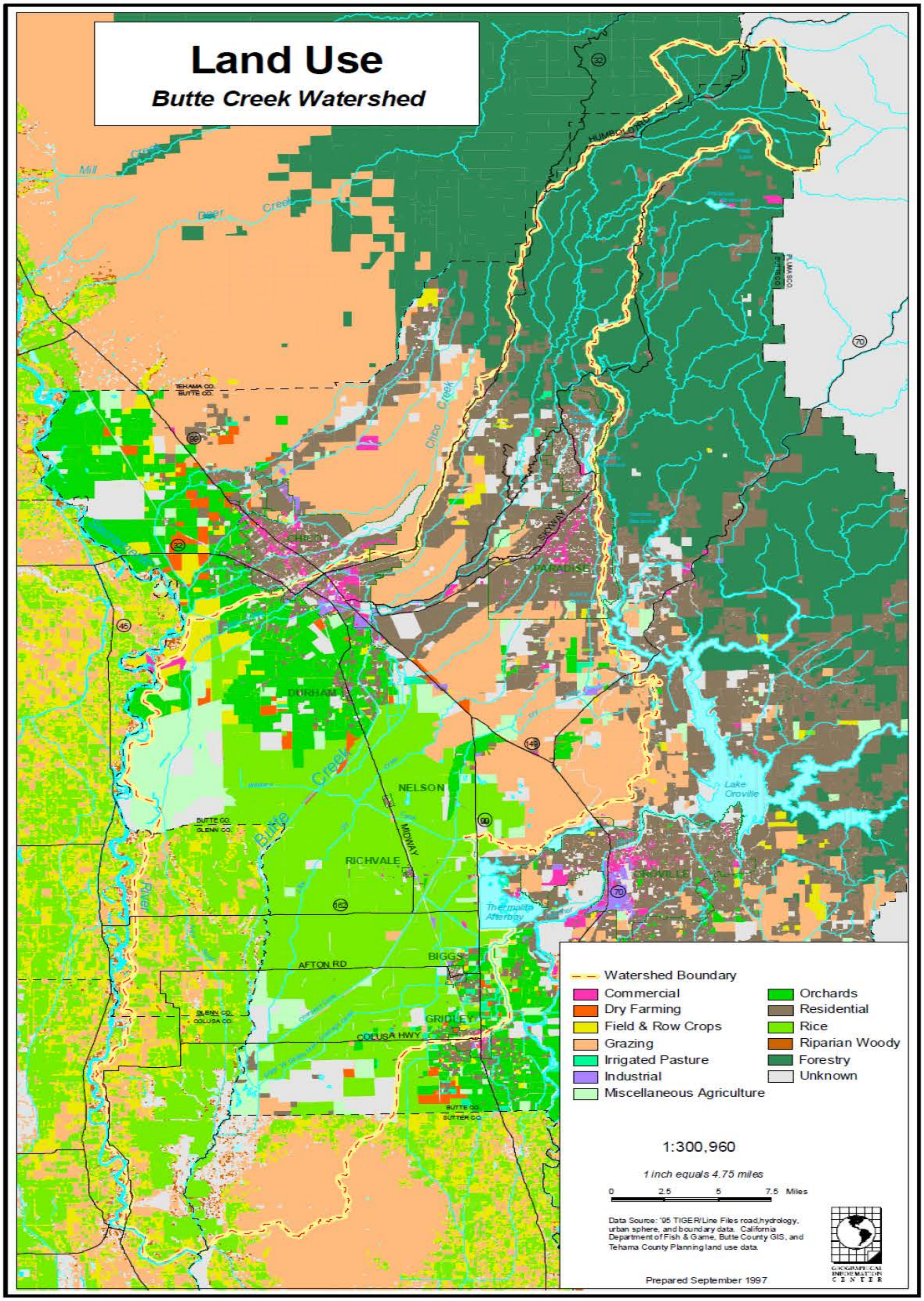

Figure 9. Land uses in the Butte Creek watershed

Source: Butte Creek Watershed Conservancy 1999. Created by the Geographic Information Center at CSU, Chico, with data provided by Butte, Tehama, Sutter, Glenn and Colusa Counties, and CDFW.

Table 7. Land use acreage in the Butte Creek watershed

Land Use Category	Acres	Percent of Butte Creek Watershed
Residential	62,362.3	12.0
Commercial	3,518.5	0.7
Industrial	1,690.0	0.3
Dry Farming	2,580.7	0.5
Field & Row Crops	24,168.0	4.7
Grazing	84,871.4	16.4
Irrigated Pasture	1,666.6	0.3
Orchards	31,254.7	6.0
Rice	158,915.7	30.7
Miscellaneous Agriculture	27,893.6	5.4
Riparian Forest	2,033.6	0.4
Upland Forest	65,708.4	12.7
Roads, rivers and creeks	51,125.3	9.9
Unknown	59.2	0.01
Total watershed acreage	517,848	100

Source: Butte Creek Watershed Conservancy 1999

Fisheries and Aquatic Habitat

Butte Creek is unique among the remaining spring-run Chinook salmon independent populations in that all of the holding and spawning area for spring-run Chinook salmon is below 285 m (931 ft) elevation, by contrast to Deer and Mill creeks where spring-run Chinook salmon hold and spawn in areas above that elevation (CDFW 2008). Due to the lower elevation habitat, Butte Creek exhibits water temperatures above the ideal temperatures for holding and spawning Chinook salmon (Ward *et al*. 2003, as cited in CDFW 2008). According to CDFW (2008), minimum instream flow levels need to be established in Butte Creek in order to assure the continued viability of fisheries resources. The extensive temperature modeling above the DeSabla Centerville dam has helped managers mitigate for this lack of cold water downstream. The cold water can be released when need because the managers now know where that colder water is in the thermocline.

Salmonids currently have access to approximately 53 miles of Butte Creek (DWR 2005). The upstream limit of migration is considered to be Quartz Bowl Falls, a 15 foot tall waterfall located at an elevation of approximately 900 feet. Fish passage through Butte Creek is affected by about 22 major structures and an estimated 60 to 80 minor structures (DWR 2005). Salmon have been observed upstream from Quartz Bowl Falls and below the Centerville Head Dam on three occasions in the past 25 years, when spring flows were in excess of 2,000 cfs (e.g., during 1998 and 2003) (DWR 2005).

Extensive habitat evaluations have been conducted throughout Butte Creek have identified and quantified habitat upstream from the Quartz Bowl that is be suitable for CV spring-run Chinook salmon production (Holtgrieve and Holtgrieve 1995). For many years, this habitat was thought to be blocked by Centerville Diversion Dam, but recent evaluations by DFG have concluded that natural, historic passage to these areas was not likely due to the presence numerous waterfalls and high gradient reaches that start approximately one mile upstream from Centerville Diversion Dam (CDFW 1998, NMFS 2006).

Since the early 1990s, restoration actions in Butte Creek have focused on improving instream flow during the critical spring immigration period, thereby increasing the likelihood that fish will succeed in reaching the upstream holding and spawning areas, even in dry years. Currently, the minimum flow deemed necessary to allow for spring-run Chinook salmon upstream passage is estimated at 80 cfs (CALFED 2006).

PG&E's minimum instream flow requirement at the Lower Centerville Diversion Dam is 40 cfs from June 1 to September 14. Average monthly flows from June through September (1998-2002) were between 46 cfs and 49 cfs. During the onset of the spring-run Chinook salmon spawning period in mid-September of 2004, PG&E, in consultation with CDFW and NMFS, increased flows to 60 cfs (PG&E 2005). Flows in Butte Creek begin to increase during the steelhead spawning period from November through April. Because there are no large storage facilities on Butte Creek, flow regimes during the winter months when agriculture diversions are not occurring tend to mimic the historic hydrology of the watershed.

Based on an analysis of the percentage of available spring-run Chinook salmon spawning habitat, CDFW (2008) recently recommended new minimum instream flows for Butte Creek from Centerville Head Dam downstream to Parrot-Phelan Diversion Dam, related to the FERC relicensing of the DeSabla-Centerville hydropower project. CDFW's analysis of spring-run Chinook salmon spawning habitat was conducted using a 2-dimensional hydraulic and habitat model (USFWS 2003, as cited in CDFW 2008), an analysis of historical regulated flow data, including inter-basin water transfer from the West Branch of the Feather River to Butte Creek data (CDFW 2008b, as cited in CDFW 2008), and water quality (e.g., temperature) benefits (CDFW 2008b, as cited in CDFW 2008). Spawning habitat was identified as a limiting-factor for spring-run Chinook salmon in Butte Creek based on a considerable amount of redd superimposition observed during data collection efforts by the USFWS (USFWS 2003; USDOI 2008, as cited in CDFW 2008). CDFW (2008) suggest that their minimum instream flow recommendations for Butte Creek would allow for greater dispersal of spring-run Chinook salmon redds and reductions in redd superimposition. CDFW's (2008) recommended minimum flows in Butte Creek for each month of the year for normal and dry water year types are presented below (Table 8).

Table 8. CDFW's recommended minimum instream flows (cfs)

Month	Normal	Dry
Oct	100	75
Nov	100	75
Dec	100	75
Jan	100	75
Feb	100	75
Mar 1-14	100	75
Mar 15-31	80	75
Apr	80	75
May	80	65
Jun	40	40
Jul	40	40
Aug	40	40
Sep	100	75

In addition to efforts to implement new minimum instream flow requirements, significant restoration efforts have been conducted in Butte Creek to remove passage barriers, rehabilitate fish passage structures, screen unscreened diversions, and improve riparian habitat conditions.

The State Water Resources Control Board is in the process of identifying new regulatory minimum instream flow requirements for Butte Creek.

Spring-run Chinook Salmon

From 2005 through 2008, Butte Creek spring-run Chinook salmon escapement was 10,625, 4,579, 4,943 and 3,935, respectively (CDFW 2009). Between 1960 and 2008, the highest annual spring-run Chinook salmon escapement was 20,259, occurring in 1998 (Table 9).

Table 9. Adult Spring-run Chinook salmon population estimates for Butte Creek from 1960 to 2012

Year	Adult Estimate	Year	Adult Estimate	Year	Adult Estimate
1960	8700	**1978**	128	**1996**	1413
1961	3082	**1979**	10	**1997**	635
1962	1750	**1980**	226	**1998**	20259
1963	6100	**1981**	250	**1999**	3679
1964	600	**1982**	534	**2000**	4118
1965	1000	**1983**	50	**2001**	9605
1966	80	**1984**	23	**2002**	8785
1967	180	**1985**	254	**2003**	4398
1968	280	**1986**	1371	**2004**	7390
1969	830	**1987**	14	**2005**	10625
1970	285	**1988**	1290	**2006**	4579
1971	470	**1989**	1300	**2007**	4943
1972	150	**1990**	250	**2008**	3935
1973	300	**1991**		**2009**	2059
1974	150	**1992**	730	**2010**	1160
1975	650	**1993**	650	**2011**	2130
1976	46	**1994**	474	**2012**	8665
1977	100	**1995**	7500		

Sources: CDFW Grandtab; personal communications with DFG and FWS biologists.

Water temperatures between the Parrot-Phelan Diversion Dam and the Centerville Head Dam in Butte Creek frequently exceed the reported optimum temperatures for spring-run Chinook spawning. Water temperatures frequently exceed 59ºF from July through September. During 2002 and 2003 elevated water temperatures, in conjunction with a large number of adult spring-run Chinook salmon returns, resulted in an outbreak of Columnaris (*Flavobacterium columnare*). 1,699 pre-spawning mortalities were observed from June 26, 2002 to September 19, 2002 from the Parrot-Phelan Diversion to the Centerville Head Dam. During 2003, an estimated 17,294 adult spring-run Chinook salmon migrated to Butte Creek, of which an estimated 11,231 died prior to spawning (Ward *et al.* 2003).

Juvenile Chinook salmon rear in the Butte Creek Canyon downstream of Centerville Head Dam for up to one year. Although summer flows of 40 cfs generally keep water temperature below 68°F throughout most of the reach (Kimmerer and Carpenter, 1989), water temperature often exceeds 76°F in the canyon between Butte Creek Head Dam and Centerville Head Dam in July and August. Moreover, water temperatures could be of concern during the late spring, particularly in the lower reaches of Butte Creek.

Studies in Butte Creek (Ward *et al*. 2003) found the majority of spring-run migrants to be fry moving downstream primarily during December, January, and February, and that these movements appeared to be influenced by flow. Small numbers of spring-run juveniles remain in Butte Creek above the Parrot-Phelan Diversion Dam prior to emigrating in the spring (Ward *et al.* 2004).

Steelhead

As reported by the Butte Creek Watershed Conservancy (1999), steelhead have been reported in Butte Creek principally through reports by CDFW wardens of angler catches. However, no estimate of steelhead abundance in Butte Creek is known to be available (Butte Creek Watershed Conservancy 1999; FERC 2008).

Adult steelhead ascend Butte Creek during the late fall and winter. Steelhead spawning occurs in tributaries such as Dry Creek and in the mainstem of Butte Creek above Parrott-Phelan diversion during winter and spring (generally December through April). As reported by the Butte Creek Watershed Conservancy (1999), the spawning area for steelhead in Butte Creek extends from the Centerville Head Dam downstream to the vicinity of the Western Canal Siphon crossing. Steelhead generally spawn upstream of the Parrott-Phelan diversion. Spawning gravel in the reach of the creek from the Centerville Head Dam downstream to the vicinity of Helltown is extremely limited, with the major gravel beds existing below the Centerville Powerhouse (Butte Creek Watershed Conservancy 1999). The Sutter Bypass is reportedly used by juvenile steelhead as rearing habitat (Butte Creek Watershed Conservancy 1999).

Big Chico Creek Watershed Profile

Listed Species Present in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Listed Species that Historically Occurred in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Diversity Group

Northern Sierra Nevada

Key Stressors

Key stressors to spring-run Chinook salmon and steelhead in Big Chico Creek include, but are not limited to the following:

- ❖ Physical passage impediments and flow-based barriers at Iron Canyon, City of Chico Swimming Holes and associated dams affecting adult immigration and holding
- ❖ Water temperatures affecting adult immigration and holding, spawning and embryo incubation
- ❖ Habitat suitability and spawning habitat availability affecting adult spawning
- ❖ Loss of floodplain habitat and natural river morphology affecting juvenile rearing and outmigration
- ❖ Passage impediments related to the reverse flows caused by M&T pumps affecting juvenile outmigration

Watershed Description

Big Chico Creek Watershed (Figure 10) is located within Butte and Tehama Counties, encompassing an area of approximately 72 square miles (USFWS 1995). The headwaters of Big Chico Creek originate from the southwest slope of Colby Mountain at an elevation of approximately 5,400 feet. Big Chico Creek is approximately 45 miles in length and enters the Sacramento River west of the City of Chico (USFWS 1995). The watershed also encompasses three smaller drainages to the north including Sycamore, Mud, and Rock creeks (USFWS 1995; USFWS 2007).

A small dependent population of spring-run Chinook salmon continues to occur in Big Chico Creek, but relies on extant independent populations for its continued survival. The run size is under 500 returning adults annually and is considered a remnant population. Steelhead do occur in Big Chico Creek along with resident trout. The numbers of steelhead have not been estimated, however, they are believed to use the foothill zone to spawn except in low water years they spawn in the lower river.

Big Chico Creek is a small watershed with substantial urban impacts in the lower watershed. Big Chico Creek contains marginally suitable habitat for salmon that most likely was opportunistically used in the past by salmon and steelhead (Yoshiyama *et al*. 1996). The middle and upper watershed areas however, are not urbanized and much effort by local groups and land owners has been made to secure conservation easements along this portion of the river corridor. These easements protect the riparian zone from the impacts of development long term. To keep this small population of spring-run and steelhead persistent in this watershed, there are several restoration actions that could help the watershed: 1) improve fish passage through Iron Canyon 2) improve habitat function in the lower habitat through riparian and off channel improvements.

One of the limiting factors for the dependent population of spring-run Chinook salmon is fish passage through Iron Canyon which lies approximately 7 miles from the town of Chico. This ladder provides access for spring-run salmon into the upper watershed where cooler water is found in the late summer. The ladder connects Big Chico Creek through a section of the valley that was impacted by a previous earthquake. There are plans to improve this fish ladder, which would be an important restoration activity for this watershed to assist the current population to remain viable.

Geology

The Great Valley geomorphic province lies to the west and the Sierra Nevada geomorphic province lies to the east and south. Rocks from the Cascade Range and Great Valley provinces are exposed along Big Chico Creek, and include Upper Cretaceous marine sedimentary rocks of the Chico Formation, Miocene volcanic rocks of the Lovejoy Basalt, and Pliocene volcanic and sedimentary rocks of the Tuscan Formation (USFWS 2006). In response to tectonic uplift and tilting, Big Chico Creek eroded through the Tuscan Formation and exposed the older Lovejoy Basalt. Continued downcutting through the very hard and resistant basalt resulted in the formation of a steep-sided, narrow canyon, primarily oriented along two primary joint sets within the basalt (USFWS 2006). Where the creek has cut entirely through the basalt into the softer Chico Formation, the steep canyon walls have been prone to instability due to undercutting and the loss of support (Guyton and DeCourten 1978 in USFWS 2006). Upstream of Higgin's Hole (RM 23), the Big Chico Creek stream channel has cut through metamorphic rock, creating a narrow canyon with big boulders, bedrock potholes, and spectacular waterfalls (USFWS 1995).

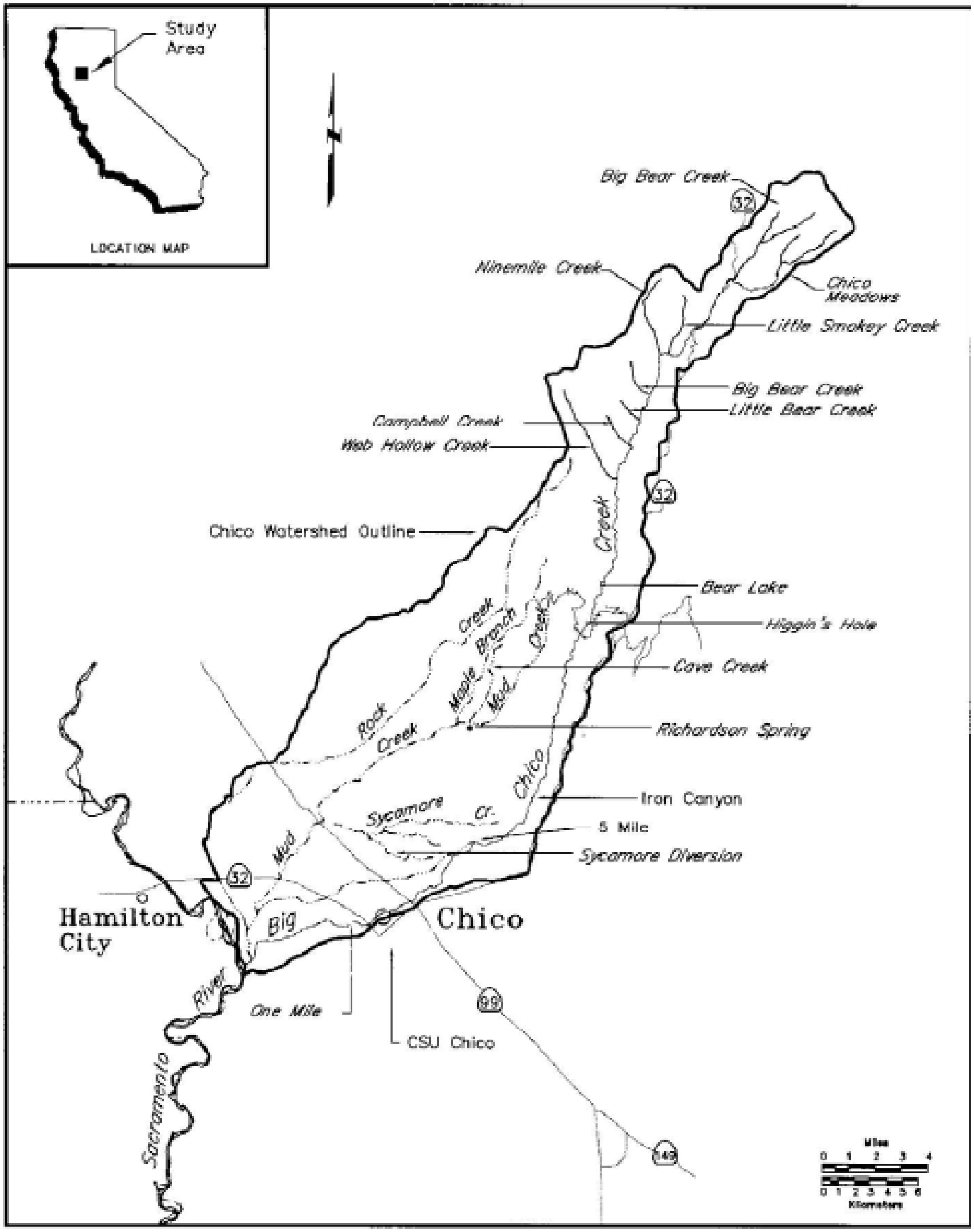

Figure 10. The Big Chico Creek Watershed Source: CDFW 2001**.**

Hydrology

The main channel of Big Chico Creek begins in Chico Meadows, fed by a number of springs that originate from Colby Mountain, and flows 45 miles to its confluence with the Sacramento River

(CDFW 2001). Big Chico Creek can be divided into three zones: (1) the upper zone extends from the headwaters and Higgin's Hole; (2) the middle zone extends from Higgin's Hole to Iron Canyon; and (3) the lower zone extends from Iron Canyon to the Sacramento River (Maslin 1997). The unimpaired average annual yield is approximately 54,000 acre-feet (USFWS 1995). Above Five-Mile Diversion, base flows in Big Chico Creek during the summer (i.e., June-October) typically range from 20 to 25 cfs. However, most of this base flow is lost to infiltration in the region of the creek's outwash fan (i.e., roughly the city of Chico), therefore, by late summer of most years surface flow does not extend downstream of Rose Avenue (USFWS 1995).

Mud Creek and Rock Creek join Big Chico Creek about 0.75 miles before it enters the Sacramento River. These two tributaries differ from Big Chico Creek, in that: (1) these two creeks receive precipitation primarily as rain, rather than snow; and (2) their channel structure is shorter and dendritic, draining from the surface of the tilted Tuscan formation at relatively lower elevations than most of the Big Chico Creek drainage. Accordingly, they are seasonal (flowing from about November to June in the Central Valley portion of their channels) and warm up more rapidly during the spring (USFWS 1995).

Flowing 26 miles before entering Big Chico Creek, Mud Creek is a spring-fed stream that is one of the primary tributaries in the Big Chico Creek Watershed. Richardson Springs (Figure 10) serves as a barrier to upstream fish migration in Mud Creek (BCCECR in CDFW 2001). An outflow weir at Lindo Channel diverts excess flows through a diversion channel to Sycamore Creek, where it then flows into Mud Creek (Maslin, Analysis of the Sycamore in CDFW 2001).

Land Use

Most of Big Chico Creek is bordered by private land with smaller holdings by the United States Forest Service and the Bureau of Land Management (USFWS 1995). Big Chico Creek flows through Bidwell Park (the third largest municipal park in the United States), downtown Chico, and the California State University campus (USFWS 1995). The headwaters of Mud and Rock creeks are in privately held forest land; foothill reaches are mostly pastured brush land or woodland; and Central Valley reaches traverse agricultural land. Both Mud and Rock creeks have minor agricultural diversions (USFWS 1995). In addition, Mud Creek is impounded for domestic water supply at Richardson Springs. The Sycamore Diversion passes floodwater from Big Chico Creek to Mud Creek (USFWS 1995).

Fisheries and Aquatic Habitat

The lowermost 24 miles of Big Chico Creek are identified as providing both historic and current aquatic habitat for anadromous salmonids (USFWS 2008). It has been reported that Big Chico Creek is important for providing aquatic habitat for adult spring-run Chinook salmon holding and spawning, while Mud, Rock and Sycamore creeks have been shown to be important non-natal rearing areas for salmonids (Big Chico Creek Watershed Alliance 1997).

Unless otherwise specified, the following information on fisheries and aquatic habitat in Big Chico Creek comes directly from the Big Chico Creek Watershed Existing Conditions Report (Big Chico Creek Watershed Alliance 2000).

In the lower reach of Big Chico Creek (known as Iron Canyon) that is located approximately 13 miles upstream of the confluence with the Sacramento River (DWR 2002), the valley narrows abruptly and the stream gradient increases. At its upper end, the basalt near the area from Bear Hole to Brown's Hole in Bidwell Park is undercut and large boulders have tumbled into the creek bed, possibly by a rock slide that occurred as a result of the 1906 San Francisco earthquake (DFG 1958 in USFWS 2006). During periods of normal creek flow, this debris field of boulders acted as an impassable barrier to upstream movement of fish and represented the most downstream barrier to fish passage. In 1958, CDFW constructed a fish ladder to provide pools of water for the fish to traverse the blocked area and reach the cooler pools to hold over the summer for fall spawning (DFG 1958 in USFWS 2006; Big Chico Creek Watershed Alliance 2008). The ladder was comprised of seventeen weirs, which reportedly were constructed to bypass a 14-foot-high waterfall created by the debris field (USFWS 2006). Since the original construction, the limited fish passage that does occur beyond the Iron Canyon Fish Ladder is believed to occur during higher flows (USFWS 2006). Over time, the fish ladder has fallen into disrepair. The Big Chico Creek Watershed Alliance (2008) has been working together with the resource agencies to fund construction of a rehabilitated fish ladder. In 2007, the final designs and specifications for rehabilitation of the structure were completed. If funding is secured, it is anticipated that the project would be constructed in the summer/ fall of 2010 (Big Chico Creek Watershed Alliance 2008).

Upstream of Iron Canyon and approximately four miles downstream of Web Hollow Creek (Figure 10), the canyon narrows and consists of large boulders, bedrock potholes, and waterfalls. Near Higgin’s Hole (RM 23), there is a considerable waterfall that is believed to be the uppermost barrier to anadromous fish passage (CDFW 2001). In very unusual years when migration corresponds exactly with high flow, salmon or steelhead may pass through this canyon to the waterfall at Bear Lake, but there is only one record of salmon being sighted at Bear Lake (Big Chico Creek Watershed Alliance 2000).

In Mud Creek, the main fish passage barrier is the 69-foot waterfall at Richardson Springs, which stops all upstream movement of fish, at the upstream extent of the valley zone. The Mud Creek foothill zone is extremely short, only extending from the top of the waterfall 1.1-mile to another series of falls. In Rock Creek, the upstream end of the valley zone for many years has been the diversion dam about 0.3 miles upstream of the Anderson Fork confluence.

Additional fish passage barriers in the Big Chico Creek watershed (depending on flow conditions) include the Lindo Channel Weir, a diversion dam at stream mile 18 in Rock Creek, a diversion dam between Ponderosa Way and Higgin’s Hole, and various undersized culverts. Higgin's Hole is the upstream limit for spring-run Chinook salmon and steelhead, approximately 0.5 to 1 mile above the crossing of Ponderosa Way (Yoshiyama *et al.* 1996). The size of the waterfalls and the scenic nature of the upstream canyon preclude construction of fishways (USFWS 1995).

Historically the foothill zone of Big Chico Creek was dominated by migratory fish including spring-run Chinook salmon and steelhead. However, there are no accurate records of historical fish populations in the watershed. Anecdotal accounts suggest existence of former populations of steelhead and spring-run Chinook salmon in both Mud and Rock creeks. However, it is unlikely that either creek could sustain its own salmon or steelhead population indefinitely; historical populations were likely lost in each series of drought years and then re-established by strays from Big Chico Creek. Although no formal counts have ever been conducted, it is likely that only a few adult salmonids stray into Mud and Rock Creeks under present conditions.

During the winter and early spring, juvenile Chinook salmon of all races move from the Sacramento River where they were spawned into tributaries for rearing (Maslin *et al.* 1997). Some move upstream substantial distances (e.g., to Hicks Lane in Mud Creek; to Highway 99 in Rock Creek), although they are more numerous closer to the Sacramento River confluence. Maslin *et al.* (1998) estimated that approximately 50,000 juvenile Chinook salmon from the Sacramento River reared in Mud and Rock creeks, including an estimated 10,000 winter-run Chinook salmon. Juvenile Chinook salmon rearing in the tributaries reportedly grow faster and are in better condition than those remaining in the Sacramento River, and smolt and emigrate earlier than they would in the mainstem Sacramento River (Maslin *et al.* 1997; 1998). However, some tributary-rearing juveniles get trapped by receding water, particularly in low water years (Maslin *et al*. 1998).

Spring-Run Chinook Salmon

A dependent population of spring-run Chinook salmon continues to occur in Big Chico Creek, relying on strays from extant independent populations for its continued survival. CDFW (2007) also reports that the creek currently exhibits only a remnant non-sustaining population of spring-run Chinook salmon and, thus, Big Chico Creek is not currently used as a population trend indicator.

As reported by the Big Chico Creek Watershed Alliance (2000), Big Chico Creek spring-run Chinook salmon spend the summer in deep pools from Iron Canyon to Higgin's Hole and spawn in adjacent riffles when temperatures drop during early Fall. Relatively high water temperatures limit the ability of holding spring-run Chinook salmon to tolerate additional stressors such as harassment by swimmers, particularly during drought years when water temperatures tend to be higher and salmon are over-summering in pools downstream of the Iron Canyon ladder. Due to elevated water temperatures in the area where adults are forced to spawn, their offspring develop rapidly; nearly all juveniles emigrate by the following spring (unlike Deer and Mill Creeks where many juveniles emigrate during the wet season more than a year after being spawned) (Big Chico Creek Watershed Alliance 2000).

The average annual run-size of Big Chico Creek spring-run Chinook salmon is believed to have been less than 500 fish during the 1950s and 1960s, but is now considered to be only a remnant population (CDFW 1993 as cited Yoshiyama *et al*. 1996). GrandTab data for Big Chico Creek spring-run Chinook salmon is available for some of the years between 1960 and 2008[6]. Between 1962 and 1969, escapement was 200, 500, 100, 50, 50, 150, 175, and 200, respectively (CDFW 2009). Between 1993 and 2008, escapement was 38, 2, 200, 2, 2, 369, 27, 27, 39, 0, 81, 0, 37, 299, 0, 0, respectively (CDFW 2009). For years not mentioned, escapement data either was not available or was intermittently available. During 2006, the most recent year that spawning fish were observed, about 83 percent (248) of estimated adults that returned to spawn in Big Chico Creek were found above the Iron Canyon Fish Ladder (USFWS 2007). In this diversity group, spring-run Chinook salmon populations seem to persist in Antelope and Big Chico creeks, albeit at an annual population size in the tens or hundreds of fish, with no returning spawners in some years (NMFS 2009a). Spring-run Chinook salmon escapement estimates for Big Chico Creek are available from 1962 through 2011 (Table 10).

Table 10. Adult spring-run Chinook salmon population estimates for Big Chico Creek from 1962 to 2011. Estimates are not available for all years.

Year	Adult Estimate	Year	Adult Estimate	Year	Adult Estimate
1962	200	**1979**		**1996**	2
1963	500	**1980**		**1997**	2
1964	100	**1981**		**1998**	369
1965	50	**1982**		**1999**	27
1966	50	**1983**		**2000**	27
1967	150	**1984**	0	**2001**	39
1968	175	**1985**	0	**2002**	0
1969	200	**1986**		**2003**	81
1970		**1987**		**2004**	0
1971	0	**1988**		**2005**	37
1972		**1989**		**2006**	299
1973	50	**1990**		**2007**	0
1974	100	**1991**		**2008**	0
1975		**1992**		**2009**	6
1976		**1993**	38	**2010**	2
1977	100	**1994**	2	**2011**	124
1978		**1995**	200		

Sources: CDFW Grandtab; personal communications with DFG and FWS biologists.

[6] *Data availability for Big Chico Creek during this period has been dependent on funding availability and other considerations (T. Parker, USFWS, pers. comm. 2009).*

Steelhead

Existing wild steelhead stocks in the Central Valley are mostly confined to the upper Sacramento River and its tributaries (e.g., Antelope, Deer, and Mill creeks and the Yuba River) (NMFS 2009a). However, populations also may exist in Big Chico and Butte creeks (McEwan and Jackson 1996).

As reported by the Big Chico Creek Watershed Alliance (2000), adult steelhead usually spawn in the foothill zone of the Big Chico Creek Watershed, but during low-flow years they may spawn in the valley zone. Historically, steelhead were probably predominant when the habitat was more suitable for anadromous salmonids. The decline of steelhead has permitted their replacement by resident rainbow trout. Studies have not been conducted to determine whether the rainbow trout are migratory (i.e., steelhead) or resident fish. Additionally, there have been no reported occurrences or estimates of steelhead spawning in Big Chico Creek (Big Chico Creek Watershed Alliance 2000).

Deer Creek Watershed Profile

Listed Species Present in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Listed Species that Historically Occurred in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Diversity Group

Northern Sierra Nevada

Key Stressors

Key stressors to spring-run Chinook salmon and steelhead in Deer Creek include, but are not limited to the following:

- Agricultural diversion dams impeding or blocking passage of immigrating adults
- Elevated water temperatures affecting adult immigration and holding
- Low flows affecting juvenile outmigration, and attraction and migratory cues of immigrating adults
- Possible catastrophic event (e.g., fire or volcanic activity)
- Loss of genetic and life history diversity from steelhead hybridization with out-of-basin rainbow trout that are planted into reaches of Deer Creek upstream from the Upper Deer Creek Falls.

Watershed Description

As reported by DWR (2009), Deer Creek is an eastside tributary to the Sacramento River that flows in a southwesterly direction for approximately 60 miles and drains 134 square miles. Deer Creek originates near the summit of Butt Mountain at an elevation of approximately 7,320 feet. It initially flows through meadows and dense forests and then descends rapidly through a steep rock canyon into the Sacramento Valley. Upon emerging from the canyon, the creek flows 11 miles across the Sacramento Valley floor, entering the Sacramento River at approximately 1 mile west of the town of Vina at an elevation of approximately 180 feet (DWR 2009).

Deer Creek, along with Mill Creek and Butte Creek, is recognized as supporting one of three remaining self-sustaining CV spring-run Chinook populations. Habitat used for holding and spawning is located at high elevations and habitat is considered to be high quality (CDFW 1998). The high elevation habitats in Deer Creek are isolated from fall-run Chinook salmon by low summer and fall flows and high water temperatures that prevent geographic co-occurrence and maintains genetic and phenotypic diversity of the population. The NMFS TRT did not conclude as to whether Mill and Deer creeks are independent of one another, although they did conclude that spring-run Chinook salmon in these streams are currently independent from other spring-run Chinook salmon populations and represent a significant lineage within Central Valley Chinook ESU.

When considering watersheds in the Central Valley that contribute current viable populations for Spring-run chinook, Deer Creek is considered a conservation stronghold for the ESU. Lindley *et al.* (2007) classified the Deer Creek spring-run Chinook salmon population as having a low risk of extinction. Over the past three years poor ocean conditions combined with drought, and other stressors have affected the abundance of the Deer Creek population and the extinction risk may be trending toward moderate to high. With the implementation of key recovery actions, the watershed has a high potential for sustaining a population at a low risk of extinction (Lindley *et al*. 2007)) for the following reasons: (1) Deer Creek contains a sufficient amount holding and spawning habitat to support a population with an effective size greater than 500 adults or a census population near 2,500 (see Table 4-1 of the Recovery Plan), based on our review of historic and recent abundance; (2) hatchery influence is low and expected to decrease over time, (3) the number and magnitude of recovery actions needed within the Deer Creek watershed are limited and localized.

Deer Creek also supports all life history stages of steelhead, although not is much is known about the long term viability of steelhead in the ESU. The carrying capacity of steelhead in Deer Creek is not known, the watershed historically supported strong populations that likely persisted at low levels of extinction prior to water development on the valley floor. Deer Creek has a high potential to support a viable, self-sustaining steelhead population because of the extensive (25 miles) or suitable spawning and rearing habitat, the existing occurrence of *O. mykiss* throughout Deer Creek at high densities (up to several thousand rearing fish per mile (Mike Berry, CDFW, pers. com., 2005)), and the limited number and localized nature of watershed-specific recovery actions.

The anadromous fish habitats in Deer Creek (along with Mill, Antelope, Battle and Butte Creeks) are probably the best remaining habitat above the Central valley for anadromous salmonids, and serve as important anchors for their recovery. It is also worth noting that aquatic resources in the Deer Creek watershed have regional significance for a number of reasons. There are diversion structures in the valley section of Deer Creek, however, as opposed to 90% of the rivers draining into the Sacramento Basin, there are no major water impoundments along the Deer Creek corridor. Unlike many other rivers in the Central Valley which find relief in the Sacramento River because their channels have been blocked by dams and diversions, anadromous fish have been able to maintain passage, and native fish communities have survived in the free flowing sections. Deer Creek is also considered essential to the recovery and perpetuation of the wild stocks of winter-run steelhead in the Central Valley (Reynolds et. al. 1993; McEwan and Jackson 1996) in part because of its current habitat conditions.

In Deer Creek the primary focus for spring-run Chinook salmon restoration is on improving flow conditions for upstream migrating adults so they can access important holding and spawning habitat (Mills and Ward 1996) and for outmigration fry. To this end, water exchange programs are underway or in development with cooperating irrigation districts. The programs are intended to develop and operate wells to offset bypass flows needed for spring-run Chinook salmon and to implement water use efficiency measures to reduce irrigation water demand.

How will Deer Creek help to buffer the negative effects of climate change for salmonids in the Central Valley?

Under the expected climate warming of around 5°C, substantial salmonid habitat would be lost in the Central Valley, with significant amounts of habitat remaining primarily in the Feather and Yuba rivers, and remnants of habitat in the upper Sacramento, McCloud, and Pit rivers, Battle and Mill creeks, and the Stanislaus River (Lindley *et al*. 2007). Under the less likely but still possible scenario of an 8°C warming, spring-run Chinook salmon habitat would be found only in the upper-most reaches of the north fork Feather River, Battle Creek, and Mill Creek (Lindley *et al*. 2007).

In addition, while warming may pose as a key threat to spring-run Chinook salmon in Deer Creek, suitable water temperature conditions should persist longer in Deer Creek (and Mill Creek), where fish can reach higher altitudes (Williams 2006). Some existing or potential habitat should also remain for some time below various dams that currently release cool water through the summer (Williams 2006).

Geology

Deer Creek is located within the southernmost extension of the Cascade Range. As reported in Armentrout *et al*. (1998), the Tuscan formation of the Pliocene age, comprised primarily of mudflows, dominates the geology. This formation dips gently and thins toward the southwestern portions of the watersheds. Geologic diversity is supplied by several influences. These include andesitic plugs that intrude the Tuscan formation along two linear trends, relatively minor exposures of marine sedimentary rocks, and at lower elevations, quaternary sediments of the Sacramento Valley. Glacial processes shaped some of the higher elevation landforms.

Soils generated from these parent materials are generally productive; erosion rates range from low to moderate on the andesitic soils to high to very high on the rhyolitic soils. Mass wasting is evident in the Deer Creek watershed, dominated by debris flows in colluvium-filled hillslope hollows. Failures are episodic and triggered by extreme precipitation events. Surface erosion, especially on the rhyolitic soils, is the other major source of sediment (Armentrout *et al*. 1998).

The soils of the Deer Creek watershed are derived from volcanic breccia, including basalt, andesite, dacite and rhyolite. Dominant soils in the Deer Creek watershed are of the Lyonsville and Jiggs association, Cohasset series, McCarthy series and the Windy series. The Lyonsville soils are generally found along ridges, are moderately deep and well-drained. The Jiggs soils are derived from volcanic flow of rhyolite and are somewhat excessively drained. The Lyonsville and Jiggs soils are mapped together because they both have erosive properties due to their rhyolitic component. The Cohasset soils are derived from weathered andesite and breccia. They are generally found on slopes of canyons in mountainous areas, and are moderately deep, moderately coarse textured, and have a granular structure. The Windy soils are well-drained soils derived from basic volcanic rocks, andesite and basaltic rocks from volcanic flows, and in some places are cemented together with tuffaceous material. These soils are found in mountainous areas (Armentrout *et al*. 1998).

Hydrology

As reported in Armentrout *et al*. (1998), precipitation varies from 25 to nearly 80 inches per year, over the range in elevation (approximately 180 to 7320 feet msl) in the Deer Creek watershed. Deer Creek produces on average 228,700 acre ft of water per year. Peak flows from the watershed are dominated by rain-on-snow events.

The majority of annual flow events occur in December, January and February when snow could be expected to be present in the transient snow zone (above about 3,000 feet in elevation). Earlier peaks (September through November) are most likely rain events with little snow influence. Later peaks (mid-March through May) indicate snowmelt generated peaks. The recorded maximum flow on Deer Creek was 23,800 cfs on December 10, 1937 (Armentrout *et al*. 1998).

There are three diversion dams and four diversion ditches on the 10 miles of stream between the canyon mouth of Deer Creek and the Sacramento River. During low flow periods, the existing water rights are sufficient to dewater the stream. Late spring and early summer diversions have resulted in flows low enough to block access for late-migrating adults (Armentrout *et al*. 1998).

Land Use

As reported by Armentrout *et al*. (1998), the Deer Creek watershed is relatively long and narrow, with moderate to steep slopes. Extended low gradient channel types are uncommon on the mainstem, restricted to Deer Creek Meadows and reaches in the Valley floor. Steep slopes adjacent to the main channel historically served as barriers to human activity, and recent land use allocations have protected these areas such that the main stem is essentially undisturbed. However, the presence of Highway 32 along portions of Deer Creek is a notable exception. In addition, timber harvest and grazing have impacted many of Deer Creek's tributary streams. These impacts have resulted in increased sedimentation to the Deer Creek watershed. The Lassen National Forest, through their Land and Resource Management Plan (USFS 1992), is decommissioning roads throughout the forest that are no longer in use. One of the primary reasons for this decommissioning is to reduce sediment load to anadromous watersheds such as Deer and Mill creeks.

Currently, approximately half of the forest lands in the region are in private ownership, providing support to local economies. Historically, range management was a major land use in the watershed. In the upper watershed, the number of animals grazing has declined substantially over the past hundred years, but ranching still provides limited employment. Pressure has increased on ranchers and growers to convert their lands to residential development (Armentrout *et al*. 1998).

Recreational activities in the watershed have steadily increased over the past decades with the increased population in the region. Lassen National Park and Forest Service Campgrounds in the Deer Creek watershed are sites of concentrated use. State Highway 32 provides easy access to stretches of Deer Creek, and is a major site of recreational fishing (Armentrout *et al*. 1998).

Fisheries and Aquatic Habitat

Deer Creek contains approximately 40 miles of anadromous fish habitat, with approximately 25 miles of adult spawning and holding habitat, most of which is on public lands managed by the Lassen National Forest. Unlike most tributary streams of the Sacramento and San Joaquin rivers that now have major water storage facilities that inundate or block miles of historical anadromous spawning habitat, headwater stream habitat in Deer Creek is still available for utilization by anadromous fish (Armentrout *et al*. 1998). Deer Creek provides approximately 42 miles of anadromous habitat extending from the confluence with the Sacramento River upstream to Upper Deer Creek Falls. Like the anadromous reaches of Mill Creek, the habitat is utilized and/or available to fulfill one or more riverine life history requirements for both spring-run Chinook salmon and winter-run steelhead.

Until 1943, when a ladder was built to provide access to habitat upstream of the falls, Lower Falls (at a reported height of 16 feet) was the upstream limit to migration (Cramer and Hammack 1952). Construction of the ladder effectively provided access to an additional five miles of habitat which is now an important area for adult holding and spawning. In the early 1950's, a fish ladder was also built at Upper Falls, although upstream habitat was not considered suitable for spring-run Chinook salmon (Armentrout *et al*. 1998). The ladder currently remains closed for a variety of reasons during the adult spring-run Chinook salmon upstream migration period. In some years, anadromous fish have been observed above Upper Falls, but habitat appears to be utilized only on rare occasions when a few hardy fish are capable of surmounting the falls under suitable conditions (Armentrout *et al*. 1998).

Evaluations of Central Valley anadromous fishery resources (Reynolds et. al. 1993; McEwan and Jackson 1996; Harvey-Arrison 2008) have consistently identified insufficient instream flows, and elevated water temperatures particularly during the adult spring-run Chinook salmon upstream migration and holding period (May-September) as factors limiting anadromous fish production in the Deer Creek watershed. Recognition of these limitations has led to the establishment of the Deer Creek Watershed Conservancy, and development of cooperative programs between local, state and federal agencies, water users, and landowners to implement water exchange and other programs to sustain spring-run Chinook salmon and steelhead in Deer Creek.

Relatively few restoration actions are needed to restore watershed and ecosystem function for the purpose of supporting the freshwater life history stages of CV spring-run Chinook salmon and CV steelhead in Deer Creek. With the exception of impaired stream flows and fish passage conditions on the valley floor below agricultural diversions, habitat in the upper watershed in good condition. Those actions that are required are localized in nature and when fully implemented have a high likelihood of restoring good fish passage conditions. In particular, long-term fish passage improvements should be addressed by installing state-of-the-art passage facilities at the Cone-Kimball, Stanford Vina, and Deer Creek Irrigation District dams, and existing dam structures should be replaced with inflatable bladder dams that can be installed during the irrigation season and lowered during periods of high stream flow and bedload transport. In the upper watershed Federal land management practices are guided by a long-term anadromous fish conservation strategy. Private timberland management plans lack a comprehensive anadromous habitat protection strategy.

Spring-run Chinook Salmon

Estimates of spring-run Chinook salmon abundance in Deer Creek are available since 1963 (CDFW Grandtab 2011) (Table 11). During the years 1992-2008, spring-run Chinook salmon counts in Deer Creek ranged from 140 to 2,759 salmon. From 2005 through 2008, Deer Creek spring-run Chinook salmon escapement was 2,239, 2,432, 644, and 140, respectively (CDFW 2009). Between 1940 and 1964, an average of 2,200 spring-run Chinook salmon was counted annually using fish ladder counts and carcass surveys. These historical surveys were often expansions of partial weir counts and incomplete carcass surveys and are not comparable to current survey efforts (Harvey-Arrison 2008).

Table 11. **Adult spring-run Chinook salmon population estimates for Deer Creek from 1963 to 2012.** Estimates are not available for all years.

Year	Adult Estimate	Year	Adult Estimate	Year	Adult Estimate
1963	2302	**1981**		**1999**	1591
1964	2874	**1982**	1500	**2000**	637
1965		**1983**	500	**2001**	1622
1966		**1984**		**2002**	2185
1967		**1985**	301	**2003**	2759
1968		**1986**	543	**2004**	804
1969		**1987**	200	**2005**	2239
1970	2000	**1988**	371	**2006**	2432
1971	1500	**1989**	84	**2007**	644
1972	400	**1990**	496	**2008**	140
1973	2000	**1991**	479	**2009**	213
1974	3500	**1992**	209	**2010**	262
1975	8500	**1993**	259	**2011**	271
1976		**1994**	485	**2012**	655
1977	340	**1995**	1295		
1978	1200	**1996**	614		
1979		**1997**	466		
1980	1500	**1998**	1879		

Sources: CDFW Grandtab 2011; personal communications with DFG and FWS biologists.

Spring-run Chinook salmon have been documented migrating upstream on Deer Creek from March through early July. Because data is limited, adult immigration timing and immigration peaks are not well known. In 1944 the peak period of adult immigration was during April, and from 1945-1948 the peak period was during May (Cramer and Hammack 1952). According to Cramer and Hammack (1952), the end of adult spring-run Chinook salmon counts made in Deer Creek (from 1940 through 1948) were always brought about by the lack of sufficient water below irrigation diversions for salmon to ascend readily, in addition to the onset of lethal water temperatures (Armentrout *et al*. 1998). From available data compiled for Deer Creek and Mill Creek (Fisher 1994), the peak spring-run migration appears to occur earlier in Deer Creek than in Mill Creek (Armentrout *et al*. 1998).

More recent data regarding the abundance of adult spring-run Chinook salmon is available from snorkel surveys to count holding adults. In late July 2007, a total of 644 adult spring-run Chinook salmon was observed (Harvey-Arrison (2008) (Table 12). Twenty-four miles of stream were surveyed from the Upper Deer Creek Falls downstream to within 2 miles of Dillon Cove (Figure 11). This encompasses the known holding habitat of adult spring-run Chinook salmon in Deer Creek (Harvey-Arrison 2008). Only 1% of the spring-run Chinook salmon population held between Upper Falls and Lower Falls in 2007 (Table 13). Normally, up to 28 % of the population holds in this reach. In 2006, only 3% held upstream of Lower Falls. Attraction flows in the Lower Falls fish ladder has been declining in recent years. The stream channel upstream of the ladder is slowly degrading, reducing the amount of flow being diverted into the ladder. In addition, the supporting wall of the lowermost weir was lost in the 1997 flood, further decreasing the attraction flow for fish. A long-term solution is being explored to improve performance of the ladder by providing more flow through the ladder (Harvey-Arrison 2008).

The Lassen National Forest conducted spring-run Chinook salmon redd surveys in Deer Creek in October 2007. A total of 403 complete redds, 21 practice redds, 18 carcasses and 87 live fish on redds was observed (Harvey-Arrison 2008) (Table 12). As with Mill Creek, this spawner survey is a one-time pass, scheduled after the peak of spawning activity. The redd-to-holding fish ratio in 2007 was 1.6, or one redd for every 1.6 fish counted in the snorkel survey. Ratios of redds to holding spring-run Chinook salmon in Deer Creek for the past 11 years have ranged from 1.1 to 2.5, with an average of 2 fish per redd (Harvey-Arrison 2008).

Table 12. Adult spring-run Chinook salmon holding and redd counts in Deer Creek for 2007

Section	Holding Survey		Spawning Survey	
	# of salmon	% of total	# of redds	% of total
Upper Falls to Potato Patch	7	1	3	1
Potato Patch to Hwy 32	3	<1	0	0
Hwy 32 to Lower Falls	1	<1	0	0
Lower Falls to A-Line	137	22	42	10
A-Line to Wilson Cove	26	4	75	19
Wilson Cove to Polk Springs	66	10	88	22
Polk Springs to Murphy Trail	224	35	63	16
Murphy Trail to Ponderosa Way	53	8	123	30
Ponderosa Way to Trail 2E17	127 [1/]	20	9	2
Trail 2E17 to Dillon Cove			ns	
Totals	**644**	100%	**403**	100%

Source: Harvey-Arrison 2008

As reported by Harvey-Arrison (2008), base flow within spring-run Chinook salmon holding and spawning habitat (measured at the DCV gage) during 2007 ranged from 255 cfs in early May to 74 cfs by the time of spawning. The average base flow during the same time periods for the previous 115 years of record are 395 cfs and 96 cfs, respectively (Harvey-Arrison 2008).

Water temperatures in Deer Creek are recorded at six locations at elevations ranging from 1,500 ft to 3,200 ft. Two recorders failed in 2007, representing thermal conditions at 1,700 ft. elevation and 2,000 ft. elevation. Water temperatures exceeded 2006 values at all locations recorded (Table 13). Water temperatures exceeded optimal values for spring-run Chinook salmon holding at all locations and may have reduced spawning success in 2007. Water temperatures were below tolerance limits for successful spawning after September 2 upstream of A-Line Bridge. At the lowest elevation of spring-run Chinook spawning in Deer Creek, water temperatures were suitable for successful spawning after September 19 (Harvey-Arrison 2008).

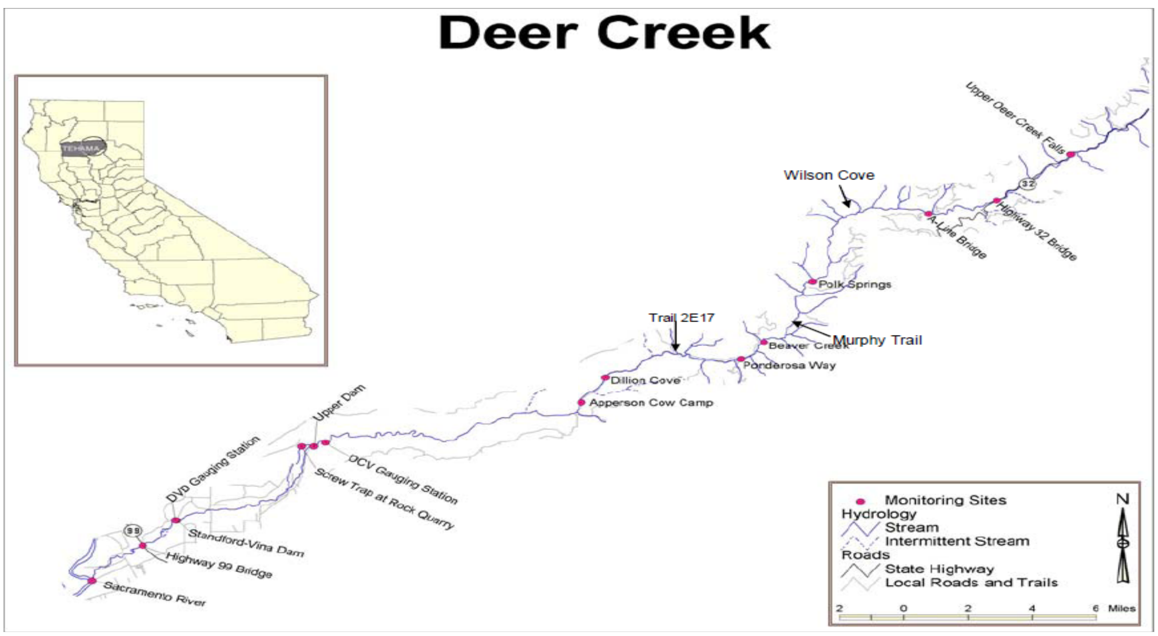

Figure 11. Spring-run Chinook salmon holding and spawning habitat in Deer Creek
Source: Harvey-Arrison 2008

Table 13. Water temperature exceedence and spring-run Chinook salmon distribution in Deer Creek, May through September, 2006 and 2007

Location	Elevation (ft)	% Holding/ % Spawning Salmon 2007	Number of Days Mean Daily Temperature Exceeds:					
			≥59.0°F normal egg viability		≥63.5°F reduced egg viability		≥68.0°F partial mortality	
			2006	2007	2006	2007	2006	2007
At Upper Falls	3600	1 / 1	5	10	0	0	0	0
To A-Line	3000	22 / 10	28	62	0	8	0	0
To Wilson Cove	2700	4 / 19	43	84	3	13	0	0
To Murphy Trail	2000	45 / 38	na	na	na	na	na	na
To Ponderosa Way	1700	8 / 30	90	na	28	na	3	na
To Trail 2E17	1500	20 / 2	99	119	43	86	4	17

Source: Harvey-Arrison 2008

During 2007, bi-monthly Chinook salmon rearing surveys were conducted in Deer Creek. Two locations were sampled (A-line Bridge and Ponderosa Way, Figure 11). Data from the rearing surveys were used to compare relative growth and occurrence of rearing spring-run Chinook salmon juveniles with fall-run and spring-run Chinook salmon juveniles captured downstream at the rotary screw trap (RST) location (Harvey-Arrison 2008a).

Studies in Butte Creek (Ward *et al.* 2003) found the majority of spring-run migrants to be fry moving downstream primarily from December through February associated with flow events, with small numbers of juveniles remaining to rear and migrate as yearlings later in the spring. Juvenile spring-run Chinook salmon emigration patterns in Deer Creek are similar to patterns observed in Butte Creek, with the exception that Deer Creek juveniles typically exhibit a later young-of-the-year migration and an earlier yearling migration (Lindley *et al.* 2004).

The RST, located approximately 9 miles upstream of Deer Creek's confluence with the Sacramento River, was operated from mid-December 2007 through late-March 2008. However, a combination of low flows, shallow water and a damaged live car reduced sampling efficiencies during this period. During this limited sampling period, 23 broodyear (BY) 2006 yearling spring-run Chinook salmon were captured, ranging in size from 66 mm fork length up to 101 mm fork length. A total of 1,197 BY 2007 young-of-year (YOY) Chinook salmon were captured during February and March, ranging in size from 32 mm to 52 mm fork length (Harvey-Arrison 2008a).

According to Lindley *et al.*, (2004) the best available information suggests that Mill and Deer creek spring-run Chinook salmon populations were never very large historically. Hanson *et al.*, (1940) estimated that Mill Creek could support about 3000 and Deer Creek about 7500 spring-run Chinook salmon spawners. Large numbers of spring-run Chinook salmon once migrated past Mill and Deer creeks on their way to upper Sacramento tributaries, and Mill and Deer creeks may have received significant numbers of strays, causing their dynamics to be linked to that of the up-river tributary populations. The NMFS TRT did not conclude as to whether Mill and Deer creeks are independent of one another, although they did conclude that spring-run Chinook salmon in these streams are currently independent from other spring-run Chinook salmon populations and represent a significant lineage within Central Valley Chinook ESU.

Steelhead

Steelhead begin migration into Deer Creek during the late-fall and winter, primarily when flows increase from storms. Ladder counts at Clough Dam, on Mill Creek, between 1953 and 1963, show that adult steelhead migrate upstream from September through June (Van Woert 1964). Harvey (1995) observed two distinct migration peaks in Van Woert=s (1964) data. The largest peak occurred from late-October to mid-November, and accounted for 30 percent of the run. A smaller peak occurred in the first 2 weeks of February, and accounted for 11 percent of the run. Because Deer Creek is in the same geographic region as Mill Creek, and runoff patterns are similar, historic steelhead migration timing was probably likely to be similar. Chinook salmon emigration studies on Deer and Mill Creeks have incidentally captured emigrating steelhead in rotary screw traps. Steelhead generally are captured from November through June, with most fish captured from December through March.

The three diversion dams on the 10 miles of stream between the canyon mouth of Deer Creek and the Sacramento River can provide passage impediments to adult steelhead during low flow periods. All of the diversion structures have CDFW designed and operated fish ladders and screens (Deer Creek Conservancy Website 2007).

The Upper Falls fish ladder is functioning during the time steelhead would be migrating upstream (Deer Creek Conservancy Website 2007). As previously discussed, the ladder is closed during the time when spring-run Chinook salmon would be migrating upstream because very little holding habitat exists above this point.

Steelhead habitat in the upper watershed is considered to be excellent with an abundance of spawning gravel (DWR 2005; USFWS 1999).

Water temperatures throughout the Deer Creek watershed are suitable for juvenile steelhead rearing except for the summer months when temperatures in the lower watershed become too high to support juvenile steelhead rearing. Cold water refugia are likely available during the summer months in the upper watershed.

The explicit time period when juvenile steelhead emigrate from Deer Creek has not been documented. However, it is likely that it occurs from October through May as seasonal flows increase. The extent to which flow fluctuations from water diversions in Deer Creek may cause juvenile stranding is currently unknown.

As described above, during 2007-2008 RST monitoring was conducted sporadically between mid-December and late-March. The Deer Creek RST was in operation a total of 32 days. A total of 18 outmigrating steelhead was captured in the Deer Creek RST between December and March, ranging in size from 58 mmfl to 282 mm (fork length) (Harvey-Arrison 2008a).

With the exception of some limited data on juvenile outmigration (mentioned above), little is known about the winter-run steelhead in Deer Creek and the distribution and abundance of their habitat. Considering steelhead life-history requirements, however, their range within the system is likely to include the range described for spring-run Chinook salmon, and may actually extend beyond this range (i.e., into potentially suitable upstream habitat or tributaries). Because steelhead are, on average, smaller in size than Chinook salmon and can utilize smaller substrate for spawning, potential habitat exists for them beyond the known range of Chinook salmon.

Mill Creek Watershed Profile

Listed Species Present in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Species that Historically Occurred in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Diversity Group

Northern Sierra Nevada

Key Stressors

Key stressors to Central Valley spring-run Chinook salmon and steelhead in Mill Creek include, but are not limited to the following:

- Elevated water temperatures affecting adult immigration and holding
- Low flows affecting attraction and migratory cues of immigrating adults
- Possible catastrophic events (e.g., fire or volcanic activity)

Watershed Description

Mill Creek is an eastside tributary to the Sacramento River that flows in a southwesterly direction for approximately 60 miles and drains 134 square miles (DWR 2009). The creek originates near a thermal spring area in Lassen Volcanic National Park (LVNP) at an elevation of approximately 8,200 feet. It initially flows through meadows and dense forests and then descends rapidly through a steep rock canyon into the Sacramento Valley. Upon emerging from the canyon, the creek flows 8 miles across the Sacramento Valley floor, entering the Sacramento River about 1 mile north of the town of Tehama, near Los Molinos, at an elevation of approximately 200 feet (DWR 2009).

Relatively few restoration actions are needed to restore watershed and ecosystem function for the purpose of supporting the freshwater life history stages of CV spring-run Chinook salmon and CV steelhead in Mill Creek. With the exception of impaired stream flows and fish passage conditions on the valley floor below agricultural diversions, habitat in the upper watershed is in good condition. Those actions that are required are localized in nature and when fully implemented have a high likelihood of restoring or maintaining good fish passage conditions. A water exchange agreement already is in place between the CDFW and water users on Mill Creek. Although the agreement improves fish passage conditions for CV spring-run Chinook salmon, a comprehensive hydraulic fish passage evaluation and monitoring plan has not been developed to assess the effectiveness of the agreement. Long-term verification of the flows, and an evaluation of existing dams for fish passage suitability are needed to ensure passage is provided at a wide range of stream flows and water year types. In the upper watershed Federal land management practices are guided by a long-term anadromous fish conservation strategy. Private timberland management plans lack a comprehensive anadromous habitat protection strategy.

Mill Creek, along with Deer Creek and Butte Creek, is recognized as supporting one of three remaining self-sustaining CV spring-run Chinook populations. Habitat used for holding and spawning is located at high elevations and is considered to be high quality (CDFW 1998). The high elevation habitats in Mill Creek are isolated from fall-run Chinook salmon by low summer and fall flows. High water temperatures prevent geographic co-occurrence and is the thermal gradient that maintains genetic and phenotypic diversity of the populations. The NMFS TRT did not conclude as to whether Mill and Deer creeks are independent of one another, although they did conclude that spring-run Chinook salmon in these streams are currently independent from other spring-run Chinook salmon populations and represent a significant lineage within Central Valley Chinook ESU.

When considering watersheds in the Central Valley that contribute current viable populations for spring-run Chinook salmon, Mill Creek is considered a conservation stronghold for the ESU. Lindley *et al.* (2007) classified the Mill Creek spring-run Chinook salmon population as having a moderate risk of extinction. Over the past three years, the abundance of the Mill Creek population has been in steep decline, and the extinction risk may be trending toward moderate to high. With the implementation of key recovery actions, the watershed has a high potential for sustaining a population at a low risk of extinction (Lindley *et al*. 2007) for the following reasons: (1) Mill Creek contains a sufficient amount of holding and spawning habitat to support a population with an effective size greater than 500 adults or a census population greater than 2,500; (2) hatchery influence is low and expected to decrease over time, (3) the number and magnitude of recovery actions needed within the Mill Creek watershed are limited and localized.

Mill Creek also supports all life history stages of steelhead, although not is much is known about the long term viability of steelhead in the DPS. Mill Creek has a high potential for supporting a viable, self-sustaining steelhead population because of the extensive (25 miles) or suitable spawning and rearing habitat.

The anadromous fish habitats in Mill Creek (along with Deer, Antelope, Battle and Butte Creeks) are probably the best remaining habitat above the Central valley for anadromous salmonids, and serve as important anchors for their recovery. It is also worth noting that aquatic resources in the Mill Creek watershed have regional significance for a number of reasons. There are diversion structures in the valley section of Mill Creek, however, as opposed to 90% of the rivers draining into the Sacramento Basin, there are no major water impoundments along the Mill Creek corridor. Unlike many other rivers in the Central Valley which find relief in the Sacramento River because their channels have been blocked by dams and diversions, anadromous fish have been able to maintain passage, and native fish communities have survived in the free flowing sections. Deer Creek is also considered essential to the recovery and perpetuation of the wild stocks of winter-run steelhead in the Central Valley (Reynolds et. al. 1993; McEwan and Jackson 1996) in part because of its current habitat conditions.

In Mill Creek the primary focus for spring-run Chinook salmon restoration is on maintaining flow conditions for upstream migrating adults so they can access important holding and spawning habitat (Mills and Ward 1996) and for outmigration fry. To this end, water exchange programs are underway or in development with cooperating irrigation districts. The programs are intended to develop and operate wells to offset bypass flows needed for spring-run Chinook salmon and to implement water use efficiency measures to reduce irrigation water demand.

How will Mill Creek help to buffer the negative effects of climate change for salmonids in the Central Valley?

Under the expected climate warming of around 5°C, substantial salmonid habitat would be lost in the Central Valley, with significant amounts of habitat remaining primarily in the Feather and Yuba rivers, and remnants of habitat in the upper Sacramento, McCloud, and Pit rivers, Battle and Mill creeks, and the Stanislaus River (Lindley *et al*. 2007). Under the less likely but still possible scenario of an 8°C warming, spring-run Chinook salmon habitat would be found only in the upper-most reaches of the north fork Feather River, Battle Creek, and Mill Creek (Lindley *et al*. 2007).

Geology

Mill Creek is located within the southernmost extension of the Cascade Range. As reported by Armentrout *et al*. (1998), the Tuscan formation of the Pliocene age, comprised primarily of mudflows, dominates the geology. This formation dips gently and thins toward the southwestern portions of the watersheds. Overlaying the Tuscan formation are flows of rhyolite, which form the Mill and Lost Creek Plateaus. Geologic diversity is supplied by several influences. These include andesitic plugs that intrude the Tuscan formation along two linear trends, relatively minor exposures of marine sedimentary rocks, and at lower elevations, quaternary sediments of the Sacramento Valley. Glacial processes shaped some of the higher elevation landforms.

Soils generated from these parent materials are generally productive; erosion rates range from low to moderate on the andesitic soils to high to very high on the rhyolitic soils. Mass wasting is evident in the Mill Creek watershed, dominated by debris flows in colluvium-filled hillslope hollows. Failures are episodic and triggered by extreme precipitation events. Surface erosion, especially on the rhyolitic soils, is the other major source of sediment. Erosion from recent volcanic deposits in and near LVNP within the headwaters of Mill Creek contributes turbidity to Mill Creek nearly year round (Armentrout *et al*. 1998).

The headwaters of Mill Creek are cutting through an ancient andesitic stratocone (layered andesitic lavas and pyroclastic deposits that were erupted at 600-400 ka). The hydrothermal system associated with this ancient volcano has altered the more permeable pyroclastic rocks in the center of it to mostly clay. This has enhanced erosion locally and is a significant contributor to the fine-grained sediment load of Mill Creek.

The soils in the Mill Creek Watershed range in parent material from volcanic breccia, including basalt, andesite, and rhyolite, to metamorphic rock. Dominant soils in the Mill Creek watershed are Toomes soils and Supan soils (Armentrout *et al*. 1998). The Toomes series is a well drained, shallow to very shallow, extremely rocky soil. The erosion hazard is moderate to severe, depending on the slope. Much of the watershed is composed of colluvial land which is characterized by steep slopes and is highly erosive due to loose rock and soil material. Therefore catastrophic events such as large rain events, stand reducing fires, and volcanic activity could lead to mass wasting events that could potentially devastate the fishery. So, management actions to address these threats, such as good fire plans need to be in place to avert this risk to the population.

Hydrology

The range in elevation in the Mill Creek watershed influences precipitation which varies from 25 to nearly 80 inches. Mill Creek produces on average 215,000 acre ft (or 2.56 ft/acre) of water per year. Peak flows from the watershed are dominated by rain-on-snow events.

The majority of annual flow events occur in December, January and February when snow could be expected to be present in the transient snow zone (above about 3,000 feet in elevation). Earlier peaks (e.g., September, October and November) are most likely rain events with little snow influence. Later peaks (mid-March through May) indicate snowmelt generated peaks. The recorded maximum flow on Mill Creek occurred on December 11, 1937. This storm was far above the gauge height (maximum at that time of 14,000 cfs), and was first calculated by USGS at 23,000 cfs, but later revised to 36,400 cfs.

Morgan and Growler Hot Springs are located along Mill and Canyon Creeks just north of Highway 36. The last additional geothermal input into Mill Creek occurs just north of the town of Mill Creek. These springs have a seasonal and diurnal variation but contribute about 10-15 % to the stream flow (Armentrout *et al*. 1998). Arsenic is added to Mill Creek by the Morgan/Growler hydrothermal system but the clay from the altered volcanics act as a stabilizing influence and adsorbs 70% of the arsenic by the time the stream reaches Highway 36 (Armentrout *et al*. 1998).

There are three diversion dams on Mill Creek. Two are operated by LMMWC and one is operated by the Clough and Owens ranches. During low flow periods the existing water rights are sufficient to dewater the stream. Late spring and early summer diversions have resulted in flows low enough to block access for late-migrating adult salmonids. Low flows may also prevent downstream migrating smolts from reaching the Sacramento River (McEwan and Jackson 1996).

Land Use

As reported by Armentrout *et al*. (1998), extended low gradient channel types are uncommon on the Mill Creek mainstem, and are restricted to upper Mill Creek and reaches in the Valley floor. Steep slopes adjacent to the main channel historically served as barriers to human activity, and recent land use allocations have protected these areas such that the mainstem is essentially undisturbed. However, timber harvest and grazing have impacted many of Mill Creek's tributary streams.

Approximately half of the forest lands in the region are in private ownership, providing support to local economies. Historically, range management was a major land use in the watershed. In the upper watershed, the number of animals grazing has declined substantially over the past hundred years, but ranching still provides limited employment. Pressure has increased on ranchers and growers to convert their lands to residential development (Armentrout *et al*. 1998).

The Lassen National Forest, through their Land and Resource Management Plan (USFS 1992), is decommissioning roads throughout the forest that are no longer in use. One of the primary reasons for this decommissioning is to reduce sediment load to anadromous watersheds such as Mill and Deer creeks.

Recreational activities in the watershed have steadily increased over the past decades with the increased population in the region. Lassen National Park and Forest Service Campgrounds in the Mill Creek watershed are sites of concentrated use.

Fisheries and Aquatic Habitat

As reported by Armentrout *et al*. (1998), Mill Creek (in addition to Antelope and Deer Creeks) still support the majority of their original native aquatic species assemblages. The three watersheds have been rated as having high "biotic integrity" (defined as "the ability to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region") (Moyle and Randall 1996 as cited in Armentrout *et al*. 1998).

Unlike most tributary streams of the Sacramento and San Joaquin rivers that now have major water storage facilities that inundate or block miles of historical anadromous spawning habitat, headwater stream habitat in Mill Creek is still available for utilization by anadromous fish. Within the boundary of the Lassen National Forest, an estimated total of 43 miles of anadromous fish habitat is present in Mill Creek. From its origin in Lassen Valley National Park (LVNP) to its confluence with the Sacramento River, Mill Creek is approximately 58 miles long. Nearly all of the mainstem aquatic habitat is utilized and/or available to spring-run Chinook salmon and winter-run steelhead for one or more life history requirements (Armentrout *et al*. 1998).

Evaluations of Central Valley anadromous fishery resources (Reynolds et. al. 1993; McEwan and Jackson 1996; Harvey-Arrison 2008) have consistently identified insufficient instream flows as one factor limiting anadromous fish production in the Mill Creek watershed. This has led to progressive cooperative programs between agencies and water users including the irrigation district, landowners, the local Conservancy, DWR and CDFW in the Mill Creek watershed to develop and operate wells, or to obtain water rights (lease or purchase) to offset bypass flows needed for spring-run Chinook salmon and steelhead.

Elevated water temperatures during the adult spring-run Chinook salmon upstream migration and holding period (May-September) also have been identified as a limiting factor, particularly at elevations ≤ 2,100 feet msl.

Spring-run Chinook Salmon

The spring-run salmon population currently represents a good example of a viable population of fish in the Central Valley. The factors that contribute to this persistent viable spring-run population are cold water inputs from the upper watershed, relatively intact riparian habitat, and unimpeded corridor. Although the watershed lies in the Lassen National Forest, where cutting has occurred, many of the road systems have been decommissioned, so sedimentation rates, with the exception of high flood events or areas that have been burned, should be considered to be at the historic baseline. Therefore, the spring-run populations are experiencing conditions still close to ideal for their evolutionary life history trajectory.

In terms of population abundance, much good data has been collected. As reported by Harvey-Arrison (2008), Mill Creek spring-run Chinook salmon populations have been monitored since the late 1940's (Table 14). Various counting methods have been employed, including carcass and redd counts, electronic counters and fish traps. The natural turbidity of Mill Creek makes annual counts by direct observation impractical. The most consistent data available is a trapping station at the Clough dam that operated from 1954 thru 1963 (Van Woert 1964, as cited in Harvey-Arrison 2008). During this 10 year period, spring-run Chinook salmon counts ranged from 1,203 to 3,485. Since the removal of Clough dam in 1997, redd counts have been used to estimate returning spring-run Chinook salmon. Spring-run Chinook salmon escapement estimates for Mill Creek are available from 1960 through 2012 (Table 14).

Table 14. Adult spring-run Chinook salmon population estimates for Mill Creek from 1960 to 2012. Estimates are not available for all years.

Year	Adult Estimate	Year	Adult Estimate	Year	Adult Estimate
1960	2368	**1978**	925	**1996**	253
1961	1245	**1979**		**1997**	202
1962	1692	**1980**	500	**1998**	424
1963	1315	**1981**		**1999**	560
1964	1539	**1982**	700	**2000**	544
1965		**1983**		**2001**	1100
1966		**1984**	191	**2002**	1594
1967		**1985**	121	**2003**	1426
1968		**1986**	291	**2004**	998
1969		**1987**	90	**2005**	1150
1970	1500	**1988**	572	**2006**	1002
1971	1000	**1989**	563	**2007**	920
1972	500	**1990**	844	**2008**	362
1973	1700	**1991**	319	**2009**	220
1974	1500	**1992**	237	**2010**	482
1975	3500	**1993**	61	**2011**	366
1976		**1994**	723	**2012**	542
1977	460	**1995**	320		

Sources: CDFW Grandtab; personal communications with DFG and FWS biologists.

Based on observations of spring-run Chinook salmon adults holding and/or spawning, the known range of salmon habitat extends a distance of approximately 48 miles from near the Little Mill Creek confluence (C. Harvey 1996, personal communications, as cited in Armentrout *et al*. 1998) upstream to within 1/2 mile of the LVNP boundary (personal observation of adult holding, as cited in Armentrout *et al*. 1998). Although adults have been reported spawning in "Middle Creek" (Armentrout *et al*. 1998), a small tributary located approximately 2 miles downstream of the park boundary, suitable spawning habitat on the mainstem of Mill Creek extends to near Morgan Hot Springs (approximately three miles downstream of LVNP).

Mill Creek spring-run Chinook salmon redd survey results from 2007 are provided in Table 15 (Harvey-Arrison 2008). Forty-one miles of spring-run Chinook salmon spawning habitat were surveyed beginning upstream of the Highway 36 Bridge downstream to the Steel Tower Transmission Lines (Figure 12). Reaches with the highest number of redds observed include Canyon Camp to Sooner Place, and Sooner Place to McCarthy.

Table 15. Mill Creek spring-run Chinook salmon spawning distribution in 2007

Survey Reach	# of Redds Counted	% of Total
Above Hwy 36	3	1
Hwy 36 to Little Hole-in-Ground	17	4
Little Hole-in-Ground to Hole-in-Ground	14	3
Hole-in-Ground to Ishi Trailhead	18	4
Ishi Trailhead to Big Bend	11	2
Big Bend to Canyon Camp	29	6
Canyon Camp to Sooner	70	15
Sooner Place to McCarthy	78	17
McCarthy to Savercool	38	8
Savercool to Black Rock	35	8
Black Rock to Ranch House	65	14
Ranch House to Avery	23	5
Avery to Pape	51	11
Pape to Buckhorn	8	2
Buckhorn to Transmission Lines [1]	ns [1]	
Total Redds	460	100%
Population Estimate (redds x 2)	920	

[1] Helicopter Survey not made in 2007

Source: Harvey-Arrison 2008

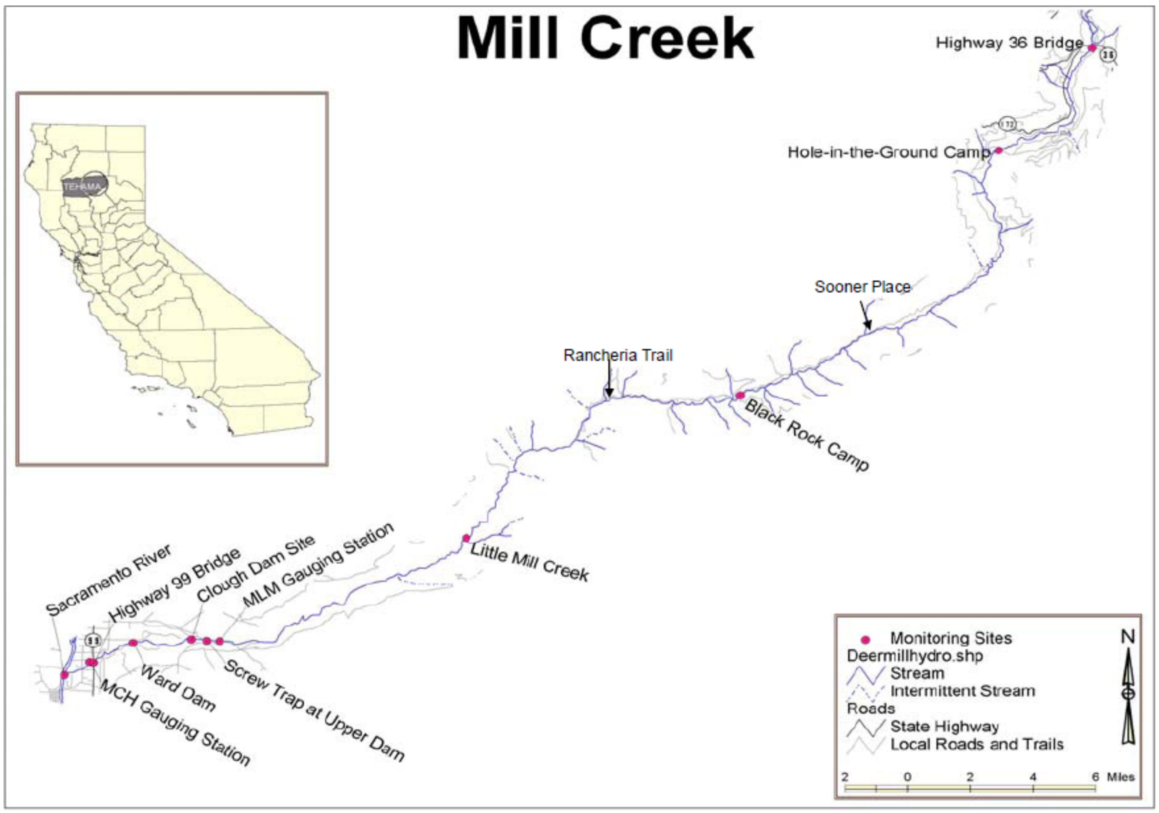

Figure 12. Map of spring-run Chinook salmon holding and spawning habitat in Mill Creek
Source: Harvey-Arrison 2008

Water temperature recorders are located in six locations in spring-run Chinook salmon holding and spawning areas in Mill Creek, ranging from 4800 ft. elevation to 1000 ft. elevation. Table 14 shows the number of days at each elevation that water temperatures exceeded upper tolerance limits for normal egg development and adult salmon survival for both 2007 and 2006. These exceedence periods have an effect on the population in terms of growth and survival, particularly in the egg and incubation stages. Mill Creek water temperatures were higher in 2007 than 2006.

In 2007, exceedence of optimal water temperatures occurred at elevations below 2800 ft. In 2006, water temperatures remained at levels supporting normal egg viability above 2100 ft elevation (Harvey-Arrison 2008).

Table 16. Water temperature exceedence and spring-run Chinook salmon spawning distribution in Mill Creek, May through September, 2006 and 2007

Location	Elevation (ft)	% Spawning Salmon 2007	Number of Days Mean Daily Temperature Exceeds:					
			≥59.0°F normal egg viability		≥63.5°F reduced egg viability		≥68.0°F partial mortality	
			2006	2007	2006	2007	2006	2007
To Brokenshire	4800	1	0	na	0	na	0	na
To Hole-in-Ground	4200	7	0	14	0	0	0	0
To Sooner Place	2800	27	5	19	0	0	0	0
To Black Rock	2100	33	26	91	3	13	0	0
To Rancheria Trail	1600	16	77	160	13	57	0	10
To Little Mill	1000	2	91	124	45	99	5	42

Source: Harvey-Arrison 2008

Studies in Butte Creek (Ward *et al.* 2003) found the majority of spring-run migrants to be fry moving downstream primarily from December through February associated with *flow events*, with small numbers of juveniles remaining to rear and migrate as yearlings later in the spring. Juvenile spring-run Chinook salmon emigration patterns in Mill Creek are similar to patterns observed in Butte Creek, with the exception that Mill Creek juveniles typically exhibit a later young-of-the-year migration and an earlier yearling migration (Lindley *et al.* 2004).

Steelhead

Steelhead begin migration into Mill Creek during the late-fall and winter, primarily when flows increase from storms. Ladder counts at Clough Dam, on Mill Creek, between 1953 and 1963, show that adult steelhead migrate upstream from September through June (Van Woert 1964). Harvey (1995) observed two distinct migration peaks in Van Woert=s (1964) data. The largest peak occurred from late-October to mid-November, and accounted for 30 percent of the run. A smaller peak occurred in the first 2 weeks of February, and accounted for 11 percent of the run. Based on observations using a video weir in Mill Creek from March 6 through June 18, 2007, peak upstream and downstream steelhead passage occurred from May 8-10, 2007 (Killam and Johnson 2008). This may represent the presence of two runs of steelhead in Mill Creek, with one run exiting the system while another run is entering the system during May (Killam and Johnson 2008).

Chinook salmon emigration studies on Deer and Mill Creeks have incidentally captured emigrating steelhead in rotary screw traps. Steelhead generally are captured from November through June, with most fish captured from December through March. Harvey-Arrison (2008a), reported that during the 2007-2008 juvenile steelhead outmigration monitoring period, 297 steelhead were captured in the Mill Creek RST from mid-October 2007 through early June 2008.

Steelhead counts in Mill Creek are available from 1953 to 1963, 1980, 1993, and 1994, for adult fish that passed Clough Dam. From 1953 to 1963, between 417 and 2,269 steelhead, with an annual average of 911 steelhead were counted at Clough Dam (Van Woert 1964). In 1980, 280 steelhead were counted, and in the 1993 to 1994 migration season, 34 steelhead were estimated. Moore (2001) used snorkel and foot surveys in January, March, and April to count adult steelhead and steelhead redds in Mill Creek. These surveys observed 15 adult steelhead and 31 redds in about 3 to 4 percent of the accessible anadromous habitat in Mill Creek. The observations do not represent a population estimate because the entire amount of habitat was not surveyed, and surveys may have missed the peak spawning period.

Antelope Creek Watershed Profile

Listed Species Present in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Listed Species that Historically Occurred in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Diversity Group

Northern Sierra Nevada

Key Stressors

Key stressors to Central Valley spring-run Chinook salmon and steelhead in Antelope Creek include, but are not limited to the following:

- Agricultural diversion dams impeding or blocking adult immigration
- Water diversions entraining juveniles
- Low flow conditions affecting immigrating adults
- Poorly defined migration channels downstream from canyon mouth
- Noxious weeds invading downstream areas affecting juvenile rearing and outmigration
- Possible catastrophic event (e.g., fire or volcanic activity)

Watershed Description

Antelope Creek originates in the Lassen National Forest in Tehama County at an elevation of about 6,800 feet. The creek flows southwest from the foothills of the Cascade Range and enters the Sacramento River at RM 235, 9 miles southeast of the town of Red Bluff. The Antelope Creek drainage encompasses approximately 123 square miles (USFWS 1995).

Relatively few restoration actions are needed to restore watershed and ecosystem function for the purpose of supporting the freshwater life history stages of CV spring-run Chinook salmon and CV steelhead in Antelope Creek. With the exception of impaired stream flows and fish passage conditions on the valley floor below agricultural diversions, habitat in the upper watershed in good condition. Those actions that are required are localized in nature and when fully implemented have a high likelihood of restoring good fish passage conditions. Antelope Creek is diverted into several channels below the Edward Diversion Dam and a single migration channel and fish passage flows need to be established to ensure that adult salmon and steelhead have unimpeded access to upstream spawning habitat and juveniles have unimpaired downstream migration. Fish screens with suitable bypass flows also need to be installed at the Edward Dam. In the upper watershed Federal land management practices are guided by a long-term anadromous fish conservation strategy. Private timberland management plans lack a comprehensive anadromous habitat protection strategy.

Antelope Creek is believed to support a natural population of spring-run Chinook salmon as well as steelhead. CDFW (1998) states that the Antelope Creek spring-run population is not persistent, and the Central Valley Technical Recovery Team considers the Antelope Creek population to be dependant upon the populations in Deer, Mill and Butte creeks (70 FR 37160 (June 28, 2005)). In addition, the upper reaches of Antelope Creek are still fairly undeveloped and contain good habitat for Chinook salmon and steelhead trout. Antelope Creek has the potential to produce a sustainable population of 2,000 spring-run Chinook salmon, although inadequate flows due to two low head diversion dams prevent runs from realizing this potential (Rectenwald 1998).

In Antelope Creek, the primary focus for anadromous salmonid restoration is on improving flow conditions and fish passage for upstream migrating adults so they can access important holding and spawning habitat, and for outmigrating fry.

Geology

Antelope Creek is located within the southernmost extension of the Cascade Range. The Tuscan formation of the Pliocene age, comprised primarily of mudflows, dominates the geology (Armentrout *et al*. 1998). This formation dips gently and thins toward the southwestern portions of the watershed. Geologic diversity is supplied by several influences. These include andesitic plugs that intrude the Tuscan formation along two linear trends, relatively minor exposures of marine sedimentary rocks, and at lower elevations, quaternary sediments of the Sacramento Valley. Glacial processes shaped some of the higher elevation landforms.

Soils generated from these parent materials are generally productive; erosion rates range from low to moderate on the andesitic soils to high to very high on the rhyolitic soils. Mass wasting is evident in the Antelope Creek watershed, dominated by debris flows in colluvium-filled hillslope hollows. Failures are episodic and triggered by extreme precipitation events. Surface erosion, especially on the rhyolitic soils, is the other major source of sediment. However, Antelope Creek has less rhyolitic soils than nearby watersheds including Deer Creek and Mill Creek and thus, has lower surface erosion rates and less mass wasting than these other watersheds (Armentrout *et al*. 1998).

Hydrology

The Antelope Creek watershed produces on average 110,800 acre ft (1.41 ft/acre) of water per year. The majority of annual flow events occur during December through February when snow could be expected to be present in the transient snow zone (i.e., above about 3,000 feet in elevation). Earlier peaks (September through November) are most likely rain events with little snow influence. Later peaks (mid-March through May) indicate snowmelt-generated peaks.

In wettest years, average flows in winter months range from 200 to 1,200 cfs. In the driest years, flows in winter average 50 cfs. In all but the wettest years, summer and early fall flows average from 20 to 50 cfs. The natural flow pattern is altered by diversions in the lower creek from spring through fall. Flows are typically diverted from April 1 through October 31 (County of Butte Website 2007).

There are two diversions on Antelope Creek, both located at the canyon mouth. One is operated by the Edwards Ranch, which has a water right of 50 cfs, and the other is operated by the Los Molinos Mutual Water Company (LMMWC), which has a water right of 70 cfs (USFWS 1995, CDFW 1998). Unimpaired natural flows are often less than the combined water rights of the two diverters, resulting in a total dewatering of Antelope Creek (92 cfs from 1940 to 1980) during critical migration periods (USFWS 1995). Although diversions typically occur between April 1 and October 31, in 2009 Edwards Ranch diverted water during January (P. Bratcher, CDFW, pers. comm. 2009). The stream can potentially be dewatered when both diversions operate. Late spring and early summer diversions have resulted in stream flows low enough to block access for late-migrating adult salmonids. In addition, flow from Antelope Creek can move through a different channel (i.e., New Creek), further impacting instream flow in Antelope Creek (P. Bratcher, CDFW, pers. comm. 2009).

Land Use

The middle and upper portions of Antelope Creek are narrow, with moderate to steep slopes (Armentrout *et al*. 1998). Extended low gradient channel types are uncommon on the mainstem, restricted to McClure Place, Paynes Place, and reaches in the Valley floor. Steep slopes adjacent to the main channel historically served as barriers to human activity, and recent land use allocations have protected these areas such that the mainstem is essentially undisturbed. Timber harvest and grazing have impacted many of Antelope Creek's tributary streams (Armentrout *et al*. 1998).

Approximately half of the forest lands in the region are in private ownership, providing support to local economies. Historically, range management was a major land use in the watershed. In the upper watershed, the number of animals grazing has declined substantially over the past hundred years, but ranching still provides limited employment. Pressure has increased on ranchers and growers to convert their lands to residential development (Armentrout *et al*. 1998).

Recreational activities in the watershed have steadily increased over the past decades with the increase in the human population in the region. Sites of concentrated recreational use in the Antelope Creek watershed include Lassen National Park, Forest Service campgrounds, and the Tehama Wildlife Area. The Tehama Wildlife Area is located approximately one hour east of Red Bluff, California, and contains 46,862 acres of oak woodland, grassland and chaparral. Recreational activities in the Tehama Wildlife Area include hunting, camping, fishing, and wildlife viewing (CDFW Website 2009).

Fisheries and Aquatic Habitat

Antelope Creek provides approximately 30 miles of anadromous fish habitat from its confluence with the Sacramento River upstream and 2 and 3 miles of habitat on the North and South Forks of Antelope Creek, respectively, above their confluence (Armentrout *et al*. 1998). CDFW habitat surveys and water temperature monitoring have identified limited, but adequate adult holding and spawning habitat for CV spring-run Chinook salmon, most of which is located in the Mainstem of Antelope Creek, near the confluence with the North and South Fork. Antelope Creek fish habitat is relatively unaltered above the valley floor but lack of adequate migratory attraction flows into the Sacramento River to this habitat prevents optimum use by anadromous fish (DWR 2009).

Two water diversions exist at the canyon mouth of Antelope Creek. Flow in Antelope Creek is typically diverted April 1 through October 31. In 1976 two fish screens were installed on the LMMWC diversion dam. Fish screens were design to keep salmon and steelhead from being lost in the diversions (Rectenwald 1998). A fish ladder at Edwards Irrigation Dam was constructed in 2007 and is reported to be adequate for fish passage. Currently, Paynes Crossing (Middle Slab) is a passage impediment during springs when there is low flow (Brenda Olson, USFWS, personal communication).

The lower reach of the stream is usually dry when both diversions are operating. Such flows affect migrating adult steelhead at the end and beginning of the run and smolts that are migrating in the spring. Also, adult spring-run are unable to enter the stream during the irrigation and diversion season (Rectenwald 1998). In 2007 and 2008, rescues of spring Chinook salmon juveniles and steelhead have been necessary due to an early irrigation season (Brenda Olson, USFWS, personal communication).

Anadromous salmonid habitat in the Antelope Creek watershed occurs at elevations of 1600 feet and below, resulting in an increased susceptibility to warmer water temperatures and potentially less optimal conditions for anadromous salmonids, compared to some of the other Northern Sierra Nevada watersheds (i.e., Mill and Deer creeks) (P. Bratcher, CDFW, pers. comm. 2009).

Spring-run Chinook Salmon

Historically, Antelope Creek supported “a few hundred” adult fish (Hallock 1956; Van Woert 1959). Hayes and Lingquist (1966) estimated the run to be about 500 fish annually. From 2005 through 2008, Antelope Creek spring-run Chinook salmon escapement was estimated at 82, 102, 26 and 2 fish, respectively (Table 15) (CDFW 2009). Between 1993 and 2008, the highest annual spring-run Chinook salmon escapement was 154, occurring in 1998 (CDFW 2009).

The range of spring-run Chinook salmon in the Antelope Creek watershed extends from upstream of Judd Creek on the North Fork, to Buck’s Flat on the South Fork, downstream to approximately Facht Place on the mainstem (Harvey-Arrison 2008). Approximately 16 miles of suitable holding and spawning habitat is available to spring-run Chinook salmon (Harvey-Arrison 2008).

Antelope Creek was snorkel surveyed to count holding adult spring-run Chinook salmon in July 2007 (Harvey-Arrison 2008). A total of 26 adult Chinook salmon were observed. Sixteen miles of stream were surveyed including the North Fork from 0.8 miles upstream of Judd Creek's confluence to the South Fork confluence, the South Fork from the South Antelope Gun Club to the North Fork confluence, and the mainstem from the North and South Fork confluence to Facht Place (Table 17 and Figure 13).

One spawning survey was completed in October 2007, covering the same reaches as the holding survey, except it omitted the North Fork upstream of Judd creek and the mainstem downstream of Canyon Mouth. A total of 10 redds, 0 carcasses and 3 live salmon was observed (Table 18 and Figure 13) (Harvey-Arrison 2008).

Table 17. Adult spring-run Chinook salmon population estimates for Antelope Creek from 1983 to 2011. Estimates are not available for all years.

Year	Adult Estimate	Year	Adult Estimate	Year	Adult Estimate
1983	59	**1993**	3	**2003**	46
1984		**1994**	0	**2004**	3
1985		**1995**	7	**2005**	82
1986		**1996**	1	**2006**	102
1987		**1997**	0	**2007**	26
1988		**1998**	154	**2008**	2
1989		**1999**	40	**2009**	0
1990		**2000**	9	**2010**	17
1991		**2001**	8	**2011**	6
1992	0	**2002**	46		

Sources: CDFW Grandtab; personal communications with DFG and FWS biologists.

Table 18. Adult spring-run Chinook salmon holding and redd counts in Antelope Creek for 2007

Section	Holding Salmon		Spawning Salmon	
	# of salmon	% of total	# of redds	% of total
North Fork	0	0	2	20
South Fork	0	0	0	
Main Stem to Paynes	2	8	0	
Paynes to Canyon Mouth	22	84	8	80
Canyon Mouth to Facht Place	2	8	ns	
Totals	**26**	100%	**10**	100%

[1] ns = no survey

Source: Harvey-Arrison 2008

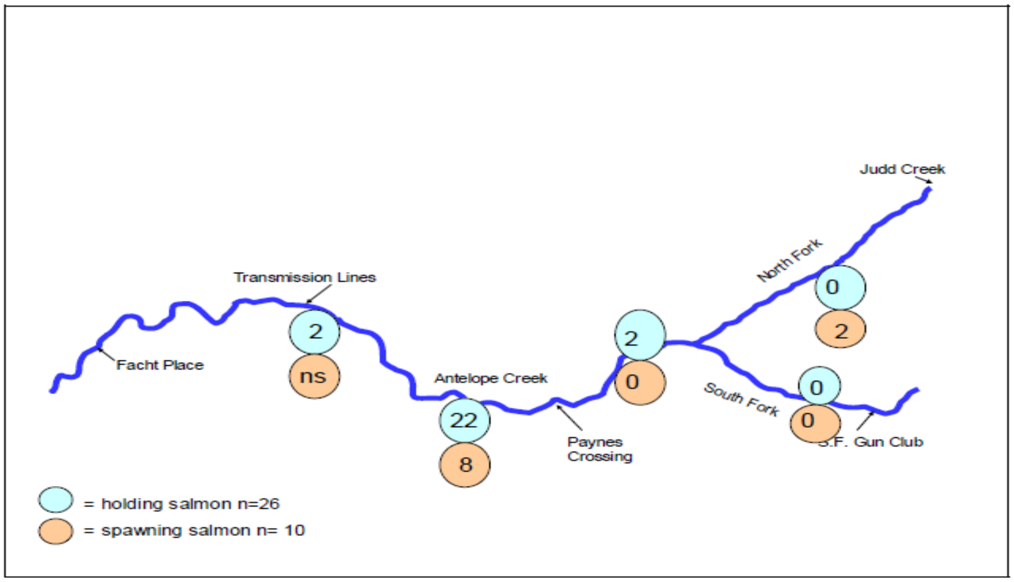

Figure 13. Map of Spring-run Chinook salmon holding and spawning distribution in Antelope Creek for 2007 Source: Harvey-Arrison 2008

Steelhead

Steelhead begin migration into Antelope Creek during the late-fall and winter, primarily when flows increase from storms. Ladder counts at Clough Dam, on Mill Creek, between 1953 and 1963, show that adult steelhead migrate upstream from September through June (Van Woert 1964). Harvey (1995) observed two distinct migration peaks in Van Woert=s (1964) data. The largest peak occurred from late-October to mid-November, and accounted for 30 percent of the run. A smaller peak occurred in the first 2 weeks of February, and accounted for 11 percent of the run. Because Antelope Creek is in the same geographic region as Mill Creek, and runoff patterns are similar, historic steelhead migration timing was probably likely to be similar.

Little is known about the winter-run steelhead in Antelope Creek, including their population status and annual run size, or their distribution in the creek and utilization of habitat. Although steelhead have been observed in Antelope Creek, records of population estimates have not been noted (Rectenwald 1998), and adult counts are limited. Moore (2001) used snorkel and foot surveys from March through May to count adult steelhead and steelhead redds in Antelope Creek. These surveys observed a total of 47 steelhead and 52 redds in about 53 percent of the accessible anadromous habitat in Antelope Creek. These numbers do not represent a population estimate because the entire amount of habitat was not surveyed, and surveys may have missed the peak spawning period. In 2007/2008, DFG installed a video camera and observed 140 adult CV steelhead moving through the newly constructed fish ladder at the Edwards Diversion.

Considering steelhead life-history requirements, however, their range within the system is likely to include the range described for spring-run chinook salmon, and may actually extend beyond this range. Because steelhead are, on the average, smaller in size than salmon and can utilize smaller substrate for spawning, habitat potentially exists for them beyond the known range of salmon (Armentrout *et al*. 1998).

BASALT AND POROUS LAVA DIVERSITY GROUP

Battle Creek Watershed Profile

Listed Species with Current Populations in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Listed Species that Historically Occurred in the Watershed

Sacramento River winter-run Chinook salmon (ESU) - *Oncorhynchus tshawytscha*
Central Valley spring-run Chinook salmon
Central Valley steelhead

Diversity Group

Basalt and Porous Lava

Key Stressors

Key stressors to Central Valley spring-run Chinook salmon and steelhead in Battle Creek include, but are not limited to the following:

- Passage impediments/barriers by hydropower dams affecting immigrating adults
- Hatchery effects (competition) on juvenile rearing and outmigration
- Flow conditions (e.g., low flows) and associated high water temperatures affecting immigrating, holding and spawning adults, as well as rearing and outmigrating juveniles
- Entrainment of rearing and outmigrating juveniles at hydropower and hatchery diversions

Watershed Description

Battle Creek enters the Sacramento River (at river mile 273) approximately five miles southeast of the Shasta County town of Cottonwood. It flows into the Sacramento Valley from the east, draining a watershed of approximately 360 square miles (DWR 2009). The watershed includes the southern slopes of the Latour Buttes, the western slope of Mt. Lassen, and mountains south of Mineral, California (Ward and Moberg 2004). Nearly 350 miles of streams in the Battle Creek watershed drain land at elevations as high as 10,400 feet and cascade steeply down through basalt canyons and foothills to the confluence with the Sacramento River (Ward and Moberg 2004).

Battle Creek is comprised of three main branches - the North Fork (approx. 29.5 miles in length from headwaters to confluence), the South Fork (approximately 28 miles in length from headwaters to confluence), and the mainstem valley reach (approximately 15.2 miles from the confluence of the North and South forks to the Sacramento River), in addition to numerous tributaries (Kier Associates 1999).

Battle Creek has had persistent spawning populations of spring-run Chinook salmon and steelhead in the reaches currently accessible on the mainstem, North Fork and South Fork in recent years, although the populations have been relatively small. Until recently, the Battle Creek Watershed has five dams blocking upstream migration of salmonids to much of the suitable and historic habitat; however, there is a major restoration project underway, the Battle Creek Salmon and Steelhead Restoration Project (Restoration Project), which started in the summer of 2009 and is scheduled for completion by the end of 2015. The Restoration Project, once complete, will open up 21 miles of currently blocked historical habitat, and will restore and enhance a total of nearly 50 miles of habitat. The Restoration Project provides increased instream flows and an adaptive management program to evaluate the effectiveness of these flows.

Early fisheries investigators claimed that Battle Creek was the most important salmon-producing tributary to the Sacramento River when its ecosystem had its original form and function before settlement in the 1850's (Rutter 1904; CDFW 1993c *as cited in* Kier Associates 1999). It is anticipated that the Battle Creek watershed, once restored, will be a conservation stronghold for spring-run and winter-run salmon and steelhead (Battle Creek AMP). Battle Creek provides the only remaining currently accessible habitat (post Restoration Project) in the Sacramento River watershed, other than the Sacramento River, that is thought to be suitable for populations of winter-run Chinook salmon. Also, Battle Creek offers the best opportunity for restoration of wild steelhead populations in the upper Sacramento River (McEwan and Jackson 1996). Battle Creek has been identified as having high potential for successful fisheries restoration, because of its relatively high and consistent flow of cold water (Newton *et al*. 2008). It has the highest base flow (i.e., dry-season flow) of any tributary to the Sacramento River between the Feather River and Keswick Dam (Ward and Kier 1999, as cited in Newton *et al*. 2008). As these cold water inputs and good flows still exist, this system, if restored, will allow access by fish to these key areas upstream where cold water is more available.

Implementation of key recovery actions (completing the Restoration Project) could improve population viability by reducing the risk of extinction to low, based on achieving an effective population size of greater than 500 spawning adults, or a census population size of greater than 2500, as described by Lindley *et al*. (2007) as criteria for assessing the level of extinction risk for Pacific salmonids.

Factors that increase the potential for these species to see increased populations or reintroduction success in this watershed, are: (1) historically, Battle Creek was a uniquely important salmon-producing watershed due to the large numbers and composition of Chinook salmon that were produced there (Kier Associates 1999); (2) McEwan and Jackson stated (1996) that Battle Creek offers the best opportunity for restoration of wild steelhead populations in the upper Sacramento River; (3) presence of a cold, spring-fed stream system that has exceptionally high flows during the dry season.; and (4) a memorandum of agreement between CDFW, USFWS and NMFS has been undertaken as a component to success for population viability to occur. Battle Creek is therefore, a great candidate to lead to a strong contribution toward population viability for spring-run and winter-run Chinook salmon and for steelhead.

How will Battle Creek help to buffer the negative effects of climate change for salmonids in the Central Valley?

Under the expected climate warming of around 5°C, substantial salmonid habitat would be lost in the Central Valley, with significant amounts of habitat remaining primarily in the Feather and Yuba rivers, and remnants of habitat in the upper Sacramento, McCloud, and Pit rivers, Battle and Mill creeks, and the Stanislaus River (Lindley *et al*. 2007). Under the less likely but still possible scenario of an 8°C warming, spring-run Chinook salmon habitat would be found only in the upper-most reaches of the north fork Feather River, Battle Creek, and Mill Creek (Lindley *et al*. 2007).

Battle Creek offers important cold water inputs for spring-run and steelhead populations, that could prove to provide some of the Central Valley's best protection against extinction for these species as climate change effects take place.

Geology

The geology of Battle Creek is unique among the tributaries to the upper Sacramento River downstream of Shasta Dam, but quite similar to tributaries upstream of Shasta Dam (Kier Associates 1999) (Figure 14).

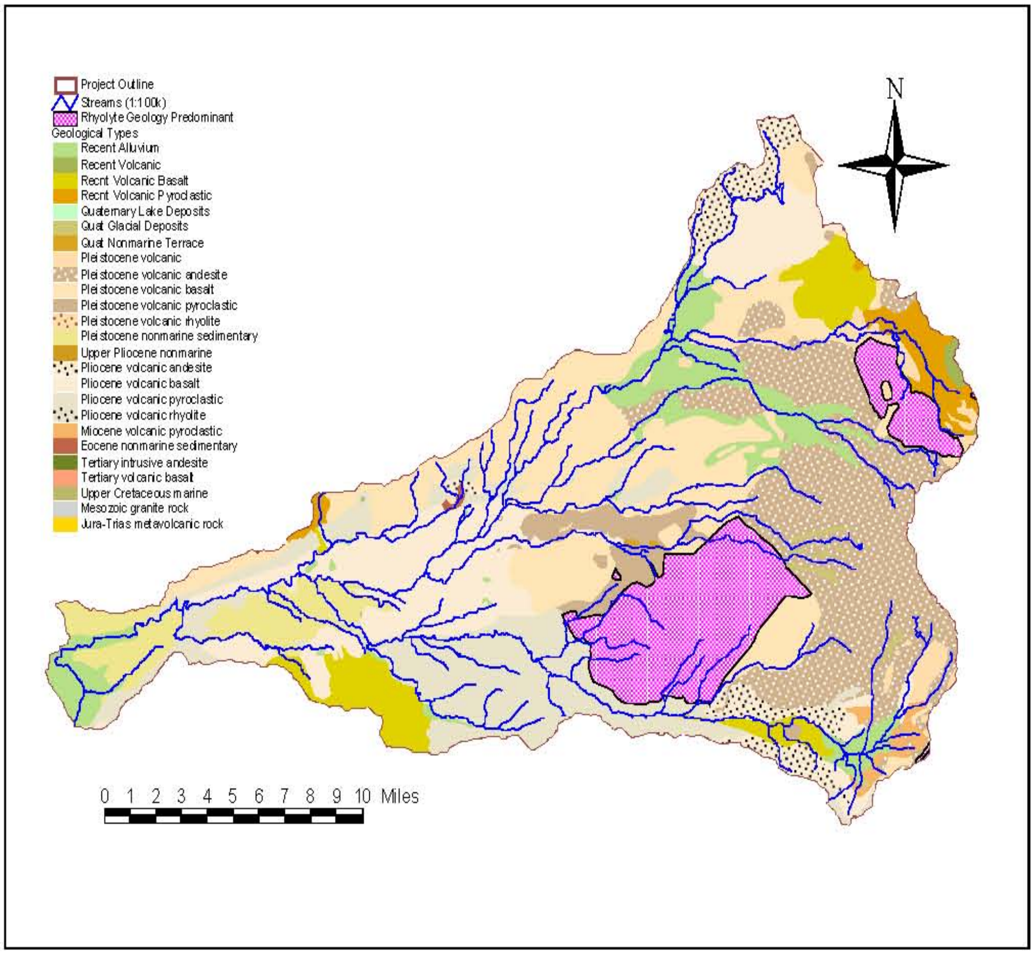

Figure 14. Battle Creek geologic types and location of rhyolitic soils (purple)
Source: Ward and Moberg 2004

Hydrology

Battle Creek has the largest base flow during the low flow season of any of the tributaries to the Sacramento River between the Feather River and Keswick Dam on the Sacramento River (Kier and Associates 1999). The spring-fed nature of Battle Creek ensures than an average September flow of 255 cfs reaches the Sacramento River (USGS 1995 as cited in Kier Associates 1999). Battle Creek and its tributaries drain the volcanic slopes of Mt. Lassen located at the top and center of the watershed (NPS circa 1998 as cited in Kier Associates 1999). The large snowfields on this 10,000 foot peak maintain stream flow until late in the summer (Kier Associates 1999). The volcanic formations and ancient stream channels buried by lava flows store a portion of the wet season runoff and convey it to the streams in the dry season via numerous cold springs (USGS 1956; NPS circa 1998; CDM n.d.; California Mines and Geology Redding Area Geologic Map; Koll Buer, DWR, Red Bluff, California, pers. comm. as cited in Kier Associates 1999).

There are two agricultural diversions in the valley reach of Battle Creek, including the Orwick Diversion (50 cfs) and the Gover Diversion (approximately 50 cfs) which are both considered to be pre-1914 water rights and enable year-round diversions. In addition, the diversions for Coleman National Fish Hatchery (CNFH) are located in the valley reach, and the amount of diversion varies seasonally (Kier Associates 1999). Irrespective of these diversions, Battle Creek remains hydraulically connected year-round, including the dry season and low flow conditions, to the Sacramento River (Kier Associates 1999). During the wet-season, the valley reach of Battle Creek has a natural unimpaired stream flow pattern (Kier Associates 1999).

Above the valley reach, Battle Creek has been extensively developed to produce hydroelectric power using a continuous series of small "run of the river" diversions (Kier Associates 1999). The structures that divert water for hydroelectric power production in the North Fork of Battle Creek include three diversion dams: (1) Wildcat Dam; (2) Eagle Canyon Dam; and (3) North Battle Creek Feeder Dam. These three dams are located downstream of natural barriers to upstream fish migration. The South Fork of Battle Creek also has three hydroelectric diversion dams downstream of natural barriers: (1) Coleman Dam; (2) Inskip Dam; and (3) South Diversion Dam.

Land Use

Land use in Battle Creek ranges from rural residential development to undeveloped wilderness areas of Lassen National Park, and is predominated by industrial timber harvesting, livestock ranch lands, grape growing, and other agricultural development (Ward and Moberg 2004). Private land adjacent to the anadromous reaches of Battle Creek is managed by relatively few landowners for agriculture and cattle grazing (Ward and Moberg 2004).

Timber harvest occurs on both publicly managed lands and privately owned lands. Sierra Pacific Industries is a major landowner in the Battle Creek watershed. Lassen National Forest also manages land for timber harvest in the upper elevation portions of the watershed. Long-term sediment monitoring studies have been conducted by the USFS and timber companies (Ward and Moberg 2004). Fine sediment in the upper watershed shows a higher percentage of fines compared to other nearby streams (e.g., Deer, Mill and Antelope creeks) (Ward and Moberg 2004). Significant timber harvest during 2005-2009 contributed high amounts of fine sediment (M. Woodhouse, pers. comm., 2009.).

Current controversy includes the active lawsuit between concerned citizens and a proposed timber harvest plan for 900 acres near Manton, California. In 2007 this clearcutting plan for over 90% of the proposed project area was approved by the state; a subsequent lawsuit was filed and the controversy is yet to be resolved (January 15, 2008 Tehama County Superior Court, State of California) (T. Parker, USFWS, pers. comm. 2009).

Fisheries and Aquatic Habitat

Historically all four runs of Chinook salmon, including winter-run, spring-run, fall-run, and late-fall-run, occurred in Battle Creek (Yoshiyama *et al*. 1996; Yoshiyama *et al*. 1998). No reliable records exist that documented the number of winter-run Chinook salmon entering Battle Creek (Kier Associates 1999). Systematic counts were not made during the high-flow winter months when adult winter-run Chinook salmon migrate upstream (Kier Associates 1999).

The Coleman National Fish Hatchery (CNFH) was established in 1942 to mitigate the loss of natural salmon to historic spawning areas. The hatchery production goal included 250,000 winter-run Chinook salmon annually (USFWS 2008). In 1998, the winter-run propagation program was relocated from CNFH to the Livingston Stone Fish Hatchery on the Sacramento River. Winter-run Chinook salmon still have access to Battle Creek upstream of the Coleman National Fish Hatchery (CNFH) weir from a fish ladder that is opened during the peak of the winter-run Chinook migration period (Ward and Kier 1999). However, if a winter-run Chinook salmon population exists in Battle Creek, its population size is unknown, likely very small, and is potentially mainly or entirely composed of strays from the mainstem Sacramento River.

As reported by Newton *et al*. (2008), since the early 1900's, a hydroelectric power generating system of dams, canals, and powerhouses, now owned by Pacific Gas and Electric Company (PG&E), has operated in the Battle Creek watershed in Shasta and Tehama Counties, California. The hydropower system has had severe impacts upon anadromous salmonids and their habitat (Ward and Kier 1999, as cited in Newton *et al*. 2008). The Central Valley Project Improvement Act's Anadromous Fisheries Restoration Program outlined several actions necessary to restore Battle Creek, including the following: "to increase flows past PG&E's hydropower diversions in two phases, to provide adequate holding, spawning, and rearing habitat for anadromous salmonids (USFWS 2001a, as cited in Newton *et al*. 2008)." CALFED, PG&E, and other contributors funded the Battle Creek Salmon and Steelhead Restoration Project (Restoration Project). The Restoration Project will provide large increases in minimum instream flows in Battle Creek, remove five dams, and construct fish ladders and fish screens at three other dams (Newton *et al*. 2008).

As reported by Newton *et al*. (2008), PG&E is required under its current FERC license to provide minimum instream flows of 3 cfs downstream of diversions on North Fork Battle Creek (North Fork) and 5 cfs downstream of diversions on South Fork Battle Creek (South Fork). Beginning in 1995, the CVPIA Water Acquisition Program (1995 to 2000) and ERP (2001 to present) contracted with PG&E to increase minimum instream flows in the lower reaches of the North Fork and South Fork (Newton *et al*. 2008). In general, flows are increased to 30 cfs (plus or minus 5 cfs) below Eagle Canyon Dam on the North Fork and below Coleman Diversion Dam on the South Fork (Newton *et al*. 2008). Increased flows were not provided on the South Fork in 2001 and most of 2002, due in part to lack of funds (Newton *et al*. 2008). Based on an agreement in 2003, flows can be redistributed between the forks to improve overall conditions for salmonids, based on water temperatures and the distribution of live Chinook salmon and redds (Newton *et al*. 2008).

As reported by Newton *et al*. (2008), the ERP-funded Interim Flow Project will continue until the Restoration Project construction begins (currently scheduled for 2009). The intent of the Interim Flow Project is to provide immediate habitat improvement in the lower reaches of Battle Creek to sustain current natural salmonid populations while implementation of the more comprehensive Restoration Project moves forward (Newton *et al*. 2008).

Central Valley Spring-Run Chinook

At the start of CNFH operations, a failed spring-run propagation effort collected 227, 1,181, 468, and 2,450 spring-run from Battle Creek in the years from 1943 to 1946, respectively, indicating that a large population was present in the creek (Kier Associates 1999). From 1946 to 1956, Battle Creek spring-run Chinook salmon numbered approximately 2,000 fish in most years (Yoshiyama *et al*. 1996). Escapement data for Battle Creek spring-run Chinook salmon is unavailable from 1960 to 1994 and 1997 to 1998. However, in 1995 and 1996, estimated adult spring-run Chinook salmon escapement was 66 and 34 fish, respectively (USFWS 1996; Croci and Hamelberg 1998). From 1999 through 2008, Battle Creek spring-run Chinook salmon escapement was estimated to be 70, 40, 100, 144, 100, 70, 80, 154, 291, and 101, respectively (CDFW 2009).

As reported by Newton *et al*. (2008), linear regression techniques indicate that the spring-run Chinook salmon population in Battle Creek increased by about 13 fish per year, on average, from 1995 to 2007. This suggests that environmental conditions in Battle Creek have been suitable to maintain and lead to a modest increase in the population; interim flows, provided by PG&E, CVPIA, and CALFED since 1995 have likely been a primary contributing factor to this increase (Newton *et al*. 2008).

Table 19 displays total escapement estimates in Battle Creek of all four runs of Chinook salmon and rainbow trout/steelhead passing upstream of Coleman National Fish Hatchery (CNFH) barrier weir. Total estimated escapement includes Chinook salmon and steelhead passed during the CNFH broodstock collection and spawning program prior to March and fish passed through the barrier weir fish ladder between March 1 and August 31 (period of ladder operation was shorter in some years). Maximum potential spring-run Chinook salmon estimates include all unclipped salmon passing during the ladder operation period. Estimated spring-run Chinook salmon escapement is a reduced estimate based on apportioning some Chinook salmon to the winter, fall, and late-fall runs (Newton *et al*. 2008).

The pre-restoration *upper* limits of spring-run Chinook salmon in the Battle Creek watershed are Eagle Canyon Dam on the North Fork and Coleman Diversion Dam on the South fork (e.g., Newton *et al*. 2007, 2008).

As reported by Newton *et al*. (2007), during 2006 the upstream-most observation of a Chinook salmon on the North Fork was a carcass observed at RM 5.06. During 2007 the upstream-most observation of a Chinook salmon on the North Fork was a carcass observed at RM 4.65 (Newton *et al*. 2008). During both 2006 and 2007, the upstream-most observation of a live Chinook salmon on the South Fork was immediately below Coleman Diversion Dam, which blocks fish passage (Newton *et al*. 2007, 2008).

In 2006, the upstream-most Chinook salmon redd observed on the North Fork was located at about RM 4.6. The upstream-most redd observed on the South Fork was located at about RM 2.5, immediately downstream of Coleman Diversion Dam. In 2007 the upstream-most Chinook salmon redd observed on the North Fork was located at approximately RM 3.8. The upstream-most redd on the South Fork was located at about RM 2.1, downstream of Coleman Diversion Dam (Newton *et al*. 2008).

Table 19. Multi-year summary of total estimated escapement in Battle Creek of all for runs of Chinook salmon and rainbow trout/steelhead passing upstream of Coleman National Fish Hatcher (CNFH) barrier weir.

Year	Winter Chinook	Spring Chinook		Fall Chinook	Late-fall Chinook	Rainbow trout / steelhead	
		Maximum	Estimate			Clipped	Unclipped
1995		66				161[a]	
1996		35				317[a]	
1997		107				344[a]	
1998		178				469[a]	
1999		73				1263[a]	
2000		78				1520[a]	
2001	0+	111	100	9 to 14	98 to 102	1382	225
2002	3	222	144	42	249	1442	593
2003	0	221	100	130	61	772	534
2004	0	90	70	20	42	329	304
2005	0	73	67	6	23	0	344
2006	1	221	154	66	50	1	438
2007	0	291			N/A[b]	3	346
2008	0	105			N/A[b]	1	279
2009	0	194			N/A[b]	20	331
2010*	0	174[c]			N/A[b]	18	392
2011*	1	159 [c]			N/A[b]	78	250
2012*	0	799[c]			N/A[b]		310

[a] Clip status was not used to differentiate hatchery- and natural-origin adult steelhead until 2001 because Coleman National Fish Hatchery did not begin marking all of their production until brood year 1998.

[b]Genetic samples have not been analyzed to determine the total estimate of Late-fall Chinook

[c]Number includes all unclipped spring-run Chinook salmon passed during ladder and video operation as well as approximately 130 clipped spring-run Chinook salmon from the Feather River hatchery.

Source: Newton and Stafford 2011; *personal communication with Matt Brown (USFWS)

Central Valley Steelhead

Escapement estimates of Battle Creek clipped and unclipped rainbow trout/steelhead passing upstream through the CNFH barrier weir fish ladder between March and August from 1995 through 2012 are presented in Table 17 (Newton and Stafford 2011; pers. comm. Matt Brown). Clip status was not used to differentiate hatchery- and natural-origin adult steelhead until 2001 because CNFH did not begin marking all of their production until brood year 1998. Battle Creek is one of the few Central Valley streams where quantification of the abundance of steelhead/rainbow trout is actually provided. The basis of the estimation of the annual run size is the number of adults passing the CNFH barrier weir. The total number of steelhead entering Battle Creek based upon these estimates increased every year from 1995 through 2002 (Newton *et al*. 2008). Starting in 2005 Coleman NFH longer passed clipped steelhead above the weir during the egg collection season, or during manual passage above the barrier weir.

Null *et al.* (2013) found between 36% and 48% of kelts released from Coleman NFH in 2005 and 2006 survived to spawn the following spring, which is in sharp contrast to what Hallock reported for Coleman NFH in the 1971 season, where only 1.1% of returning adults were fish that had been tagged the previous year.

Cow Creek Watershed Profile

Listed Species Present in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Listed Species that Historically Occurred in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Diversity Group

Basalt and Porous Lava

Key Stressors

Key stressors to steelhead in the Cow Creek Watershed include but are not limited to the following:

- Passage impediments/barriers affecting adult immigration and holding and spawning
- Flow conditions (i.e., low flows) associated with attraction and migratory cues into Cow Creek affecting adult immigration
- Passage impediments/barriers in the Cow Creek Watershed and resultant effects associated with redd superimposition, competition for habitat, hybridization/genetic integrity affecting adult spawning
- Elevated water temperatures and poor water quality affecting adult immigration and holding, spawning, embryo incubation, and juvenile rearing and outmigration
- Changes in flow conditions (low flows) in Cow Creek affecting juvenile rearing and outmigration
- Flow dependent habitat availability affecting juvenile rearing and outmigration
- Entrainment at individual unscreened permanent and temporary water diversions affecting juvenile rearing and outmigration
- Loss of natural river morphology, riparian habitat and instream cover, and floodplain habitat affecting juvenile rearing and outmigration
- Predation affecting juvenile rearing and outmigration
- Hatchery effects associated with trout stocking in upper Cow Creek affecting the genetic integrity of steelhead

Watershed Description

The Cow Creek watershed encompasses approximately 425 square miles and has an average annual discharge of more than 500 thousand acre-feet (USFWS 1995). Cow Creek flows southwest from the base and foothills of Mt. Lassen and enters the Sacramento River at RM 280

(USFWS 1995, USFWS 2000). Most of the Cow Creek tributaries originate at 5,000 to 7,000 feet in elevation, and have steep gradients in their upper reaches. The landscape in the higher elevations consists predominately of mixed conifer forest of ponderosa pine, Douglas-fir, incense cedar, and California black oak (USFWS 1995). The oak-digger pine association is predominant in the lower foothills, while the valley floor is dominated by oak grassland and pasture (USFWS 1995).

As reported in the Cow Creek Watershed Assessment (SHN 2001), Cow Creek has been identified by DFG and USFWS as a candidate for restoration of anadromous fisheries. The Working Paper on Restoration Needs, compiled by the Anadromous Fish Restoration Program Core Group in 1995, identified Cow Creek and its tributaries as in “relatively good condition” regarding salmon and steelhead spawning habitat (WSRCD and Cow Creek Management Group 2001). During several DFG fish surveys in 2002 and 2003 primarily Terri Moore (DFG unpublished data) noted that there are sections throughout the watershed that appear to have suitable water temperatures year-round (primarily in the upper reaches of Old Cow and South Cow creeks). Overall, the habitat appeared to be suitable for spawning adult and rearing juvenile steelhead trout, with no definite barriers to anadromy. Moore further noted that there is no obvious reason for the absence of adult steelhead in the upper reaches of South Cow Creek. Yet, many sections of the watershed do not have suitable habitat, insufficient flows (*e.g.* irrigation and hydropower diversions – over 20 unscreened diversion in the watershed), resulting in water temperatures in holding pools that become too warm for spring-run Chinook salmon by midsummer (California Agriculture 2006). In addition, water temperatures and flows for rearing steelhead are less suitable than other nearby watersheds. Extensive restoration is needed in the Cow Creek Watershed for a population to persist. There have been an increase in focus on restoration in the system, particularly addressing passage and entrainment issues, as well as the large hydropower project has filed decommission plans, which will return flows to their natural state, as well as remove passage impediments and entrainment concerns for these areas.

Geology

As reported by USFWS (2000), Cow Creek and its tributaries carve into diverse layers of geologic features. The eastern high of the Cow Creek watershed elevation reaches are the result of relatively recent volcanic activity, with the last eruption series occurring from 1915-1917 (Alt and Hyndman 1975 *as cited in* USFWS 2000). Encrusted lava rocks along with loose volcanic debris were deposited over more ancient (Cretaceous) marine sandstone and shale formations (USFWS 2000). Over time the Cow Creek tributaries have sliced through the blanket of volcanic deposits and eroded into the underlying sandstone and shale producing extensive alluvial deposits (Alt and Hyndman *as cited in* USFWS 2000). Gradient-transition points (i.e., head-cuts or knick-points) are evident in all five of the main tributaries at approximately 1000 feet elevation, forming notable waterfalls. These erosional deposits are the source of rich, well-draining soils that support lush forests and agricultural development (USFWS 2000).

Hydrology

The Cow Creek watershed is a dendritic system and can be divided into five main tributary subbasins, including Little Cow Creek, Oak Run Creek, Clover Creek, Old Cow Creek and South

Cow Creek (USFWS 2000) (**Table 20**). The following subbasin descriptions come from USFWS (2000).

Table 20. Summary data for tributaries of the Cow Creek basin

Stream Name	Basin Area (square miles)	Stream Length
Little Cow Creek	148	36
Oak Run Creek	42	23.5
Clover Creek	54	27.5
Old Cow Creek	80	32.9
South Cow Creek	78	28.5
Main Stem Cow Creek	29	15
Total to Sacramento River	**430**	**47.8**

Source: USFWS 2000

Little Cow Creek

Also known as North Cow Creek, this subbasin drains 148 square miles. The headwaters (Cedar Creek, North Fork, and Mill Creek) originate at an elevation of roughly 5900 feet on the west slopes of Tolladay Peak, Snow Mountain and Clover Mountain. Little Cow Creek flows for 36 miles southwesterly, and then southerly prior to joining the Cow Creek mainstem at Hwy 44.

Oak Run Creek

Oak Run Creek is the smallest of the five main tributaries, draining 42 square miles. Oak Run Creek originates at an elevation of approximately 3200 feet. Oak Run Creek flows 23.5 miles southwesterly to its confluence with the Cow Creek mainstem in Palo Cedro.

Clover Creek

Clover Creek drains 54 square miles and originates at approximately 5500 feet on the south slope of Clover Mountain. Clover creek flows 27.5 miles from its headwaters to its confluence with the mainstem of Cow Creek.

Old Cow Creek

Old Cow Creek drains 80 square miles and originates at an elevation of 6500 feet in the Latour Demonstration State Forest. Old Cow Creek flows 32 miles and joins with Hunt Creek, Glendenning Creek, Canyon Creek and Coal Gulch prior to entering South Cow Creek three miles east of Millville.

South Cow Creek

South Cow Creek drains a 78 square mile basin and originates at an elevation of 5800 feet in the Latour Demonstration State Forest. South Cow Creek flows 28.5 miles to its confluence with Old Cow Creek near Hwy 44. Its larger tributaries include Atkins Creek, Beal Creek, Hamp Creek, and Mill Creek.

Land Use

Settlers were initially drawn to the Cow Creek watershed for its agricultural potential, due to its fertile floodplains (USACE 1971). Irrigation in the Cow Creek basin began soon after its settlement and continues today with a complex series of diversions and lift-pumps in all of the main tributaries. Diversions and pumps carry water to fields, pasturelands and residences in the upper and lower elevation areas. The lowland area primarily supports livestock ranches. Private and public timberlands dominate the eastern upland parts of the basin (above 2000 ft). Mining activity was limited to the northern portion of the basin along Little Cow Creek, where the Afterthought Mine near Ingot (Hwy 299) was a source for gold and copper ore from 1862 to 1952 (Albers and Robertson 1961 *as cited in* USFWS 2000). Hydro-power plants were established on Old Cow Creek (Kilarc Reservoir and Powerplant) and South Cow Creek (Olsen Diversion) in the early 1900s to provide electricity for copper smelting, businesses and residents (Allen 1979 *as cited in* USFWS 2000). PG&E is in the process of decommissioning the Kilarc-Cow Creek hydroelectric project (FERC 606). There are also multiple small individual hydropower setups throughout the watershed, including on Clover Creek (P. Bratcher, pers. comm., 2009).

Fisheries and Aquatic Habitat

As reported by USFWS (1995), primary limiting factors for anadromous salmonids include low fall and summer flows, caused in part by irrigation diversions. Irrigation diversions also affect steelhead by delaying or blocking adult immigration and entraining juveniles. Loss of habitat and water diversions in the Cow Creek watershed is largely due to activities associated with livestock production (USFWS 1995).

As reported by USFWS (1995), agricultural diversions in the Cow Creek watershed are unscreened, and ditches are unlined and poorly maintained. Habitat surveys conducted by DFG in 1992 identified several permanent and temporary irrigation diversions in the various tributary streams, including 13 diversions in South Cow Creek, 10 diversions on Old Cow Creek, one on Clover Creek, and two on North Cow Creek (USFWS 1995). No surveys were conducted on Oak Run Creek. Steelhead are directly affected by water diversions because they impede upstream migration of adults and entrain downstream migrating juveniles. Agricultural diversions and Pacific Gas and Electric Company's hydropower diversions on South Cow Creek also reduce summer flows important for juvenile steelhead rearing (USFWS 1995).

As reported by USFWS (1995), livestock grazing has reduced riparian vegetation and eroded streambanks in the various tributary streams and in the mainstem Cow Creek, degrading the quality of spawning gravel in Cow Creek. Habitat surveys conducted by DFG in 1992 identified stream sections within the various tributaries where excessive erosion has occurred. Fencing these stream sections to protect the riparian corridor has been recommended for approximately 42,600 feet of stream on South Cow Creek, 45,600 feet on Old Cow Creek, 39,120 feet on Clover Creek, and 19,500 feet on North Cow Creek (Harvey pers. comm., as cited in USFWS 1995). Population growth in the towns of Palo Cedro, Bella Vista, Oak Run, and Millville is resulting in increased demand for domestic water and is affecting riparian habitat within the Cow Creek watershed (Reynolds *et al*. 1993, as cited in USFWS 1995).

According to data collected during 2002 and 2003, water temperatures appear to be suitable for salmonids year-round in the upper reaches of Old Cow and South Cow creeks. Stressful and lethal water temperatures were observed in the lower reaches, but may not affect steelhead adult immigration or emigrating steelhead smolts because water temperatures are relatively cool between October and June (Moore 2003).

Steelhead

As reported in the Cow Creek Watershed Assessment (SHN 2001), steelhead populations have not been estimated in Cow Creek. No specific studies have been conducted on Cow Creek to estimate the size of the steelhead spawning run, although CDFW estimated that Cow Creek supported annual spawning runs of 500 steelhead (SHN 2001). Adult steelhead have been observed in North Cow, Old Cow and South Cow creeks; however, it is unknown what percentage of the steelhead run utilizes the other tributaries (SHN 2001). Most steelhead spawning in South Cow Creek probably occurs above South Cow Creek diversion. The best spawning habitat occurs in the 5-mile reach of stream extending from about 1.5 miles below South Cow Creek Diversion Dam to 3.5 miles above the diversion dam (Healy 1997, as cited in

SHN 2001). Additional spawning habitat occurs upstream of this reach, but it is much less abundant. Sightings of adult steelhead have been made at the South Cow Creek Campground (approximately 8.5 miles upstream of the South Cow Creek Diversion Dam) and in Atkins Creek, located just upstream from the campground (SHN 2001).

During February – April of 2002 snorkel surveys were conducted in South Cow Creek, but no steelhead adults, carcasses or redds were identified (Moore 2003). During February – April of 2003, snorkel surveys and one walking survey in South Cow Creek, and one snorkel survey in Old Cow Creek were conducted to identify steelhead adults, carcasses and redds. Seven adult steelhead and two possible redds were identified in South Cow Creek (Moore 2003).

Upper Sacramento River Watershed Profile

Listed Species Present in the Watershed

Central Valley winter-run Chinook salmon
Central Valley spring-run Chinook salmon
Central Valley steelhead

Listed Species that Historically Occurred in the Watershed

Central Valley winter-run Chinook salmon
Central Valley spring-run Chinook salmon
Central Valley steelhead

Diversity Group

Basalt and Porous Lava Diversity Group

Key Stressors

Key stressors to winter-run Chinook salmon in the upper Sacramento River include, but are not limited to the following:

- Passage impediments/barriers affecting adult immigration and holding and spawning (Keswick and Shasta Dams)
- Flow conditions affecting embryo incubation
- Predation of juveniles due to Glen Colusa Irrigation District (GCID) Dam, Red Bluff Diversion Dam (RBDD) and other structures
- Short-term inwater construction affecting embryo incubation
- Water quality affecting embryo incubation
- Water temperatures affecting spawning and embryo incubation
- Loss of natural morphologic function affecting juvenile rearing and outmigration
- Habitat suitability affecting spawning

Watershed Description

The upper Sacramento River watershed includes sub-basins above Shasta Dam and (Little Sacramento River, McCloud, and Pit Rivers) and areas below the Shasta and Keswick Dams downstream to the vicinity of Red Bluff. The areas above Shasta Reservoir include nearly 5,000 square miles of steep mountainous terrain, mid to high gradient stream channels, forested by mixed conifers at high elevations and oak woodlands, scattered pines and brush at lower elevations. Watershed condition, geology, hydrology, land ownership and land use are diverse. The Little, or Upper, Sacramento is a spring-fed river draining Mt. Shasta. The Little Sacramento River is a moderate-size basin (2370 km2) and well-isolated from the McCloud River (Lindley *et al*., 2004). The Little Sacramento River historically supported winter-run

Chinook salmon, as well as spring-run Chinook salmon (Yoshiyama *et al*., 1996). In their report to the California Fish and Wildlife Commission (DFG 1998), concerning the status of spring-run Chinook salmon in the Central Valley, DFG states there are no precise estimates of spring run abundance upstream of the present day site of Shasta Dam, this was the principle spawning area of the Sacramento River basin, and the numbers of fish must have been high. Lindley *et al.*, (2007) concluded that the Little Sacramento was large enough and well-isolated enough to have supported an independent population of spring-run Chinook salmon. Access to the Little Sacramento is presently blocked by Keswick and Shasta dams.

The McCloud River is spring-fed tributary to the Lower Pit River and drains Mt. Shasta, and was swift, cold and tumultuous before hydropower development (Moyle *et al*., 1982). The McCloud River supported winter-run and spring-run Chinook salmon and steelhead. The area above 500 m elevation is isolated from other areas historically used by spring-run Chinook salmon. Lindley *et al*. (2007) concluded that the McCloud River was large enough and well-isolated enough to have supported an independent population of spring-run Chinook salmon. Access to this watershed is now blocked by Keswick and Shasta dams.

The upper Pit River, Fall River and Hat Creek are documented to have contained spring-run Chinook salmon (Yoshiyama *et al*., 1996). The middle and upper Pit is relatively low gradient, meandering across a flat valley floor, and is warm and turbid (Moyle *et al*., 1982). Large falls block access shortly above the confluence of the Fall River (Yoshiyama *et al*., 1996). The Fall River arises from springs at the edge of a lava field, and subsequently has a fairly large discharge of clear water. Hat Creek is similar to the Fall River. The whole region is above 500 m, and Hat Creek and the Fall River are within 50 km of each other. Based on the similarity and proximity of Hat Creek and the Fall River, and the fairly short lengths of accessible habitat within the tributaries, Lindley *et al.* (2004) decided that this area probably was occupied by a single population that had significant substructure. Access to this watershed is presently blocked by Keswick and Shasta dams on the Sacramento River, and numerous other hydroelectric facilities throughout much of its length. Unlike the Little Sacramento and McCloud Rivers, the Pit River is significantly impaired by hydro development and much of the historic habitat is either inundated by reservoirs or dewatered.

The Sacramento River reach below Keswick Dam is the most urbanized and industrialized of the four Sacramento River reaches, while also supporting agriculture. It has three water control structures (i.e., Anderson-Cottonwood Irrigation District[ACID] dam, RBDD dam operated with gates out year round after 2012, and GCID dams). This dams are operated for mainly agricultural diversions from April through October. The broad alluvial portion of the reach between Redding and Balls Ferry has the potential to support significant tracts of riparian forest. Along much of this reach, however, riparian forests are confined to narrow corridors at the base of canyon walls (SRCAF 2003).

How will the Upper Sacramento River help to buffer the negative effects of climate change for salmonids in the Central Valley?

Under the expected climate warming of around 5°C, substantial salmonid habitat would be lost in the Central Valley, with significant amounts of habitat remaining primarily in the Feather and

Yuba rivers, and remnants of habitat in the upper Sacramento, McCloud, and Pit rivers, Battle and Mill creeks, and the Stanislaus River (Lindley *et al*. 2007). Under the less likely but still possible scenario of an 8°C warming, spring-run Chinook salmon habitat would be found only in the upper-most reaches of the north fork Feather River, Battle Creek, and Mill Creek (Lindley *et al*. 2007).

The upper Sacramento River most likely will offer important cold water inputs for and steelhead populations, that could prove to provide some of the Central Valley's protection against extinction for these species as climate change effects take place.

Geology

The upper Sacramento River watershed geology above Shasta Reservoir is dominated by the Cascade Range Geomorphic Province to the west and the Modoc Plateau Geomorphic Province to the East. The Cascade region contains some of the highest peaks in California, and includes several active volcanic formations. The Modoc region is dominated high elevation plateaus with basalt geology.

As reported by SRCAF (2003), the geologic characteristics of the upper Sacramento River reach vary greatly. From Keswick Dam to Redding the river flows through volcanic and sedimentary formations. The canyon is relatively narrow in this area with little floodplain and a correspondingly narrow riparian corridor. From Redding to the Cow Creek confluence there are limited areas where the river has meandered over a broader floodplain of alluvium derived from the Klamath Mountains and the Coast Ranges. From the Cow Creek confluence to near Red Bluff the river is almost entirely controlled by the Tuscan Formation (DWR 1981, as cited in SRCAF 2003). Here the channel is often narrow and deep, between high canyon walls. Table Mountain, a 2-mile long volcanic plateau adjacent to the river, and steep-sloped Iron Canyon (RM 250-253) are both examples of Tuscan Formation outcrops. At Red Bluff the river flows out onto the broad alluvial floodplain of the Sacramento Valley (SRCAF 2003).

As reported by SRCAF (2003), the bed material and floodplain deposits of this portion of the Sacramento River consist generally of well-rounded material composed of various metamorphic, sedimentary, and igneous rocks. The size of this material ranges from clay fines to boulders (DWR 1981, as cited in SRCAF 2003). Since the closure of Shasta Dam in December 1943, the transport of sediment from reaches upstream of the dam has ceased, resulting in an armored channel surface below the dam as the river has transported sediments out of the area (DWR 1981, as cited in SRCAF 2003).

Other factors influencing the sediment supply in this reach include: (1) the urbanization of the Redding-Anderson area, resulting in reduced bank erosion due to the installation of bank protection and levees; and (2) large quantities of sand and gravel being mined at locations in and adjacent to the Sacramento River and its tributaries (DWR 1981, as cited in SRCAF 2003).

Hydrology

As reported by USFWS (1995), the Sacramento River is the largest river system in California, yielding 35% of the state's water supply. The median historical unimpaired run-off above Red

Bluff is 7.2 million acre-feet (maf), with a range of 3.3-16.2 maf (USFWS 1995). Most of the Sacramento River flow is controlled by the USBR Shasta Dam, which stores up to 4.5 maf of water (USFWS 1995). As reported by SRCAF (2003), the Keswick-Red Bluff Reach is highly influenced by the altered hydrology resulting from the operation of the Central Valley Project (CVP). The operation of the CVP in this reach includes Shasta and Keswick Dams on the mainstem of the Sacramento River, as well as the diversion of Trinity River and Clear Creek water through Whisketown Reservoir to Keswick Reservoir via the Spring Creek tunnel (SRCAF 2003).

As reported by SRCAF (2003), CVP operations reduce flood peaks during the winter and spring and increase discharge during the summer and autumn. For example, without the CVP, a 100-year flood is calculated to be about 336,000 cubic feet per second (cfs) at Bend Bridge (SRCAF 2003). Under the controlled operation of the CVP, however, this is reduced to 202,000 cfs (SRCAF 2003). A smaller 2-year flood is reduced from 110,000 cfs to 70,800 cfs (TNC 1996, as cited in SRCAF 2003). During July, August, and September, the mean monthly flows of the Sacramento River at Keswick since 1963 are nearly 400 percent higher than the mean monthly flows prior to 1943 (DWR 1981, as cited in SRCAF 2003). The effect of these changes to hydrology is most obvious directly below the dams. The principal west side tributaries to the Sacramento River in the Keswick-Red Bluff Reach include Clear, Cottonwood, and Dibble Creeks. These creeks flow from the valley floor and parts of the Klamath Mountains to the Sacramento River. Main east side tributaries include Churn, Stillwater, Cow, Bear, Ash, Battle, and Paynes Creeks. Battle and Paynes Creeks originate in the Cascade Mountains east of Redding and flow through confined canyons before joining the Sacramento River (SRCAF 2003).

Land Use

Land ownership in the upper sub-basins above Shasta Reservoir is up to 50 percent public (USFS and USBLM) and land use is dominated by timber management, hydroelectric energy production, grazing, and agriculture. Historic land use included extensive mineral management.

As reported by SRCAF (2003), the Keswick-Red Bluff Reach has a variety of land uses—urban, residential, industrial, and agricultural. About 35 percent of the area is in agriculture, and about 12 percent is urban, residential, or industrial. Predominant agricultural crops include walnuts, mixed pasture and prunes. Industrial land uses within this reach include lumber mills and gravel removal operations. Residential and commercial land uses in the cities of Redding, Anderson, and Red Bluff are common as well. In addition, this reach has the most recreational facilities on the Sacramento River (SRCAF 2003). Historically, the river between Redding and Anderson supported several gravel mining operations (SRCAF 2003).

Fisheries and Aquatic Habitat

The distribution of Sacramento River winter-run spawning and rearing historically is limited to the upper Sacramento River and its tributaries, where spring-fed streams provided cold water throughout the summer, allowing for spawning, egg incubation, and rearing during the mid-summer period (Slater 1963, Yoshiyama *et al.* 1998). CV spring-run Chinook salmon and CV steelhead also occurred in these tributaries. The headwaters of the McCloud, Pit, and Little Sacramento Rivers, and Hat and Battle Creeks, historically provided clean, loose gravel; cold, well-oxygenated water; and optimal stream flow in riffle habitats for spawning and incubation. These areas also provided the cold, productive waters necessary for egg and fry development and survival, and juvenile rearing over the summer. Approximately, 299 miles of tributary spawning habitat in the upper Sacramento River is now inaccessible to winter-run (NMFS 2009a). Yoshiyama *et al.* (2001) estimated that in 1938, the Upper Sacramento had a "potential spawning capacity" of 14,303 redds. Most components of the winter-run life history (*e.g.*, spawning, incubation, freshwater rearing) have been compromised by the habitat blockage in the upper Sacramento River.

CDFW (1998) reports that Clark (1929) characterized CV spring-run Chinook salmon habitat above Shasta Dam as ideal. Yoshiyama (1996) concluded that CV spring-run Chinook salmon would have had access to habitat in the Little Sacramento River as far upstream as the vicinity of Box Canyon Dam, near Mount Shasta. Spring-run Chinook salmon also could have ascended as high as Lower Falls, on the McCloud River but probably stopped near Big Spring (Wales 1939 as reported in CDFW 1998); and ascended the Pit River to the Fall River (Yoshiyama 1996), Hat and Kosk Creek, and the lower one mile of Burney Creek (CDFW 1998). Much of the historic spawning habitat in the Little Sacramento and McCloud Rivers is still present above Shasta Reservoir without significant reductions in amount or connectivity. The Pit River has an extensive hydroelectric footprint, and much of the historic habitat is currently impounded, dewatered or otherwise affected by the presence and operation of facilities.

The ACID Dam (RM 298.5) was constructed in 1917 about three river miles downstream of the current Keswick Dam. Originally the ACID Dam was a barrier to upstream fish migration until 1927 when a poorly designed fish ladder was installed (NMFS 1997). The ACID Dam is only installed during the irrigation season which typically runs from early April to October, or early November. As mentioned above, the fish ladder providing passage around the dam was poorly designed and although winter-run Chinook salmon were able to negotiate the ladder, it did present a partial impediment to upstream migration. However, a new fish ladder installed in 2001 appears to be operating effectively (CDFW 2004). The high volume releases from the ACID's canal downstream of the dam may create false attraction flows for migrating adult salmon where they could be stranded (NMFS 1997). Also, flow fluctuations necessary to install the dam may dewater salmon redds.

The proportion of the winter-run Chinook salmon spawning above ACID has increased since the ladder improvements in 2001.An average of 62% spawn between Keswick Dam and ACID Dam (CDFW 20012 unpublished aerial redd counts). Data on the temporal distribution of winter-run Chinook salmon upstream migration suggest that in wet years about 50 percent of the run has passed the RBDD by March, and in dry years, migration is typically earlier, with about 72 percent of the run having passed the RBDD by March (CUWA and SWC 2004).

The RBDD at RM 243 has 11 gates which are raised or lowered to control the level of Lake Red Bluff, enabling gravity diversion into the Tehama Colusa Canal (TCC). Permanent fish ladders are located on each abutment of the dam, however, the ladders are inefficient in allowing upstream migration of adult salmonids (NMFS 1997). Winter-run Chinook salmon, spring-run

Chinook salmon, and CV steelhead experienced delays during spawning runs due inefficient ladders at RBDD. Juvenile Chinook salmon and steelhead were also subject to predation as they passed downstream through Lake Red Bluff and the gates. Since 1993 NMFS had required gates out for winter-run Chinook salmon upstream passage for longer and longer periods from May through September. In 2012 the gates were left open year round to meet NMFS' Biological Opinion on the Long-term Operations of the CVP and SWP (2009). The gates out operation was accommodated with construction of a new pumping plant and fish screen to divert water for irrigation, with an initial capacity of 2,180 cfs (Tehama-Colusa Canal Authority 2008).

During recent years the majority of winter-run Chinook salmon (*i.e.*, > 50 percent since 2007) spawn in the area from Keswick Dam downstream to the ACID Dam (approximately 5 miles). Keswick Dam re-regulates flows from Shasta Dam and mixes it with water diverted from the Trinity River through the Spring Creek tunnel to control water temperatures below ACID pursuant to actions in the NMFS (2009a) biological opinion.

Sacramento River winter-run Chinook salmon

The upper Sacramento River contains the only existing habitat for Sacramento River winter-run Chinook salmon. As reported by NMFS (2009a), historical winter-run population estimates, which included males and females, were as high as over 230,000 adults in 1969, but declined to under 200 fish in the 1990s (Good *et al.* 2005). A rapid decline occurred from 1969 to 1979 after completion of the RBDD. Over the next 20 years, the population eventually reached a low point of only 186 adults in 1994. At that point, winter-run Chinook salmon were at a high risk of extinction, as defined by Lindley *et al*. (2007). However, several conservation actions, including a very successful captive broodstock program (i.e., Livingston Stone National Fish Hatchery (LSNFH)), construction of a temperature control device (TCD) on Shasta Dam, maintaining the RBDD gates up for much of the year, and restrictions in ocean harvest, have likely prevented the extinction of wild winter-run Chinook salmon.

In recent years, the carcass survey population estimates of winter-run Chinook salmon included a high of 17,205 (Table 17) in 2006, followed by a precipitous decline in 2007 that continued in 2008, when less than 3,000 adult fish returned to the upper Sacramento River. The total escapement estimate for winter-run Chinook salmon in 2012 is 2,581 (CDFW 2013).

Table 21 also provides data on the cohort replacement rate (CRR), which is similar to the SRR recommended by Anderson *et al*. (2009), that is, the ratio of the number of recruits returning to the spawning habitat divided by the number of spawners producing those recruits. As discussed, above, the majority of winter-run spawners are 3 years old. Therefore, NMFS calculated the CRR using the spawning population of a given year, divided by the spawning population 3 years prior.

A conservation program at LSNFH located at the base of Keswick Dam annually supplements the in-river production by releasing on average 180,000 winter-run smolts into the upper Sacramento River. The LSNFH operates under strict guidelines for propagation that includes genetic testing of each pair of adults and spawning less than 25 percent of the hatchery returns.

This program and the captive broodstock program (phased out in 2007) were instrumental in stabilizing the winter-run Chinook population following very low returns in the 1990s.

Table 21. Winter-run population estimates from RBDD counts (1986 to 2001) and carcass counts (2001 to 2008), and corresponding cohort replacement rates for the years since 1986

Year	Population Estimate[a]	5-Year Moving Average of Population Estimate	Cohort Replacement Rate[b]	5-Year Moving Average of Cohort Replacement Rate	NMFS-Calculated Juvenile Production Estimate (JPE)[c]
1986	2,596	-	-	-	
1987	2,186	-	-	-	
1988	2,885	-	-	-	
1989	696	-	0.27	-	
1990	433	1,759	0.20	-	
1991	211	1,282	0.07	-	40,100
1992	1,240	1,092	1.78	-	273,100
1993	387	593	0.90	0.64	90,500
1994	186	491	0.88	0.77	74,500
1995	1,297	664	1.05	0.94	338,107
1996	1,337	889	3.45	1.61	165,069
1997	880	817	4.73	2.20	138,316
1998	3,002	1,340	2.31	2.48	454,792
1999	3,288	1,961	2.46	2.80	289,724
2000	1,352	1,972	1.54	2.90	370,221
2001	8,224	3,349	2.74	2.76	1,864,802
2002	7,441	4,661	2.26	2.22	2,136,747
2003	8,218	5,705	6.08	3.02	1,896,649
2004	7,701	6,587	0.94	2.71	881,719
2005	15,730	9,463	2.11	2.83	3,556,995
2006	17,205	11,259	2.09	2.70	3,890,534
2007	2,488	10,268	0.32	2.31	1,100,067
2008	2,850[d]	9,195	0.18	1.13	1,152,043[e]
median	**2,488**	**1,961**	**1.54**	**2.31**	**370,221**

a Population estimates were based on RBDD counts until 2001. Starting in 2001, population estimates were based on carcass surveys.

b The majority of winter-run spawners are 3 years old. Therefore, NMFS calculated the CRR using the spawning population of a given year, divided by the spawning population 3 years prior.

c JPE estimates were derived from NMFS calculations utilizing RBDD winter-run counts through 2001, and carcass counts thereafter for deriving adult escapement numbers. Only estimated to RBDD, does not include survival to the Delta.

d CDFW (2009)

e NMFS (2009b) preliminary estimate to Reclamation

Sources: CDFW 2004, CDFW 2007, CDFW 2009, NMFS 2009b

Lindley *et al.* (2007) determined that the winter-run Chinook salmon population, which is confined to spawning below Keswick Dam, is at a moderate extinction risk according to population viability analysis (PVA), and at a low risk according to other criteria (*i.e.*, population size, population decline, and the risk of wide ranging catastrophe). However, concerns of genetic introgression with hatchery populations are increasing. Hatchery-origin winter-run from LSNFH have made up more than 5 percent of the natural spawning run in recent years and in 2005, it exceeded 18 percent of the natural run. If this proportion of hatchery origin fish from the LSNFH exceeds 15 percent in 2006-2007, Lindley *et al*. (2007) recommends reclassifying the winter-run population extinction risk as moderate, rather than low, based on the impacts of the hatchery fish over multiple generations of spawners. In addition, data used for Lindley *et al*. (2007) did not include the significant decline in adult escapement numbers in 2007 and 2008, and thus, does not reflect the current status of the population size or the recent population decline. Furthermore, the drought conditions in 2007, 2008 and 2009 in the Central Valley were not incorporated into the analysis of the winter-run population status in Lindley *et al*. (2007) as a potential catastrophic event.

In consideration of the almost 7-fold decrease in population in 2007, coupled with the dry water year type in 2007, followed by the critically dry water year type in 2008 (which could be qualified as a high-risk catastrophe) and likely a similar forecast for 2009, NMFS concludes that winter-run Chinook salmon are at high risk of extinction based on population size (NMFS 2009a).

CV spring-run Chinook Salmon

The status of the spring-run population within the mainstem Sacramento River above RBDD appears to have declined from a high of 25,000 in the 1970s to the current low of less than 800 counted at RBDD (Figure 15). Significant hybridization with fall-run has made identification of a spring-run in the mainstem very difficult to determine, and there is speculation as to whether a true spring-run still exists below Keswick Dam. This shift may have been an artifact of the manner in which spring-run were identified at RBDD. Fewer spring-run are counted today at RBDD because an arbitrary date, September 1, was used to determine spring-run and gates are now open year round for winter-run passage (NMFS 2009a). It is unknown if spring-run still spawn in the Sacramento River mainstem, but the physical habitat conditions below Keswick Dam is capable of supporting spring-run, although in some years high water temperatures can result in substantial levels of egg mortality. Current redd surveys have observed 20-40 salmon redds in September, from Keswick Dam downstream to the Red Bluff Diversion Dam. This is typically when spring-run spawn, however, there is no peak that can be separated out from fall-run spawning, so these redds also could be early spawning fall-run. Additionally, even though habitat conditions may be suitable for spring-run occupancy, spring-run Chinook salmon depend on spatial segregation and geographic isolation from fall-run Chinook salmon to maintain genetic diversity. With the onset of fall-run Chinook salmon spawning occurring in the same time and place as potential spring-run Chinook salmon spawning it is likely to have caused extensive introgression between the populations (CDFW 1998).

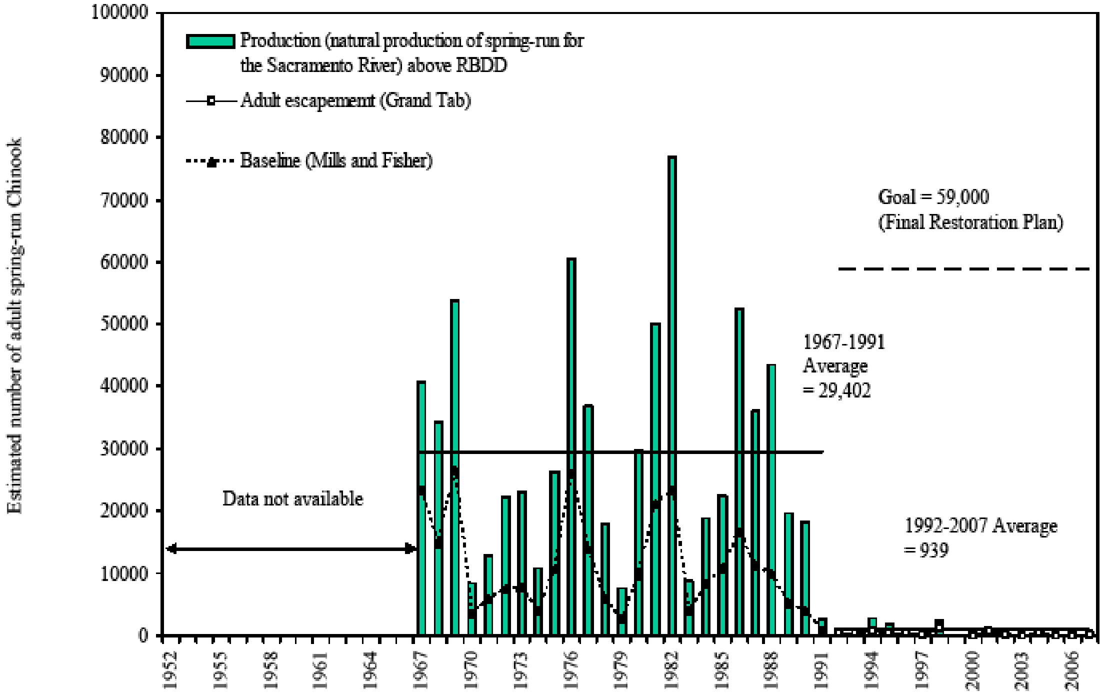

Figure 15. Estimated yearly spring-run escapement and natural production above RBDD
Source: Hanson 2008

CV steelhead

Estimates of CV steelhead abundance in the mainstem Sacramento River typically use the RBDD counts for historical trend data. Since 1991, the RBDD gates have been opened after September 15, making estimates of CV steelhead pass RBDD unreliable. Based on counts at RBDD, adult migration into the upper Sacramento River can occur from July through May, but peaks in September, with spawning occurring from December through May (Hallock 1998). Since the RBDD gates started operation in 1967, the CV steelhead abundance in the upper Sacramento River has declined from 20,000 to less than 1,200 (Figure 16). CV steelhead passage above RBDD after 1991 can be estimated based on the average of the 3 largest tributaries (*i.e.*, Battle Creek, Clear Creek and Cottonwood Creek). The average of these tributaries for the last 14 years (1992 through 2005) is 1,282 adults, which represents a continuous decline from the 1967 through 1991 average RBDD count of 6,574 (Figure 16). The decline in CV steelhead abundance is similar to winter-run and spring-run declines.

Actual estimates of CV steelhead spawning in the mainstem Sacramento River below Keswick Dam have never been made due to high flows and poor visibility during the winter time. Aerial redd surveys conducted for winter-run have observed resident *O. mykiss* spawning in May and late-falls spawning in January. Since resident trout redds are smaller than steelhead redds and late-fall salmon spawn at the same time as steelhead, it would seem likely that CV steelhead redds could be observed. A CV steelhead monitoring plan is being developed by CDFW with a goal of determining abundance in the Sacramento River (Jim Hopelain per.com 2008).

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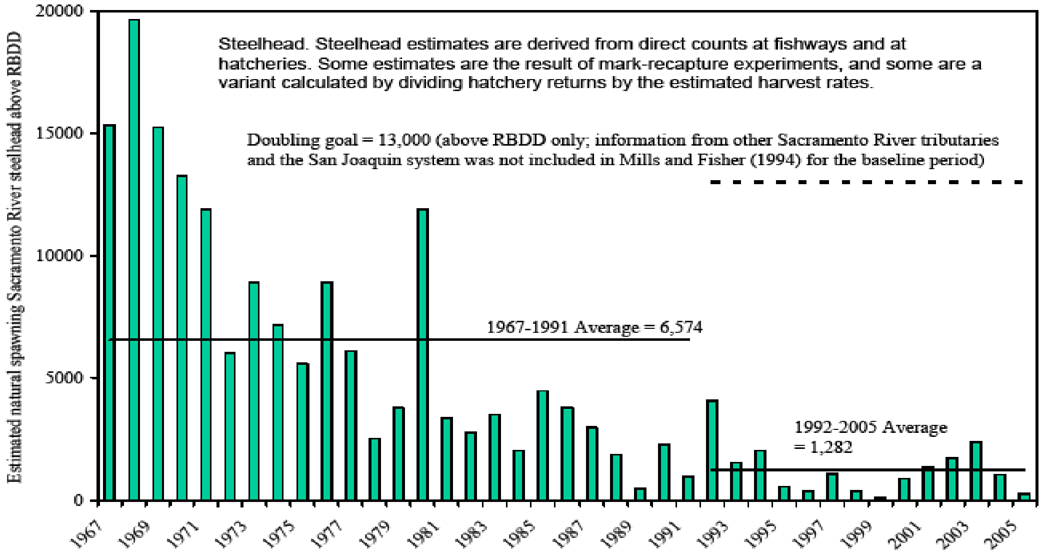

Figure 38. Estimated yearly number of natural spawning of steelhead on the Sacramento River, upstream of the RBDD (Mills and Fisher, 1994). Data for 1992-2005 is from CDFG, Red Bluff.

Figure 16. Estimated yearly number of natural spawning CV steelhead on the Sacramento River upstream of the RBDD 1967-2005. Data from 1992 to 2005 is based on tributary counts from CDFW, Red Bluff Source: Hanson 2008

Small Tributaries to the Upper Sacramento River[7]
(including Salt, Sulphur, Olney, Churn, Stillwater, Inks, and Paynes Creeks)

Listed Species Currently and Historically Occurring in these Creeks
Central Valley Steelhead

Key Threats and Stressors

Key threats and stressors (i.e., identified as "Very High") to Central Valley steelhead in the Upper Sacramento River Tributaries include, but are not limited to the following:

- Passage impediments/barriers in the upper Sacramento River tributaries
- Physical habitat alternation associated with limited supplies of instream gravel affecting adult spawning
- Water temperature and water quality effects on adult immigration and holding, and on juvenile rearing and outmigration
- Flow conditions (i.e., low flows) affecting attraction and migratory cues for adult immigration and holding, and flow dependent habitat availability affecting juvenile rearing and outmigration
- Entrainment at individual diversions affecting juvenile rearing and outmigration
- Predation effects on juvenile rearing and outmigration
- Loss of riparian habitat and instream cover affecting juvenile rearing and outmigration

Additional stressors for both species are presented in Appendix A.

General Description

Along the Sacramento River are many small, often ephemeral, tributaries that are not used to any significant extent by spawning anadromous salmonids (Figure 17). Maslin and McKinney (1994) have shown that these tributaries may be used as rearing habitat by juvenile salmonids. Only a few of the potential tributaries have been investigated, but those that have been examined contained juvenile Chinook salmon. In some cases, the juveniles had gone as far as 14 miles upstream from the river. Most of these tributaries also have resident rainbow trout populations in upstream perennial reaches. For many, there also are anecdotal accounts of historical steelhead runs (USFWS 1995).

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[7] For this appendix, the Upper Sacramento River section starts at Keswick Dam and ends at the Red Bluff Diversion Dam site.

USFWS (1995) identified several small Sacramento River tributaries in which juvenile salmon had been reported, and the characteristics of these known rearing streams were compared to those of streams for which no information was available. Table 22 presents a list of small Sacramento River tributaries thought to not support, or to be of minimal utilization, for salmonid spawning (USFWS 1995) and divides them into the following categories:

- Tributaries known to support juvenile rearing
- Tributaries that are of similar in morphometry and location to known rearing streams and, thus, presumed to support juvenile rearing
- Tributaries that have steep gradients near the river or that enter the river upstream from any spawning habitat and, therefore, are presumed to have low potential to support juvenile rearing

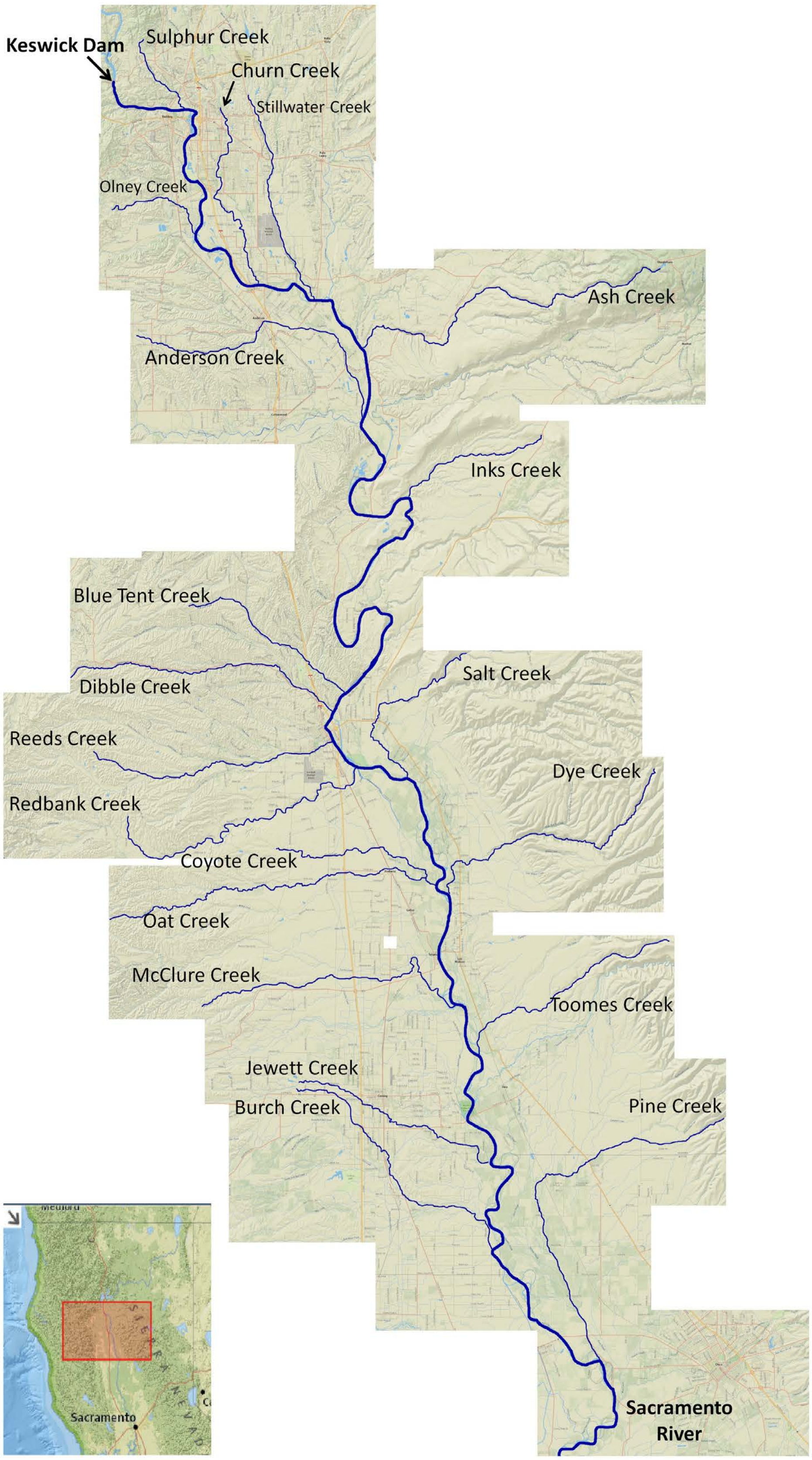

Figure 17. Upper Sacramento River Tributaries

Table 22. Upper Sacramento River Tributaries that May Provide Juvenile Rearing Habitat for Salmonids

Name	USGS Quad	Tributary Proximity to the Sacramento River
Tributaries Known to Support Juvenile Salmonid Rearing		
Pine	Ord Ferry	East
Toomes	Vina	East
Dye	Los Molinos	East
Oat	Los Molinos	West
Coyote	Gerber	West
Reeds	Red Bluff East	West
Brewery	Red Bluff East	West
Blue Tent	Red Bluff East	West
Dibble	Red Bluff East	West
Inks	Bend	East
Anderson	Ball's Ferry	West
Olney	Enterprise	West
Tributaries Presumed to Support Juvenile Salmonid Rearing		
Burch	Foster Island	West
Jewett	Vina	West
McClure	Vina	West
Red Bank	Red Bluff East	West
Salt	Red Bluff East	East
Ash	Ball’s Ferry	East
Stillwater	Ball’s Ferry	East
Churn	Cottonwood	East
Sulfur	Redding*	East
Tributaries with Low Potential to Support Juvenile Salmonid Rearing		
Seven Mile	Red Bluff East	East
Frasier	Bend	West
Spring	Bend	West
Clover	Cottonwood	East
Middle	Redding[a]	West
Salt	Redding[a]	West
Jenny	Redding[a]	West
Rock	Redding[a]	West
[a] Indicates 15-minute topographical quadrangle map		

Source: Modified from USFWS 1995

Fisheries and Aquatic Habitat

In addition to the diverse aquatic habitat provided by major and perennial tributaries to the Sacramento River, intermittent tributaries, floodplains and seasonal sloughs provide important non-natal seasonal rearing habitat for anadromous salmonids and seasonal breeding and rearing habitat for native and non-native resident fish species (Tehama County 2008). Rearing conditions in the tributaries are reported exist from approximately December through March. By April, conditions may be less favorable as water temperatures rise to intolerable levels, and piscivorous fish enter the tributaries to spawn. Juvenile Chinook salmon entering the tributaries early in the year, such as winter- and spring-run, probably derive the most benefit from tributary rearing (Maslin *et al*. 1995).

Intermittent tributaries in Tehama County where anadromous salmonid non-natal rearing has been observed include Toomes, Dye, Oat, Coyote, Reeds, Blue Tent, Dibble, Inks, Red Bank and Reeds Creek (Maslin *et al*. 1997; Maslin *et al*. 1998; and Maslin *et al*. 1999). However, there is no recent quantitative data on the extent to which salmon and steelhead use these intermittent streams (Tehama County 2008).

Many other small streams that feed larger tributaries may be found to be important for salmonid rearing. Because many of these small streams may have characteristics and habitat constraints similar to those listed in Table 1, they are not discussed in detail. In addition to its many tributaries, the Sacramento River has many sloughs (partially abandoned river or creek channels). The dynamics of the river change sloughs too rapidly for topographic maps to be useful in locating or describing them. Therefore, they can be addressed only generally. Sloughs that are open to the river, particularly if they have any flow from seepage, small tributaries, or agricultural drainage, have potential to provide rearing habitat. These sloughs have characteristics and habitat needs similar to the tributaries (USFWS 1995). Additional information regarding aquatic habitats for anadromous salmonids in the upper Sacramento River tributaries is summarized below for the north westside tributaries, Salt Creek (near Keswick), Sulphur Creek, Olney Creek, Churn and Stillwater Creeks, Inks Creek, and Paynes Creek .

North Westside Tributaries - Small streams draining the west side of the Sacramento Valley in the Redding-Anderson municipal area include Olney, Anderson, Salt (near Keswick Dam, not Red Bluff), and Middle creeks. These creeks do not have natural flow during the dry season. During the wet season, however, they have relatively large flows compared to the small size of the watersheds. The high flash-flood potential of the streamflow regime is attributable to the intensity of rainstorms at the north end of the valley and is further amplified by urbanization of the watershed. These tributaries enter the Sacramento River downstream of Shasta Reservoir.

The watersheds of these streams drain parts of the Coast Ranges and Klamath Mountains. The soils in these mountains are moderately to severely erodible in contrast to the soils of the eastside Sierra Nevada watersheds. Also in contrast with the eastside tributaries, the geology of the west side of the valley is not as conducive to the large groundwater springs that provide cold, sustained flows in the dry season (UFWS 1995).

Salt Creek Watershed – The Salt Creek watershed encompasses an area of about 2,800 acres and contains about 3 miles of tributary streams (Western Shasta RCD 2005). Salt Creek is an alluvial channel with some bedrock along its length, and flows from southwest to northeast, originating in the gently rolling terrain. The channel transports fine to medium coarse sediment with maximum sizes reaching one foot. The channel is somewhat confined in the lower one-half of its length (Highway 299 to Sacramento River) and has broader floodplain areas above Highway 299 with significant sediment depositional areas. The channel appears to be in relatively good condition from its confluence to its headwaters, and there is minimal channel modification, consisting mostly of road crossings (Western Shasta RCD 2005). Salt Creek is reportedly one of the last remaining relatively undeveloped watersheds in the rapidly growing Redding area (Shasta Resources Council 2005).

Salt Creek enters the west side of the Sacramento River approximately a half mile below Keswick Dam. Because Salt Creek is still relatively undeveloped and of good water quality, flows entering the Sacramento River just below Keswick Dam aid in dilution of contaminants entering from Iron Mountain Mine (Shasta Resources Council 2005). Resident rainbow trout, steelhead and fall-run Chinook salmon are known to use lower Salt Creek for spawning and juvenile rearing (CDFG 2004). Since 1997, Reclamation has injected over 96,000 tons of spawning gravel in the Sacramento River at the mouth of Salt Creek. In 2001, CALFED agencies funded activities to improve two fish ladders and a fish screen at the ACID diversion dam located in the Sacramento River downstream of Salt Creek. These spawning gravels and fish passage improvement were implemented to encourage spawning by natural runs of Chinook salmon, particularly winter-run Chinook salmon and steelhead in the Sacramento River between the ACID and Keswick dams (CDFG 2004).

Sulphur Creek Watershed – The Sulphur Creek watershed encompasses almost 3,000 acres, and has about 7 miles of intermittent stream and 2 miles of ephemeral stream, all located within a protected greenway. One of these intermittent streams, Sulphur Creek, is an urban stream that drains about 4.42 square miles in Shasta County and the City of Redding (SWAG 2004). Extensive mining, road building and railroad construction within the watershed resulted in the deterioration of fisheries and wildlife habitat, alteration of the natural hydrology, and stream channel degradation (SWAG 2004). The Sulphur Creek hydrograph has been dramatically altered by historic and current land-use practices. The long and narrow shape of the watershed leads to naturally-occurring high peak flows with a relatively short time of concentration (CALFED ERP 1998). These hydrograph conditions are compounded and exacerbated by the level of urbanization within the watershed. The channel in the lower reach of Sulphur Creek was filled with large deposits of boulders and cobbles, and there is evidence that later gravel mining further concentrated large sediment deposits in the channel. Additionally, when the stream was diverted through dredger mine tailings in the 1940’s, it self-adjusted to the increased bedload transport by straightening and steeping itself (CALFED ERP 1998). The resulting abnormally high bedload in this reach has caused aggradation, which in turn has caused lateral migration of the stream causing extreme bank erosion, loss of riparian vegetation, and an increase in the width-to-depth ratio (SWAG 2004).

Sulphur Creek, especially the lower reach, is believed to provide winter spawning and rearing habitat for native anadromous fish (SWAG 2004).

Olney Creek Watershed – The Olney Creek watershed encompasses an area of about 9,400 acres and contains about 8 miles of tributary streams. Flows during the dry months vary based on precipitation patterns, and the larger tributaries, such as Rock and Olney creeks, receive groundwater seepage throughout the summer months. This seepage may include normal groundwater discharge and seepage from the ACID canal (Western Shasta RCD 2005). Olney Creek flows from west to east through relatively undeveloped areas east of Highway 273 and through moderately developed areas between Highway 273 and the Sacramento River. The two-year peak flood flow in Olney Creek is estimated to be 1,939 cubic feet per second (cfs). The

100-year peak flood flow is estimated to be 4,318 cfs. The lower reach consists of flat gradient, meandering alluvial channel while the upper reaches are mostly confined with significant reaches of continuous bedrock. The channel transports fine to coarse sediment, with maximum sizes reaching three feet or greater. The upper reaches of Olney Creek appear to be in fair condition. Water quality samples taken from Olney Creek between September 2001 and July 2002 indicate that pH values ranged between 7.26 and 8.09. Dissolved oxygen was measured during 2002 and was detected from 8.8 to 9.1 mg/l. While some development has occurred, including construction of small dams and water diversions, the channel is relatively stable in that there are no significant erosion or depositional areas. The lower reach, however, has undergone some modification in the form of channelization, road crossings, and bank stabilization. As a result, the channel exhibits typical morphology for this stream type, with some available floodplain areas, pools and riffles, and riparian vegetation along stream banks (Western Shasta RCD 2005).

Western Shasta RCD has recently completed a fish passage barrier removal project for tributaries on the west side of Redding, including Olney Creek. Although CDFG does not believe that Olney Creek is suitable for fall-run Chinook salmon, it is believed that it would increase significant spawning area for resident (Sacramento River) rainbow trout (CDFG 2007). The removal of this structure would broaden the time window and the geographic range for upstream and downstream migration of *O. mykiss*.

Stillwater-Churn Creek Watershed – The Stillwater-Churn Creek watershed encompasses about 78,000 acres and is located in Shasta County east/northeast of Redding, California (SWRCB 2008). The area is bordered on the east by the Cow Creek watershed, west and southwest by the Sacramento River, and on the north by the Upper Sacramento River watershed. Stillwater, Churn and Clover creeks are the primary tributaries to the Sacramento River (SWRCB 2008). Precipitation occurs mostly during the winter and spring months as rain and averages 33.3 inches annually. The area exhibits a Mediterranean climate consisting of summers that are hot and dry, and winters that tend to be cool, rainy, and overcast. Temperatures average 62.0°F and range from an average of 55.3°F in the winter to 98.3°F in the summer. Extended periods of air temperatures exceeding 100° F during the day are not uncommon. Elevation ranges from 500 to 1,600 feet above sea level, and the topography of the watershed ranges from being nearly flat at the confluences with the Sacramento River, undulating in the foothills, and being of steep mountainous terrain at the headwaters of Stillwater and Churn Creeks (SWRCB 2008).

Stillwater, Churn, and Clover Creeks are intermittent streams that provide seasonally available habitat to fish and other aquatic organisms. Portions of Stillwater and Churn Creeks are designated as critical habitat for steelhead (*Oncorhynchus mykiss*) and spring-run Chinook (*O. tshawytscha*). However, salmonids have been observed in upstream portions that are not currently designated Critical Habitat (SWRCB 2008). There is no documentation of spawning spring-run Chinook salmon (Western Shasta RCD 2008). Steelhead may use the system as well, though most *O. mykiss* are likely the more common resident Sacramento River rainbow trout (Western Shasta Resource Conservation District 2008). Churn Creek may be a gravel-poor system and, while the creek remains un-dammed, it in many ways illustrates similar geomorphic responses that are frequently observed following impoundment, including: (1) winnowing of finer gravels from riffles; (2) channel incision; (3) long pools with steep banks and reduced complexity, (4) heavily vegetated riffles; (5) gravel bars entombed by vegetation (GMA 2006, Western Shasta RCD 2008 and SWRCB 2008). Urbanization (with commensurate alterations to the hydrologic regime and reduction in available sediment supply) is believed to be the primary driver for the modifications in physical processes resulting in these and other conditions (Western Shasta RCD 2008). These features make it challenging for Chinook salmon to find areas with adequate gravel for spawning and habitat for rearing juveniles.

Inks Creek Watershed – Inks Creek in an intermittent stream that enters the Sacramento River at RM 265. The watershed contains a Tuscan-Inks soil association found on old terraces east of the Sacramento River, which is comprised of soils that are cobbly and can be shallow to moderately deep. The Tuscan soils typically have a cemented hardpan, and the Inks soils consist of cobbly loam and a clay loam over a cemented substratum (Tehama County 2008). The Inks Creek watershed contains public lands managed by the Bureau of Land Management.

Inks Creek is reported to contain potential and current non-natal rearing habitat for juvenile Chinook salmon (Tehama Country RCD 2008). In 1989, CDFG surveyed about 3.5 miles of Inks Creek from the mouth to the confluence with the south fork. Ten salmon carcasses, four live fish, and three redds were observed. However, a population estimate was not made (CDFG 1989).

Paynes Creek Watershed – Originating in a series of small lava springs about 6 miles west of the town of Mineral, California, Paynes Creek flows into the Sacramento Valley from the east, and drains a watershed of approximately 93 square miles (USFWS 1995). Paynes Creek enters the Sacramento River at RM 253, which is about 5 miles north of the town of Red Bluff, California. Although there are no significant dams located on the stream, flows in Paynes Creek have been significantly affected by the recent drought conditions, as well as by 16 seasonal diversions for irrigation and stock watering. The lowermost irrigation diversion, about 2 miles upstream from the mouth, is the largest, with a capacity of approximately 8 cfs. This diversion provides water to irrigate the agricultural water rights holders who live in the Bend District, and BLM's Paynes Creek wetlands. CDFG owns and operates a fish screen on this diversion (USFWS 1995).

Paynes Creek is reported to support fall-run Chinook salmon when water conditions are adequate (USFWS 1995). Low flow and inadequate spawning gravel have been identified as significant factors limiting salmon production in Paynes Creek. In 1988, CDFG built five spawning riffles using 1,000 tons of spawning gravel. Because of low flows attributable principally to the recent drought, however, the reconstructed riffles have been sparsely used (USFWS 1995).

NORTHWESTERN CALIFORNIA DIVERSITY GROUP

Putah Creek Watershed Profile

Listed Species Present in the Watershed

Central Valley steelhead

Listed Species that Historically Occurred in the Watershed

Central Valley steelhead

Diversity Group

Northwestern California

Key Stressors

Key stressors to Central Valley steelhead in Putah Creek include, but are not limited to the following:

- ❖ Passage impediments/barriers by Solano Dam and Montecello dams affecting immigration and holding
- ❖ Low flow conditions and flow fluctuations affecting adult immigration and holding, juvenile rearing and outmigration, and embryo incubation
- ❖ Physical habitat alteration (i.e., limited instream gravel supply) affecting spawning
- ❖ Loss of floodplain habitat, natural river morphology, and riparian habitat and instream cover affecting juveniles

Watershed Description

The watershed of Putah Creek begins in the Coast Ranges at Cobb Mountain in Lake County at an elevation of 4,700 feet, and flows down to the Central Valley where it empties into the Yolo Bypass near sea level (Lower Putah Creek Coordinating Committee 2005). Putah Creek is the southernmost major drainage entering the Sacramento Valley from the west. The Putah Creek watershed is defined by two subbasins, the lower and upper Putah Creek watersheds (Lower Putah Creek Coordinating Committee 2005).

Lower Putah Creek is located in the southwestern corner of the Sacramento Valley and flows 26 miles across the valley floor from the Putah Diversion Dam to the Toe Drain in the Yolo Bypass. Putah Diversion Dam is a reregulating reservoir below Monticello Dam. The upper Putah Creek subbasin is defined by the portion of the watershed located upstream of Monticello Dam, which forms Lake Berryessa. Lake Berryessa captures runoff from 90 percent of the watershed. The upper watershed occupies about 600 square miles within the Coast Ranges (Lower Putah Creek Coordinating Committee 2005).

Geology

Four major rock units characterize the Coast Ranges, including areas in which the Putah Creek watershed has formed: (1) the Franciscan formation; (2) the Great Valley sequence; a relatively thin (1 mile or more thick) layer of black igneous rock and unusual green serpentinite (between the Franciscan and Great Valley units) that is believed to have originated in the Earth's mantle from beneath the continental crust; and (4) a fossil-filled sandstone and mudstone layer that is younger than the other formations and lays over the top of them (Lower Putah Creek Coordinating Committee 2005). The upper Putah Creek watershed area is formed within the steep mountain slopes formed by sandstone and shale, local areas of serpentine, and areas of volcanic rocks. As Putah Creek emerges from the mountains it enters the Central Valley, which was formed by the filling of an inland sea with thousands of feet of marine deposits, and with alluvial deposits from the Coast Ranges and the Sierra Nevada (Lower Putah Creek Coordinating Committee 2005).

Over the geologic timescale, high-flow events in Putah Creek have transported large quantities of erosive sandstone and other parent material from the mountains to the valley floor (Lower Putah Creek Coordinating Committee 2005). These high-flow events would deposit large-sized alluvium near the base of the mountains, forming the Putah Creek fan, and finer sediments were transported farther east onto the valley floor, providing the basis for the formation of productive agricultural soils that exist today (Lower Putah Creek Coordinating Committee 2005).

Hydrology

Hydrologic conditions in Putah Creek have been significantly modified since the construction of Monticello Dam and other Solano Project facilities (Putah Diversion Dam and Putah South Canal). Prior to the completion of Monticello Dam and other Solano Project facilities, runoff events were large and escaped the confinement of the stream banks, and caused extensive flooding along the creek (Lower Putah Creek Coordinating Committee 2005). Following the construction of the Solano Project facilities, Putah Creek's hydrologic regime became highly regulated (Lower Putah Creek Coordinating Committee 2005).

The seasonal instream flow and release patterns from Monticello Dam have become regulated through the May 2000 Putah Creek Accord (Accord) (Solano County Superior Court 2000). The Accord is intended to balance the competing uses for water and create as natural of a flow regime as feasible from the Putah Diversion Dam to the connection at the East Toe Drain in the Yolo Bypass. The focus of the Accord is on the protection and enhancement of native resident and anadromous fish populations and maintenance of riparian vegetation. Four functional flow requirements are set forth in the Accord pertaining to juvenile rearing flows, spawning flows for native resident fishes, supplemental flows for anadromous fishes, and drought-year flows. Table 18 shows the basic required flow regimes specified by the Accord as prescribed for "normal" and "drought" conditions (Lower Putah Creek Coordinating Committee 2005).

Land Use

The lower Putah Creek watershed is comprised of public and private lands. Private lands within and adjacent to the riparian corridor account for 78% of the creek and creek-side parcels, while 21.2% of the parcels within and adjacent to the creek are designated as public lands (Lower Putah Creek Coordinating Committee 2005). Land use consists of agriculture, idle farmland, and urban uses (i.e., residential, commercial, and industrial).

Fisheries and Aquatic Habitat

Prior to the mid-1800s, Putah Creek flowed out of the mountains spreading to the Sacramento Valley and deposited a delta-like sheath of silts, sands, and cobbles by major flood events (Lower Putah Creek Coordinating Committee 2005). With each major flood event, the sediment deposition elevated the creek bed, resulting in Putah Creek changing its course, leaving levee-like strips of gravel flanking the channel (Lower Putah Creek Coordinating Committee 2005). These natural levees were overtopped as the creek sought new configurations (Lower Putah Creek Coordinating Committee 2005).

During the Euro-American settlement, riparian vegetation was removed along the creek to accommodate agricultural practices (Shapovalov 1946 *as cited in* Lower Putah Creek Coordinating Committee 2005). Riparian vegetation removal narrowed the riparian corridor and resulted in elevated water temperatures (Lower Putah Creek Coordinating Committee 2005). Flood control modifications reduced flow velocities and increased the ratio of still to flowing water by widening the channel and eliminating floodplains within incised channels (Marovich, R., pers. comm. 2003 *as cited in* Lower Putah Creek Coordinating Committee 2005). The combination of these alterations increased habitat for introduced warmwater species (e.g., common carp, small mouth bass, etc.) (Lower Putah Creek Coordinating Committee 2005). The Solano Projects altered the flow regime, and further altered physical channel characteristics (e.g, channel structure, sediment transport, etc) and biological characteristics (e.g., species diversity, trophic structure, etc.) (Lower Putah Creek Coordinating Committee 2005).

Table 23. Summary of flows at or near Putah Diversion Dam before and after construction of the Solano Project, and the Putah Creek Accord release schedule

Variable	Flow (cfs)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pre-Project (1934–1956) [1]												
Max	3,957	6,468	3,506	2,729	452	156	64	32	21	45	807	5,110
Med	794	1,075	736	281	125	42	7	5	6	6	37	296
Min	45	67	151	50	17	7	2	0	2	1	3	9
Post Project (1971–1981, 1985–1990) [1]												
Max	1,239	2,239	3,403	2,020	51	43	43	34	36	20	50	85
Med	38	41	33	46	43	43	43	34	20	20	25	25
Min	25	18	26	45	33	33	33	26	16	15	26	25
Putah Creek Accord Release Schedule [2]												
Normal Year – PDD [3,4,5]	25	16	26	46	43	43	43	34	20	20	25	25
Normal Year – I-80 [3, 4, 5]	15	15	25	30	20	15	15	10	5	5	10	10
Drought Year – PDD [6]	25	16	26	46	33	33	33	26	15	15	25	25
Drought Year – I-80 [6]	2	2	2	2	2	2	2	2	2	2	2	2

1 Adapted from USFWS 1993; years post-project data selected to reflect periods similar to available pre-project conditions.
2 Solano County Superior Court 2000 and Moyle, pers. comm., 2002. Note: specific pulse flow requirements not shown.
3 Normal year rearing flows. Normal year exists when Lake Berryessa storage exceeds 750,000 acre-feet on April 1. Values are shown as daily average flow requirements. Continuous flow must be maintained from the I-80 bridge to the Yolo Bypass.
4 Spawning flows modify the normal year rearing flows, as follows: a) 3-day pulse release at PDD sometime between February 15 and March 31 every year, with minimum of 150 cfs, then 100 cfs, then 80 cfs, each for 24 hours, and following the pulse; b) 30 days of releases sufficient to maintain 50 cfs at I-80 bridge, then ramped down over 7 days to match the normal year rearing requirements.
5 Supplemental flows modify the normal year rearing flows, as follows: a) 5-day pulse is required sometime between November 15 and December 15 (timed following removal of flash boards at Los Rios dam) to maintain at least 50 cfs average daily flow at confluence with East Toe Drain, and following the pulse; b) a minimum of 19 cfs is required at I-80 bridge until March 31; and c) 5 cfs flow at East Toe Drain is required from November 1 to December 15 and from April 1 to May 31.
6 Drought year exists when Lake Berryessa storage is less than 750,000 acre-feet on April 1. Values reported in same format as for normal year flow requirements. Continuous flow is not required at Yolo Bypass.

Source: Lower Putah Creek Coordinating Committee 2005.

Steelhead

Anadromous steelhead are considered to have historically spawned in the upper tributaries flowing into Putah Creek above the Berryessa Valley (now Lake Berryessa). Steelhead were sometimes reported to occur downstream of the Putah Diversion Dam, but the reports are unconfirmed (Moyle and Crain 2003). O.mykiss continue to spawn in the tributaries to Lake Berryessa (Moyle, pers. comm., 2003, as cited in Lower Putah Creek Coordinating Committee 2005).

Stony Creek Watershed Profile

Listed Species Present in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Listed Species that Historically Occurred in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Diversity Group

Northwestern California

Key Stressors

Key stressors to Central Valley steelhead in Stony Creek include, but are not limited to the following:

- ❖ Passage impediments/barriers by Black Butte and North Diversion dams affecting immigrating adults
- ❖ Water temperature and/or water quality changes in Stony Creek affecting adult immigration and holding, juvenile rearing and outmigration, and embryo incubation

Watershed Description

Originating in the Coast Ranges (USFWS 1995), Stony Creek is the second-largest west-side tributary to the Sacramento River and drains approximately 740 square miles along California's Coastal Range in Tehama, Glenn, Colusa, and Lake Counties. The Stony Creek watershed has three reservoirs (Black Butte, Stony Gorge, and East Park), which have a combined storage capacity of more than 260 thousand-acre-feet (taf) (GCRCD 2009). Typically, the watershed is discussed as two separate sections, the Upper Stony Creek Watershed and the Lower Stony Creek Watershed, with Black Butte Dam and its associated ridgeline forming the boundary (H.T. Harvey and Associates 2007a). The upper watershed encompasses approximately 473,915 acres including the Grindstone Creek, Briscoe Creek, Upper and Middle Stony Creek watersheds, while the lower watershed is approximately 24,497 acres in size (H.T. Harvey and Associates 2007a).

Existing conditions in Stony Creek preclude the annual production of spring-run Chinook salmon and steelhead (H.T. Harvey and Associates 2007a). Excessively low flows and warm water temperatures in Stony Creek during all life stages prevents the successful production of spring-run Chinook salmon and steelhead (H.T. Harvey and Associates 2007a). Any efforts to improve habitat conditions for anadromous salmonids in Stony Creek should consider the potential effects of climate change, which may prohibit successful production of coldwater fish in this low elevation watershed.

Geology

Upper Stony Creek

The Upper Stony Creek Watershed overlies mechanically weak volcanic, metamorphic and metasedimentary rocks of the Franciscan Complex (Swanson and Kondolf 1991 *as cited in* H.T. Harvey and Associates 2007a). The west side of the north-south trending linear valley marks the contact between the Franciscan Complex and younger sedimentary marine sandstones and conglomerates of the Great Valley Sequence, tertiary volcanic rocks, and alluvial deposits of Pleistocene and Holocene age (H.T. Harvey and Associates 2007a). The older non-marine alluvial deposits consist of consolidated inter-bedded gravel, sandstones, and siltstones (H.T. Harvey and Associates 2007a).

Lower Stony Creek

The majority of the Lower Stony Creek Watershed is comprised of alluvial fan deposits of the Pleistocene and Holocene epochs (H.T. Harvey and Associates 2007a). Releases from Black Butte Dam enter lower Stony Creek near the apex of the Stony Creek alluvial fan, and lower Stony Creek flows entirely through these Pleistocene and Holocene Stony Creek alluvial fan deposits, until near Mills Orchard, where the fan deposits become interbedded with finer-grained Sacramento River floodplain deposits (H.T. Harvey and Associates 2007a).

The alluvial fan surface's broad, concave-upward topography typically drains rainfall-derived runoff away from, not into the lower Stony Creek channel. The alluvial fan surface does not contribute flow to the channel so it is not technically within the watershed (H.T. Harvey and Associates 2007a). The Lower Stony Creek Watershed area is therefore a narrow band, which includes the currently active channel area and formerly active channel and floodplain terraces inset within the broader inactive fan deposits (H.T. Harvey and Associates 2007a).

Hydrology

Upper Stony Creek Watershed

Streamflows in the Upper Stony Creek Watershed are regulated by East Park and Stony Gorge reservoirs before flowing into Black Butte Lake. The main tributary streams drain eastward from their headwaters into a broad north-south trending valley through which Stony Creek flows northerly for about 30 miles to its confluence with Grindstone Creek, then flows northeasterly for about 10 miles to Black Butte Lake (Swanson and Kondolf 1991 *as cited in* H.T. Harvey and Associates 2007a).

East Park and Stony Gorge reservoirs impound water for irrigation and have no flood control capacity. These reservoirs likely attenuate flood peaks from the upper watershed to some degree, but their primary effect on the hydrology of the system is increasing summer base flows downstream. These reservoirs do not significantly reduce the sediment yield from the upper basin because they do not intercept sediment from tributaries with the greatest sediment yield, notably Grindstone Greek (H.T. Harvey and Associates 2007a).

Lower Stony Creek Watershed

Flows from Lower Stony Creek Watershed are controlled by releases made from Black Butte Lake for flood control and irrigation, and irrigation diversions. Black Butte Lake is operated from April to October for irrigation by the U.S. Bureau of Reclamation, while the U.S. Army Corps of Engineers (USACE) operates the reservoir from November to March for flood control purposes (H.T. Harvey and Associates 2007a).

Since the construction of Black Butte Dam in 1963 the frequency and extent of flooding along lower Stony Creek has been significantly reduced (H.T. Harvey and Associates 2007a). However, there are now higher and more variable summer and early fall flows, attributed to irrigation releases. Flows are often sustained through late fall. In 2007, H.T. Harvey and Associates (2007b) conducted a detailed analysis of hydrologic changes due to Black Butte Dam. Their analysis showed that the dam reduced the duration of flows larger than 15,000 cfs by an average of about 1 day per year since 1963, while the duration of flows between 14,000 and 15,000 cfs has increased by an average of 0.62 days per year (H.T. Harvey and Associates 2007b).

Land Use

Upper Stony Creek Watershed

The majority of the Upper Stony Creek Watershed is publicly owned (i.e., Mendocino National Forest) (H.T. Harvey and Associates 2007a). The landscape of the Upper Stony Creek Watershed reflects the inhabitation and management of several cultures and eras, including Native American residence and Euro-American settlement (USDA 1995 *as cited in* H.T. Harvey and Associates 2007a). Mining, timber harvesting, agriculture and grazing, water management, and recreational land use practices can be observed in the Upper Stony Creek Watershed.

Lower Stony Creek Watershed

Compared to the Upper Stony Creek Watershed, the Lower Stony Creek Watershed is smaller in area. By contrast, approximately 96% of the land within the lower watershed is privately owned. Land uses include agriculture, grazing, gravel mining and rural residences (USBR 1998 *as cited in* H.T. Harvey and Associates 2007a). Some public land, associated with diversion canals and other types of infrastructure also exists within the lower watershed (H.T. Harvey and Associates 2007a).

Fisheries and Aquatic Habitat

The upper limit of anadromous fish access in Stony Creek is Black Butte Dam. The existing opportunistic use by salmonids of Stony Creek is currently limited both spatially and temporally, due to unsuitable water temperatures and flows. Only fall-run Chinook salmon have life history requirements nearly compatible with the existing conditions of lower Stony Creek. Improvements to water temperature and flows sufficient to support annual production of fall-run Chinook salmon also would enhance periodic rearing of non-natal Chinook salmon and steelhead trout (H.T. Harvey and Associates 2007a).

Stony Creek does not currently support a sustained annual cycle of anadromous salmonid production. When connected with the Sacramento River, Lower Stony Creek provides non-natal rearing habitat for steelhead and all four runs of Chinook salmon (H.T. Harvey and Associates 2007a).

Steelhead

Data on the relative abundance of fishes in lower Stony Creek comes from trapping and netting by the U. S. Bureau of Reclamation from 2001-2004 (Corwin and Grant 2004). From a total catch of 64,962 fish, two were juvenile steelhead (H.T. Harvey and Associates 2007a). As reported by H.T. Harvey and Associates (2007a), 53 stranded juvenile steelhead were rescued from Lower Stony Creek in March 1997.

While natal rearing by salmonids in Stony Creek occurs during some years, many juvenile steelhead (and Chinook salmon) from Lower Stony Creek are believed to primarily represent non-natal rearing by juveniles spawned elsewhere in the Sacramento River system. Maslin and McKinney (1994) collected fall-run Chinook salmon, spring-run Chinook salmon and steelhead juveniles in the lower three miles of Stony Creek. Corwin and Grant (2004) linked capture of steelhead (and spring- run Chinook salmon) in Lower Stony Creek to specific hatchery releases upstream in the Sacramento River or at Coleman National Fish Hatchery (H.T. Harvey and Associates 2007a).

Thomes Creek Watershed Profile

Listed Species Present in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Listed Species that Historically Occurred in the Watershed

Central Valley spring-run Chinook salmon (Dependant, not historically abundant) - *Oncorhynchus tshawytscha*
Central Valley steelhead

Diversity Group

Northwestern California

Key Stressors

Key stressors to Central Valley spring-run Chinook salmon and steelhead in the Thomes Creek watershed as identified in the Recovery Plan, include but are not limited to the following:

- Passage impediments/barriers by agricultural diversion dams, braiding and natural channel gradients affecting adult immigration and holding
- Water temperature changes affecting adult immigration and holding, spawning, and embryo incubation
- Agricultural diversions limiting instream flows

Watershed Description

As reported by TCRCD (2006), Thomes Creek originates in the western portion of the Tehama West Watershed and flows eastward for approximately 70 miles before entering the Sacramento River four miles north of the town of Corning, California. The Thomes Creek Watershed extends from the Yolla Bolly-Middle Eel Wilderness Area, south to Anthony Peak.

Numerous seasonally created agricultural diversions in Thomes Creek reduce instream flows, impede fish passage, and entrain small fish. Most of these diversions are unscreened. Restoration actions for anadromous salmonids in Thomes Creek should be directed at minimizing the adverse effects of agricultural diversions and improving fish passage to the upper watershed. Much of Thomes Creek can be characterized as boulder filled canyons, which likely present challenging conditions for spring-run Chinook salmon and steelhead on their upstream migration to holding and spawning habitats in the headwaters.

Geology

The Tehama West Watershed encompasses an area of diverse geologic features critical to Tehama County's agricultural and mining industries (TCRCD 2006). The Thomes Creek watershed includes portions of the eastern Coast Range and western Great Valley Geologic Provinces (TCRCD 2006). The Coast Range Province is characterized by northwest-trending mountain ranges composed of thick Mesozoic and Cenozoic strata, commonly characterized by zones of extensive shearing and the presence of ophiolite/serpentinite mélanges (TCRCD 2006). The Great Valley Province is a sedimentary basin, characterized by a thick deposit of moderately deformed Jurassic and Cretaceous marine sedimentary layers that consist of detrital materials derived from uplifted basement rocks of the Klamath Mountain and Coast Range Provinces (TCRCD 2006). Great Valley rocks consist primarily of mudstone, shale, and sandstone (TCRCD 2006). These units yield an abundance of suspended sediment but relatively little gravel to the watershed (TCRCD 2006). An analysis by the USGS showed that the annual suspended sediment yield of Thomes Creek is nearly three times higher than other streams of comparable size (TCRCD 2006). Thomes Creek continuously transports and deposits eroded sediments along floodplains of the Sacramento River (TCRCD 2006).

For further information on the geology of the Thomes Creek Watershed, refer to the Tehama West Watershed Assessment (TCRCD 2006).

Hydrology

Thomes Creek drains a watershed of approximately 188 square miles and contributes a mean annual run-off of about 200,000 acre-feet (TCRCD 2006). Although there are two seasonal diversion dams located near Paskenta and Henleyville, Thomes Creek does not have any major dams (TCRCD 2006).

Headwaters of the streams in the Tehama West Watershed, including Thomes Creek, have relatively little, if any, drainage area with significant snowpack (TCRCD 2006). However, the upper-most elevation of Thomes Creek exceeds 5,000 feet and during some years may have significant snowpack. In the lower portion of the drainage, snowfall is infrequent and does not significantly contribute to streamflow in Thomes Creek (TCRCD 2006). Thomes Creek is usually dry or intermittent below the USGS stream gauge near Paskenta until the initial heavy Fall rains occur (DWR 2009). Hence, Thomes Creek exhibits rapid responses to storms, and flow levels fluctuate greatly between storm-periods and intervening dry spells (TCRCD 2006). Peak flows in Thomes Creek generally occur during the month of February (Table 24).

Due to the hydrology of the Tehama West Watershed, including Thomes Creek, groundwater is the primary water supply, and because surface water supplies are unpredictable and limited, future growth in the region and water demand during drought conditions will depend on the continued availability of groundwater (TCRCD 2006).

Table 24. Thomes Creek monthly stream flow

Month	Thomes Creek (1921 – 1996)		
	Mean	Minimum	Maximum
January	583	12.4	2,900
February	706	23.2	3,483
March	620	48.9	2,080
April	551	45.3	1,879
May	354	18.2	1,406
June	116	1.41	591
July	23.5	0	133
August	6.28	0	38.1
September	5.08	0	25.5
October	24.7	0	310
November	159	2.85	1,500
December	395	6.93	2,879
Average	295	-	-

Source: TCRCD 2006

Land Use

The Thomes Creek Watershed is largely rural, with isolated pockets of human inhabitants, primarily concentrated along Interstate 5 (TCRCD 2006). Land use in this watershed largely depends on ownership (TCRCD 2006). While most of the low- and mid-elevation lands are held by private individuals who use these areas primarily for agriculture (i.e., ranching and farming) and residential uses, the upper elevations are held by commercial timber companies and the U.S. Forest Service or the Bureau of Land Management (TCRCD 2006).

Fisheries and Aquatic Habitat

The physical and hydrologic characteristics of the Thomes Creek watershed determine the habitat availability to fishery resources. Flows tend to rise quickly following storm events, drop equally promptly following storms, and carry very large quantities of sediment (TCRCD 2006). The snowpack in this watershed results in relatively light warm-season runoff, resulting in perennial Coast Range stream reaches; mid-reach sections that may be dry in mid-summer; and lower reaches near the Sacramento River that may contain small amounts of water from irrigation run-off (TCRCD 2006). Thomes Creek has an unimpaired hydrologic pattern of flashy winter and spring flows and very low summer and fall flows, creating an environment of fairly inconsistent habitat (CALFED 2000a). Thomes Creek is usually dry or intermittent below the USGS stream gage near Paskenta until the first heavy fall rains occur (DWR Website 2007). Therefore, spring-run Chinook salmon utilization of Thomes Creek would likely only occur during wet years. Inconsistent flows, particularly during the fall and early winter months, promote an increased potential for redd dewatering.

There are no significant dams on Thomes Creek other than two seasonal diversion dams, one near Paskenta and the other near Henleyville. Several small pump diversions are seasonally operated in the stream (DWR Website 2007). These dams would be in place during the time when spring-run Chinook salmon would be immigrating to upstream areas and likely present obstacles to upstream immigration. Additionally, gravel mining downstream of the Tehama-Colusa Canal siphon crossing has reportedly resulted in a partial barrier to salmonids returning to Thomes Creek to spawn (Vestra Resources, Inc. 2006).

Thomes Creek has been evaluated in recent years with regards to its upper reach accessibility to anadromous fish. In May 2004 the California Department of Fish and Wildlife determined that an impassible barrier to Chinook salmon and steelhead exists at the point immediately above the confluence of the stream with Horse Trough Creek (Barron, F. Personal communications, as cited in TCRCD 2006). This location is approximately 9 miles upstream from Paskenta and at an elevation of approximately 1,500 feet (TCRCD 2006).

During most years, water temperatures during the summer months are likely too warm to support adult spring-run Chinook salmon holding. Chinook salmon utilizing Thomes Creek for spawning likely hold in the mainstem Sacramento River.

The lower reach of Thomes Creek has been significantly altered by the construction of flood control levees and bank protection measures (i.e., riprapping) (CALFED 2000a), resulting in reduced habitat availability for juvenile salmonids.

Spring-Run Chinook Salmon

GrandTab escapement data for Thomes Creek spring-run Chinook salmon is generally unavailable. However, in 1998 and 2002, spring-run Chinook salmon escapement was reported to be 1 and 2, respectively (CDFW 2009; D. Killam, pers. comm., 2009).

As reported in the Tehama West Watershed Assessment (TCRCD 2006), California Department of Fish and Wildlife files provide anecdotal information regarding Chinook salmon usage of Thomes Creek. In one memo, spring-run Chinook were reported in the stream in 1946 and 1961; however, the locations of the observations were not noted. In 1958 a rancher observed 30–40 spring-run Chinook salmon near Henleyville (TCRCD 2006).

Steelhead

As reported by TCRCD (2006), in 1982, 22 species of fish were recorded within various portions of Thomes Creek (Brown *et. al*. 1983 as cited in CALFED 2000). Steelhead were reported to be the most abundant fish species above the “Gorge”, however, these fish were likely rainbow trout, as there is an anadromous fish barrier a short distance above the “Gorge” (TCRCD 2006).

Cottonwood/Beegum Watershed Profile

Listed Species Present in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Species that Historically Occurred in the Watershed

Central Valley spring-run Chinook salmon (Dependant population, not historically abundant)
Central Valley steelhead

Diversity Group

Northwestern California

Key Stressors

Key stressors to Central Valley spring-run Chinook salmon and steelhead in the Cottonwood/Beegum watershed include, but are not limited to the following:

- Loss of floodplain and riparian habitat and instream cover from gravel mining affecting juvenile rearing and outmigration\]
- Loss of natural river morphology from gravel mining (e.g., channel braiding) affecting adult immigration, juvenile rearing and outmigration
- Low flow conditions (i.e., low flows and flow fluctuations) associated with attraction and migratory cues in Cottonwood Creek affecting adult immigration, spawning and embryo incubation
- Natural elevated water temperatures and poor water quality affecting adult immigration and holding, spawning and embryo incubation
- Natural Spawning habitat availability affecting adult spawning

Watershed Description

Cottonwood Creek is the third largest watershed tributary west of the Sacramento River and the largest undammed tributary in the upper Sacramento River basin (CALFED 1997). The watershed is located within Shasta and Tehama counties on the north-west side of northern California's Central Valley, with a peak elevation of approximately 7,860 feet (CH2MHILL 2002, 2007) (Table 25). The lower two-thirds of the drainage lies in the Central Valley uplands, while the upstream portion includes the east slope of the North Coast Mountain Range and Klamath Mountains, and the southern slopes of the Trinity Mountains (CH2MHILL 2002). Cottonwood Creek is fed by three major branches (i.e., North, Middle, and South forks).

Cottonwood Creek itself does not contain suitable spawning habitat to support a spring-run Chinook salmon population. However, Beegum Creek, a tributary of Cottonwood Creek, does currently support a small persistent population (since 1998). Lindley *et al*. (2004) considers the Beegum Creek population to be dependant upon input of migrants from populations such as Deer, Mill and Butte creeks (thereby classified as a "dependent" population). Another possibility is that the group of streams in the Northwestern California Diversity Group operate as a metapopulation (Hanski and Gilpin, 1991), i.e., individual populations may not be viable on their own, but migration among members of the group maintains persistence of the whole group. Either way, the small area of available habitat argues against the existence of an independent population historically. The classification of these populations as dependent does not mean that they have no role to play in the persistence or recovery of the Central Valley spring-run Chinook salmon ESU. If these populations are adapted to their unusual spawning and rearing habitats, they may contain a valuable genetic resource (perhaps being more tolerant of high temperatures than other spring-run Chinook salmon). These habitats and populations may also serve to link other populations in ways that increase ESU viability over longer time scales (Lindley *et al*. 2004).

The prospects for spring-run Chinook salmon in Beegum Creek are dampened by global warming. Spring-run Chinook salmon in Beegum Creek are limited to low elevation habitat that is thermally marginal now, and will become intolerable within decades if the climate warms as expected (Williams 2006).

Table 25. Cottonwood Creek watershed characteristics

Characteristic	Value
Watershed Area	938 square miles
Cottonwood Creek Stream Length	68 miles
Headwater Elevation	7,680 feet
Mean Discharge	860 cubic feet per second (cfs)
10-year Flood	50,000 cfs
100-year Flood	93,000 cfs
Mean precipitation	36 inches

Source: CH2MHILL 2007

Beegum Creek is a major tributary to the Middle Fork Cottonwood Creek. The North, Middle, and South forks of Beegum Creek originate in the easternmost portion of the Shasta-Trinity National Forests and converge to form the mainstem of Beegum Creek before entering a remote, steep-sided canyon known as Beegum Gorge (CH2MHILL 2002).

Geology

The three principal geological provinces in the Cottonwood Creek watershed are the Great Valley Province, the Coast Range Province, and the Klamath Mountain Province. The Great Valley Province is a 400-mile-long by 60-mile-wide sedimentary basin that comprises the majority of the watershed (CH2MHILL 2002). The Coast Range Province and the Klamath Mountains Province consist of various highly erosive formations including South Fork Mountain

Schist, Rattlesnake Creek terrain, and North Fork terrain, in addition to the decomposed granitic soils of the Shasta Bally Batholith (CH2MHILL 2002).

The Coast Range fault, Stoney Creek fault, Cold Fork fault, Sulfur Spring fault, Oak Flat fault, Battle Creek fault, and numerous cross faults and thrust faults occur in the Cottonwood Creek watershed. Fault traces located east of South Fork are likely obscured by stream activity and agricultural practices (USGS 1988; WET 1991; Dupras 1997 *as cited in* CH2MHILL 2002). The most recent fault movement is believed to have occurred more than 125,000 years ago (DWR 1993 *as cited in* CH2MHILL 2002).

Large, active landslides that contribute to the sediment discharge are abundant in the South Fork Mountain Schist of the South Fork of Cottonwood Creek (DWR 1992 *as cited in* CH2MHILL 2002) and the Rattlesnake Creek terrain of Beegum Creek (USFS 1997 *as cited in* CH2MHILL 2002). A notable slide is located on Slide Creek, tributary to the South Fork of Cottonwood Creek; in 1995 this slide contributed a large amount of sediment to South Fork Cottonwood Creek. Cottonwood Creek is a major contributor of spawning gravel to the Sacramento River (P. Bratcher, pers. comm., 2009).

Hydrology

The entire Cottonwood Creek watershed is essentially unregulated, although a small reservoir, Rainbow Lake (capacity 4,800 acre-feet), is located on the NF Cottonwood Creek (Graham Matthews and Associates 2003). The hydrology of Cottonwood Creek is typical of watersheds found along the west side of the Sacramento Valley (CH2MHILL 2002). The relatively low elevation of the watershed limits the amount of snowpack that can accumulate in any given year, which results in a hydrologic regime closely correlated to storm events (CH2MHILL 2002). Mean annual runoff in Cottonwood Creek from 1941-2000 is approximately 645,000 acre-feet (Graham Matthews and Associates 2003). Cottonwood Creek is a source of flood flow in the Sacramento River between Shasta Dam and Ord Ferry. Groundwater development is largely limited to the alluvial area near the confluence with the Sacramento River (CH2MHILL 2002).

Land Use

Human impacts on Cottonwood Creek watershed began in the 1850's with gold mining operations. The gold mining in placer deposits commonly used dredge, hydraulic, and ground-sluicing techniques, resulting in the discharge of sediment to the watershed. Effects resulting from historical mining operations have generally dissipated, with the possible exception of the presence of residual mercury wastes in the tailings of historical mining sites (CH2MHILL 2007).

The Cottonwood Creek Watershed remains relatively undeveloped, and is generally characterized by tracts of harvestable timber in the upper reaches, irrigated pastureland in the middle reaches, and ranches, residential housing, and gravel mining operations in the lower reaches. Approximately 70 percent of land within the watershed is privately owned (CH2M HILL 2002). The Beegum Creek watershed is generally forest-covered and has not been significantly modified (D. Killam, CDFW, pers. comm. 2009).

Fisheries and Aquatic Habitat

The Cottonwood Creek watershed continues to provide habitat for anadromous fish, including spring-run Chinook salmon and steelhead. Within the Cottonwood Creek Watershed, spring-run Chinook salmon and steelhead are known to utilize the mainstem, North Fork, Middle Fork and South Fork of Cottonwood Creek, in addition to Beegum Creek (CH2MHILL 2002). However, Beegum Creek is the principal location for spring-run Chinook salmon holding and spawning in the Cottonwood Creek watershed. Refer to Table 26 for habitat characteristics of Cottonwood and Beegum Creeks. Environmental factors including hydrology, stream temperature, channel morphology, and gravel recruitment allow Cottonwood Creek to support significant fish populations on a seasonal and year-round basis (RMI 1987 *as cited in* CH2MHILL 2002).

Spring-Run Chinook Salmon

Historically, approximately 500 adult spring-run Chinook salmon may have spawned in Cottonwood and Beegum Creeks annually (CH2MHILL 2002). Recent Beegum Creek spring-run Chinook salmon escapement estimates are displayed in Table 27. The highest known spring-run Chinook salmon escapement in Beegum Creek is 477, occurring in 1998. Spring-run Chinook salmon escapement has generally exhibited a downward trend from 2001 through 2008.

Table 26. Habitat characteristics of Cottonwood and Beegum Creeks

Creek	Total Length (miles)	Anadromous Access (miles)	Maximum Elevation (feet)	Suitable Spawning Habitat (sq. ft.)
Mainstem	20.57	20.57	350	152,400
North Fork	28.0	20.24	5,720	37,400
Middle Fork	30.5	Unknown	7,860	36,600
South Fork	56.78	43.91	7,900	165,900
Beegum Creek	33.49	18.0	Unknown	Unknown

Source: CH2MHILL 2002. Data from CDFW (1978)

Table 27. Adult spring-run Chinook salmon population estimates for Cottonwood Creek from 1993 to 2011. Estimates are not available for all years.

Year	Adult Estimate	Year	Adult Estimate	Year	Adult Estimate
1993	1	**2000**	122	**2007**	34
1994		**2001**	245	**2008**	
1995	8	**2002**	125	**2009**	
1996	6	**2003**	73	**2010**	15
1997		**2004**	17	**2011**	2
1998	477	**2005**	47		
1999	102	**2006**	55		

Sources: CDFW Grandtab; personal communications with DFG and FWS biologists.

Steelhead

Cottonwood Creek is one of the major tributaries to the Sacramento River system that supports steelhead spawning (CH2MHILL 2002). Because they migrate during high flows, and it is difficult to distinguish juvenile steelhead from resident rainbow trout, few steelhead population estimates have been recorded in Cottonwood Creek (CH2MHILL 2002). The USFS and CDFW have observed populations of juvenile steelhead in the upper South Fork Cottonwood Creek Yolla Bolly Middle Eel Wilderness Area in the summer of 1976 (CH2MHILL 2002). Small runs of adult steelhead have been observed to migrate in the mainstem and lower reaches of the North, Middle, and South Fork Cottonwood Creek.

Clear Creek Watershed Profile

Listed Species Present in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Listed Species that Historically Occurred in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Diversity Group

Northwestern California

Key Stressors

Key stressors to spring-run Chinook salmon and steelhead in Clear Creek include, but are not limited to the following:

- Passage impediments/barriers at Whiskeytown Dam affecting adult immigration, and consequently holding, spawning, redd superimposition, competition for habitat, hybridization and genetic integrity
- Water temperatures and water quality affecting adult immigration and holding, spawning and embryo incubation
- Physical habitat alteration (particularly associated with limited supplies of instream gravel), affecting adult spawning habitat suitability
- Flow conditions (i.e., low flows) affecting juvenile rearing and outmigration
- Sedimentation affecting embryo incubation (*e.g*., recent fires)
- Loss of floodplain habitat and natural river morphology affecting juvenile rearing and outmigration

Watershed Description

Clear Creek is the first major tributary to the Sacramento River below Shasta Dam. Clear Creek originates in the mountains east of Clair Engle Reservoir and flows approximately 35 miles to its confluence with the Sacramento River at RM 289 near the south Redding city limits in Shasta County, California. Clear Creek drains approximately 238 square miles (USFWS 1995).

Whiskeytown Dam, constructed in 1963 near RM 18.1, stores and regulates run-off from the Clear Creek watershed and diversions from the Trinity River (USFWS 1995). The former McCormick-Saeltzer Dam was located approximately 12 miles downstream from Whiskeytown Dam at RM 6.4, and diverted water for irrigation use (USFWS 1995), but was removed in 2000.

The stream channel below Whiskeytown Dam can be divided into two predominant types at Clear Creek Road Bridge (RM 8.5) (USFWS 1995). Upstream, the creek is mainly confined by steep canyon walls and is characterized by falls, high gradient riffles, and deep pools (USFWS 1995). The substrate is mainly bedrock, large boulders, and fine sand. Downstream from RM 8.5 is the alluvial reach with a much lower gradient and a much wider valley relatively unconstrained by bedrock (USFWS 1995). Substrate is mainly a mixture of cobble, gravel, and sand (USFWS 1995).

The climate in the Clear Creek watershed is Mediterranean, with most precipitation occurring in the winter months (i.e., November through April), and dry summers with temperatures exceeding 100°F (McBain and Trush *et al*. 2000). Average annual precipitation in the Clear Creek watershed varies from 20 inches near the confluence with the Sacramento River to over 60 inches in the upper watershed (McBain and Trush *et al*. 2000). Precipitation is primarily rainfall, with snow occurring at the highest elevations of the watershed (McBain and Trush 2000).

The Clear Creek spring-run Chinook salmon and steelhead populations are currently considered persistent, dependent upon input of migrants from populations such as Deer, Mill and Butte creeks (thereby classified as a "dependent" population). Clear Creek historically was not known to support a large Central Valley spring-run population. Records from historical data sets are sparse, so the abundance that is seen in Clear Creek today for spring-run salmon and for steelhead does not have an adequate baseline to determine what the original carrying capacity was for this watershed. Since 1998, spring-run Chinook salmon have shown an increasing trend in abundance. In 2000 a small dam was removed which opened up 12 miles of prime spawning habitat for spring-run and steelhead. Increasing abundance is due in part to the reliable cool water source diverted from the Trinity River water, released at Whiskeytown Reservoir (Reclamation 2008). In addition, spring-run Chinook salmon and steelhead populations in Clear Creek have also responded to extensive restoration efforts by joint agency partnerships through such programs as CVPIA and CALFED.

Geology

Lower Clear Creek flows over Pleistocene age stream gravel that has been extensively mined. The historical pre-dam transport of gravel into lower Clear Creek is not known, and the present transport and recruitment of gravel in lower Clear Creek also is unknown. Lower Clear Creek, below Whiskeytown Dam can be grouped into two reaches. The upper canyon-bound reach of Clear Creek has stream slopes in the range of 0.6 to 2.0 percent, as measured from USGS 1:24,000 scale topographic quadrangles. The lower reach has an average stream gradient of 0.3 percent (Castro 1996 in Sacramento River Watershed Program 2008). Upstream tributaries to the canyon bound reach typically have stream slopes greater than 4 percent (Sacramento River Watershed Program 2008). The lower reach has lost its natural meander pattern. In places, the stream runs in straight highly entrenched channel dugs to facilitate gravel mining. Steep bluffs, composed of the Pleistocene epoch Riverbank and Red Bluff formations (Helly and Harwood 1985) occur where Clear Creek has cut into these formations and where hydraulic placer mining historically occurred (Sacramento River Watershed Program 2008).

The impoundment-induced coarse sediment deficit and concomitant reduction in habitat quality in Clear Creek below Whiskeytown Dam has been well documented by various investigators (Coots 1971 as cited in McBain and Trush 2001, GMA 2003). Effects of reduced coarse sediment supply include: riffle coarsening, fossilization of alluvial features, loss of fine sediments available for overbank deposition and riparian re-generation, and a reduction in the amount and quality of spawning gravels available for anadromous salmonids.

Below Whiskeytown Dam to Clear Creek Road, the channel exhibits typical inner-gorge, bedrock dominated, morphology with a high degree of confinement and little alluvial storage. However, exhibits remnant alluvial features and hence, demonstrates potential for alluvial processes to develop. Tributary sources of coarse sediment for the first 1.8 miles below the dam are extremely limited and contribute coarse sediment only during highly infrequent stochastic events (Rasmussen 2006; Steensen 1997). Colluvial sources (canyon walls) contribute very little within practical management timeframes and such material is of limited ecological value until is transported and rounded over some distance. Gravel bars, coarse-cobble riffles and (post-dam) abandoned floodplains alternate with deep scour pools and bedrock-constricted chutes. Most spawning riffles in this reach have coarsened and appear relatively immobile at intermittent high flows from dam-spills and spring time pulse flows (NMFS 2009a), but lacking sediment input, do not replace finer material.

Below Clear Creek Road, the combination of over-extraction and reduced coarse sediment supply led to channel down-cutting and a loss of floodplain connectivity (McBain and Trush 2001). Many of these effects are exacerbated in the lower parts of the watershed by the legacy of dredging and gravel extraction overlain by the increase in fine sediment production from impacted tributaries and by the removal of a relic dam (McCormick -Saeltzer Dam).

Hydrology

The median historical unimpaired run-off in Clear Creek is 69 thousand acre-feet (TAF), with a range of 0-421 TAF (USFWS 1995). Construction of Whiskeytown Dam greatly reduced the volume and magnitude of historic flows (McBain and Trush *et al*. 2000).

Since 1964, a portion of the flow from the Trinity River Basin has been exported to the Sacramento River Basin through Whiskeytown Reservoir (Reclamation 2008). Water is diverted from the Trinity River at Lewiston Dam via the Clear Creek Tunnel and passes through the Judge Francis Carr Powerhouse as it is discharged into Whiskeytown Lake on Clear Creek (Reclamation 2008). From Whiskeytown Lake, water is released through the Spring Creek Power Conduit to the Spring Creek Powerplant and into Keswick Reservoir. All of the water diverted from the Trinity River, in addition to a portion of Clear Creek flows, is diverted through the Spring Creek tunnel into Keswick Reservoir (Reclamation 2008). A larger volume of water from the Trinity River goes to the Sacramento River through the Spring Creek Power Conduit than goes to Clear Creek (Reclamation 2008). On average, 1.2 maf (up to 2,000 cfs) of water from the Trinity River is diverted each year into Keswick Reservoir compared to 200 cfs released to Clear Creek for fishery needs (NMFS 2008) between the Fall and Spring. Flows provided to Clear Creek below Whiskeytown Dam are consistently at least 200 cfs from October through June. During the summer months, flows are increased to provide adequate water temperatures for holding adult spring-run Chinook salmon and water temperatures for rearing steelhead per the 2004 OCAP Biological Opinion (NMFS 2008). The Spring Creek Power Conduit water is used primarily to deliver agricultural, municipal and industrial water, and generate power. This water helps cool the Sacramento River during the spring for winter-run Chinook salmon spawning and embryo incubation (Reclamation 2008).

Land Use

As reported in the Lower Clear Creek Floodway Rehabilitation Project Design Document (McBain and Trush *et al.* 2000), lower Clear Creek has undergone significant changes due to land use beginning with the discovery of gold at Reading Bar in 1848. Various forms of gold mining transformed the natural landscape into piles of placer, hydraulic, and dredger tailings. In most locations, the entire lower Clear Creek floodway was "turned upside down" in the search for gold. Gold mining also brought secondary impacts to the creek, including road building, deforestation, and urban development. Dredger tailings adjacent to the creek between the former Saeltzer Dam and Clear Creek Road Bridge are the most pronounced relics of historic gold mining activity, with the tailings confining the river and providing very little value as floodplain or riparian habitat (McBain and Trush *et al.* 2000).

The most recent significant land use impact to lower Clear Creek was instream and off-channel gravel mining, occurring from 1950 to 1978 (McBain and Trush *et al*. 2000). Impacts to channel morphology and salmonid habitat were significant; the bankfull channel was destroyed and floodplains removed, leaving wide shallow channels and interspersed deep pits (McBain and Trush *et al*. 2000).

Fisheries and Aquatic Habitat

Historically, there were approximately 25 river miles of Chinook salmon habitat available for use in Clear Creek of which only 18.1 are currently accessible (NMFS Website 2005) because of the construction of a dam to create power and water for the Redding area. Whiskeytown Dam is a complete barrier to fish passage and is the uppermost boundary of habitat available to anadromous salmon and steelhead.

Other negative effects to the spring-run and the steelhead fishery resulted from Whiskeytown Reservoir being "stretched" across this wild river. The construction of Whiskeytown Dam, gold mining, and gravel mining in the Clear Creek watershed has diminished suitable spawning gravel substrate and reduced riparian habitat along the lower sections of Clear Creek (CDFW 2004). Excessive gravel removal exposed a clay hardpan over much of the channel bottom, directly removing salmonid spawning and fry rearing habitat (McBain and Trush *et al*. 2000). Gravel mining also resulted in lost channel confinement, allowing both adult and juvenile salmonids to stray into adjacent pits and become stranded (McBain and Trush *et al*. 2000). Construction of Whiskeytown Dam reduced the magnitude and frequency of high flow events responsible for creating and maintaining lower Clear Creek, which allowed fine sediment to accumulate in the channel and allowed riparian vegetation to establish and mature along the low flow channel (McBain and Trush *et al*. 2000). As the vegetation matured, the combined root strength of the riparian band "fossilized" gravel deposits and reduced the quantity and quality of aquatic habitat in some areas (McBain and Trush *et al*. 2000).

One of the keys to success for recovery of both populations of salmonids includes a good supply of cold water from Whiskeytown Reservoir. Water temperatures in Clear Creek at the USGS Igo gaging station (RM 10.85) are maintained below 60°F from June through September and 56°F from September to October for steelhead and spring-run spawning and rearing (NMFS 2009a). The spring-run Chinook salmon population in Clear Creek does not appear to be currently habitat-limited as long as water temperatures are suitable (Reclamation 2008).

In recent years, a multi-phase restoration project on lower Clear Creek (i.e., The Lower Clear Creek Floodway Rehabilitation Project) *recreated a defined channel and floodplain, and included construction of a natural bar (plug) to reduce stranding of juvenile salmon and improve passage conditions for adult salmon migrating upstream* (California Association of Resource Conservation Districts 2005). In addition, aggregate extraction pits within the stream channel and floodplain were filled, and active rehabilitation was conducted including improving floodplain connectivity, and re-vegetation of natural riparian communities (California Association of Resource Conservation Districts 2005).

Success in increasing population abundance has occurred in part because of the numerous gravel augmentation projects (per CVPIA requirements) that have been implemented in lower Clear Creek, resulting in the addition of over 100,000 tons of gravel (Table 28). Spawning gravel is routinely added every year at various sites to compensate for channel down-cutting. Spawning gravel augmentation has greatly improved suitable habitat for spring-run Chinook salmon and steelhead (NMFS 2009a). Additional gravel augmentation at 11 sites along lower Clear Creek is being proposed by the National Park Service and the Bureau of Land Management (NPS and BLM 2008). Up to 25,000 tons of gravel would be placed system-wide annually for ten years (NPS and BLM 2008).

Table 28. Past gravel augmentation totals in Clear Creek (as of April 2007)

Placement Site	Total Quantity (Tons)	Jurisdiction
Whiskeytown Dam	23,258	BOR
Below NEED Camp	3,602	NPS
Placer Road Bridge	19,802	Non-Federal
Clear Creek Road	3,003	BLM
Reading Bar	999	BLM
Saeltzer Gorge	36,953	BLM
Above Phase 3A	1,730	BLM
Floodway	11,721	BLM
Phase 2B Exchange	1,404	BLM
TOTAL	102,470	

Source: Graham Matthews & Associates 2007a, as cited in NPS and BLM 2008

Spring-run Chinook Salmon

Historically, Clear Creek supported spring-run Chinook salmon (Reclamation 2008). However, historical accounts of spring-run Chinook in Clear Creek are sparse and population estimates are nonexistent (Reclamation 2008). Since 1998, spring-run Chinook salmon have shown an increasing trend in abundance from 50 (in 1998) to about 200 adults (highest number on record) in 2008 (Table 29). From 2005 through 2008, Clear Creek spring-run Chinook salmon escapement was estimated at 69, 77, 194 and 200 adults, respectively (CDFW 2009).

Some spring-run Chinook salmon in Clear Creek may be descendants of Chinook salmon from the Feather River Hatchery (FRH), which were stocked into Clear Creek in the early 1990's (Newton and Brown 2004). In order to re-establish spring-run Chinook salmon in Clear Creek, approximately 200,000 juveniles from the FRH were planted in Clear Creek annually in 1991, 1992 and 1993 (Brown 1996, as cited in Newton and Brown 2004). Contribution by the stocked FRH fish to the current spring-run Chinook salmon population may be limited due to: 1) a lack of suitable water temperatures during their holding and early spawning periods; and 2) probable hybridization with fall-run Chinook salmon (Newton and Brown 2004).

Table 29. Adult spring-run Chinook salmon population estimates for Clear Creek from 1993 to 2012 from USFWS. Estimates are not available for all years.

Year	Adult Estimate	Year	Adult Estimate	Year	Adult Estimate
1993	1	**2000**	19	**2007**	194
1994	0	**2001**	0	**2008**	200
1995	2	**2002**	66	**2009**	120
1996		**2003**	25	**2010**	21
1997		**2004**	98	**2011**	8
1998	47	**2005**	69	**2012**	68
1999	35	**2006**	77		

Sources: CDFW Grandtab; personal communications with DFG and FWS biologists.

Since 2003, the USFWS has separated fall-run Chinook salmon adults from spring-run Chinook salmon adults holding in the upper reaches of Clear Creek with the use of a picket weir located at either RM 8.1 or 7.4 (S. Giovannetti, USFWS, pers. comm., 2009). The weir is operated from approximately August 23 to November 1 to prevent fall-run Chinook from spawning in spring-run Chinook spawning areas to reduce hybridization, superimposition and competition. After November 1, fall-run Chinook salmon have access to the entire river for spawning, but rarely move upstream into spring-run Chinook salmon spawning areas.

Under dry and warm climate conditions, water temperatures above 60° F occur in Clear Creek. Lindley *et al*. (2004) suggested that Clear Creek appears to offer habitat of marginal suitability to spring-run, having limited area at higher elevations and being highly dependent on rainfall.

Steelhead

Historically, steelhead probably ascended Clear Creek past the French Gulch area, but access to the upper basin was blocked by Whiskeytown Dam in 1964 (Yoshiyama *et al.* 1996). Operation of Whiskeytown Dam can produce suitable coldwater habitat downstream to Placer Road Bridge depending on flow releases (DFG 1998, as cited in (Reclamation 2008)). Removal of the McCormick-Saeltzer Dam in 2000 has provided steelhead access to an additional 12 miles of habitat (NMFS 2009a). Steelhead have re-colonized this area and taken advantage of newly added spawning gravels.

Recent redd surveys conducted since 2001 indicate a small but increasing population resides in Clear Creek (Figure 18), with the highest density in the first mile below Whiskeytown Dam (USFWS 2007, as cited in NMFS 2009a). Spawning distribution has recently expanded from the upper 4 miles to throughout the 18 miles of Clear Creek, although it appears to be concentrated in areas of newly added spawning gravels (NMFS 2009a).

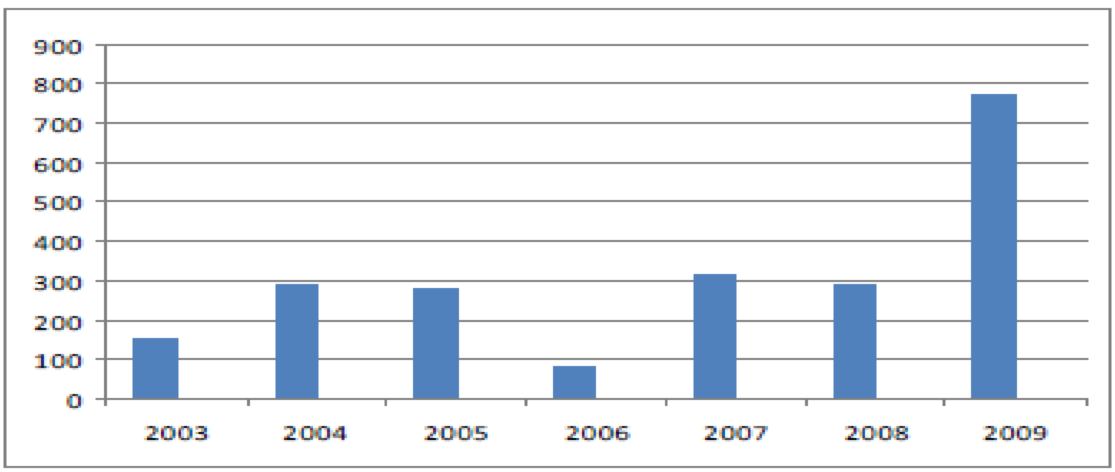

Figure 18. Abundance of steelhead in Clear Creek based on annual redd counts 2003-2009. Spawning population based on average 1.23 males per female on the American River (Hannon and Deason 2007). 2009 estimate is preliminary based on 4 surveys (USFWS 2008, Brown 2009) Source: NMFS 2009a.

In addition to the anadromous form of *O. mykiss*, many resident trout reside in Clear Creek, making it difficult to identify CV steelhead except when they are spawning (*i.e.*, resident trout spawn in the spring and have smaller size redds). Large riverine *O. mykiss* that reside in the Sacramento River can migrate up Clear Creek to spawn with either the anadromous or resident forms. No hatchery steelhead (*i.e*., presence of adipose fin-clip) were observed during the 2003-2007 kayak and snorkel surveys in Figure 17, indicating that straying of hatchery steelhead is probably low in Clear Creek (USFWS 2008).

SOUTHERN SIERRA NEVADA DIVERSITY GROUP

Calaveras River Watershed Profile

Listed Species Present in the Watershed

Central Valley steelhead

Listed Species that Historically Occurred in the Watershed

Central Valley steelhead

Diversity Group

Southern Sierra Nevada

Key Stressors

Key stressors to Central Valley steelhead in the Calaveras River include, but are not limited to the following:

- Fish passage impediments/barriers at Mormon Slough, the Old Calaveras River channel, Camanche Dam, Pardee Reservoir Dam, Bellota Weir and other locations affecting adult immigration and holding, and juvenile rearing and outmigration
- Flow conditions (i.e., low flows) affecting passage, attraction and migratory cues for adult immigration and holding
- Water quality conditions (i.e., urban and agricultural runoff) in the Calaveras River affecting adult immigration and holding
- Physical habitat alteration associated with limited supplies of instream gravel affecting spawning
- Water temperatures affecting spawning and embryo incubation, and juvenile rearing and outmigration
- Hatchery effects related to redd superimposition, competition for spawning habitat, and genetic integrity
- Flow dependent habitat availability affecting juvenile rearing and outmigration
- Hatchery effects related to juvenile rearing and outmigration

Watershed Description

In the San Joaquin River system, the Calaveras River is a relatively small Sierra watershed between the Mokelumne and Stanislaus rivers, and encompasses parts of Calaveras, Stanislaus, and San Joaquin counties (USFWS 2003). The Calaveras River watershed (Figure 19) is approximately 600 square miles with an average historic unimpaired runoff of 150,000 acre-feet per year and a minimum of about 12,000 acre-feet per year. The North Fork begins at Pine Ridge at an elevation of about 4,000 feet. The headwaters of the South Fork, San Antonio Creek, begins at Summit Level Ridge at an elevation of 6,000 feet (USFWS 2003).

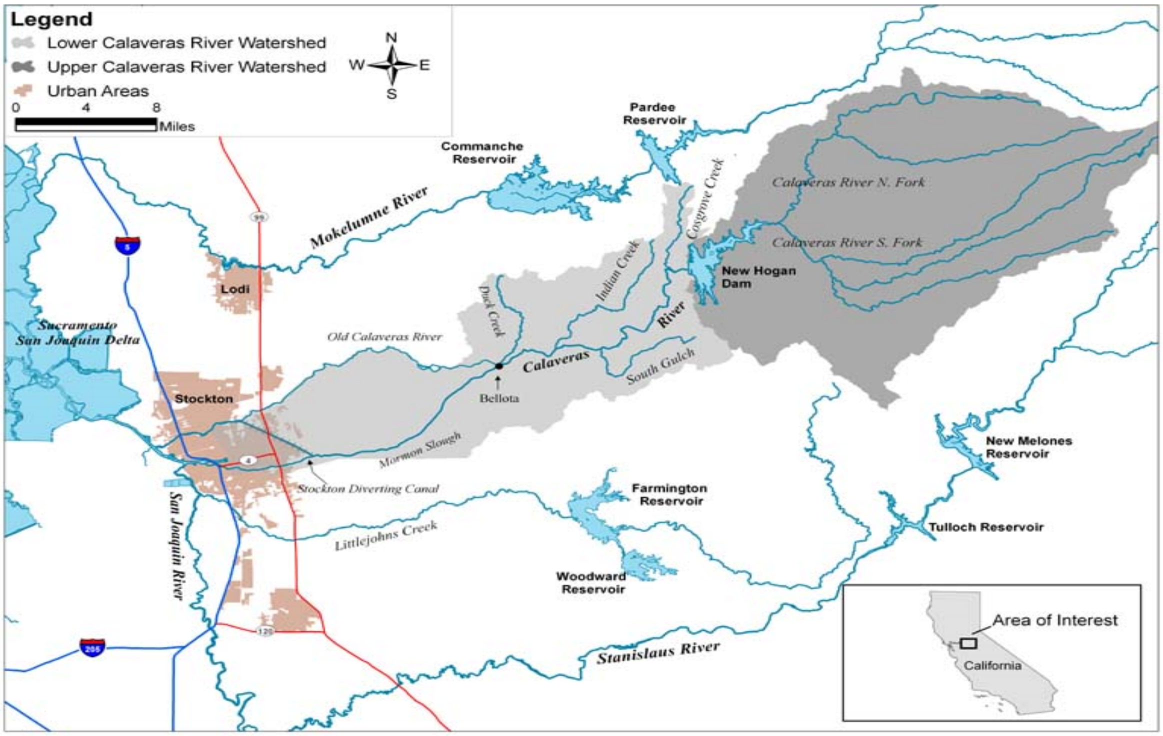

Figure 19. Calaveras River Watershed Source: Calaveras River Watershed Stewardship Group 2007

Geology

The Eastern San Joaquin Subbasin underlies a large portion of the eastern area of San Joaquin County. This basin is drained from the San Joaquin River and several of its tributaries including the Stanislaus, Calaveras and Mokelumne Rivers (California Department of Water Resources 2006a in San Joaquin Council of Governments 2007). Water bearing formations in this subbasin consists of the Alluvium and Modesto/Riverbank Formations, Flood Basin Deposits, Laguna Formation, and the Mehrten Formation (San Joaquin Council of Governments 2007). In the northern portion of Calaveras County, soils are reportedly coarse, very acidic, and nutrient-poor, mostly derived from the Eocene Ione formation (Holland 1986 in Calaveras County 2008).

Hydrology

Average precipitation ranges from about 20 inches a year in the western region to 60 inches in the northeast, and the rainy season extends from October 1 through May 1 (Calaveras Country 2008).

The most prominent manmade facility in the watershed is New Hogan Dam and Reservoir at river mile (RM) 42 (measured via the Mormon Slough route) which controls flows on the lower Calaveras River. Streamflow in the lower watershed is controlled by releases from New Hogan Reservoir, a 317,000 acre-foot U.S. Army Corps of Engineers (Corps) flood control and water supply reservoir formed by New Hogan Dam, which was constructed in 1964 and is located 38 miles upstream from the mouth of the river (USFWS 2003). Prior to construction of New Hogan Dam, the hydrology of the Calaveras River exhibited higher flow during the winter and spring, as well as periods of low-to-no flow during the late summer and fall. After New Hogan Reservoir was constructed in 1964, winter and spring flow peaks have been reduced and water now flows year round between New Hogan Dam and Bellota Weir (Marsh 2006). Because of the paucity of high elevation habitat capable of holding snowpack, the Calaveras watershed is a rain-driven system unlike other surrounding watersheds. Thus, New Hogan Reservoir captures most of the rainfall into the watershed, and local runoff in the lower Calaveras River below New Hogan Dam seeps quickly into the groundwater table (USFWS 2003).

The four main tributaries below New Hogan Dam are Cosgrove Creek, South Gulch, Indian Creek, and Duck Creek. Cosgrove Creek provides the largest contribution of runoff to the Calaveras River, as much as 8,500 acre-feet in some years (Calaveras River Watershed Stewardship Group 2007). The lower Calaveras River Mormon Slough area below New Hogan Dam encompasses approximately 115,000 acres and receives up to 90,000 acre-feet of surface water supply from the lower Calaveras River.

Releases from the New Hogan Reservoir provide year-round flows downstream to Bellota (USFWS 2003). Releases from the spring through early fall irrigation season generally range from 150 to 250 cfs. Non-irrigation season releases in non-drought years range from a minimum of 20 to 50 cfs to meet downstream municipal water supply demands. In drought years, non-irrigation season releases may be less, dependent on adaptive management determinations that will be made between SEWD and NMFS during implementation of the Calaveras River Habitat Conservation Plan. Water diversions from New Hogan Dam downstream to Bellota, including those of Stockton East Water District (SEWD) and the Calaveras County Water District (CCWD), remove most of the river flow, except during the rainy season. Water is released into the Old River channel and Mormon Slough at Bellota during the irrigation season for downstream users including groundwater recharge; however, the lower channels near Stockton are usually dry except during the rainy season. The two main water diversions are the CCWD diversion just below New Hogan Dam, which diverts water via an infiltration gallery, and the SEWD Bellota Intake diversion that feeds the Dr. Joe Waidhofer Water Treatment Plant via the Bellota Pipeline. In addition there are 29 operating agricultural water diversions between New Hogan Dam and Bellota Weir, and several more in each channel below the Bellota Weir (USFWS 2003).

Most of the water entering the lower Calaveras system at Bellota is diverted to Mormon Slough for irrigation and flood control purposes (USFWS 2003). Only during flood flows does water pass over the weir into the Old Calaveras River channel. Some water is diverted into the Old River channel through gated culverts during the irrigation season. Near Stockton, Mormon Slough flows are diverted to the Stockton Diverting Canal back to the Old Calaveras River channel, where water flows downs to the San Joaquin River. Below the Bellota Weir, the Calaveras River system has been reconfigured as a flood control and storm drainage system with Mormon Slough and the Diverting Canal being the principle water conveyance channels. During the dry season, both Mormon Slough and the Old River Channel serve as conveyance for local irrigation supplies (USFWS 2003).

The river reach above the Bellota Weir upstream to New Hogan Dam is a natural stream channel confined in most places by a foothill canyon. The lower section of the river immediately above Bellota has a lower gradient and its floodplain has been altered for agriculture. The channels below Bellota are essential ditches designed to carry irrigation water during the irrigation season and flood flows in winter and spring (USFWS 2003).

Land Use

Near its confluence with the San Joaquin River, the Calaveras River is bordered on both banks by the City of Stockton, passing through housing subdivisions, the University of the Pacific campus, and parks (USFWS 1998, as cited in Marsh 2006). The Calaveras River serves as an important source of water for agricultural and municipal uses in Calaveras and San Joaquin counties. Levees along Mormon Slough and the Stockton Diverting Canal are covered with sparse grass or shrubs, and adjacent to the old Calaveras River channel are orchards or light industry (Marsh 2006). Additionally, local stakeholder groups have expressed concerns regarding potential effects to water quality and aquatic habitats resulting from storm water runoff, agriculture, recreation, mining, unscreened diversion operations, and other land uses in the basin (The Calaveras River Watershed Stewardship Group 2007).

Fisheries and Aquatic Habitat

While very few studies of the fishery resources in the Calaveras River have been conducted to date, recent monitoring indicates that steelhead opportunistically use the watershed when sufficient rainfall produces passage flows in the system (Fishbio 2008). As reported by Marsh (2006), anadromous fish have access to 36 miles of the Calaveras River between New Hogan Dam and the San Joaquin River, when flows permit. Downstream of New Hogan Dam there is a dense riparian corridor bordering the river along the 18 miles down to Bellota Weir (USFWS 1998, as cited in Marsh 2006). Eighteen river miles upstream from the mouth, Bellota Weir splits the Calaveras River into two channels, Mormon Slough and the Old Calaveras River channel. Mormon Slough and the Stockton Diverting canal downstream are the primary channels used by migrating anadromous fish to access upstream spawning areas in the mainstem Calaveras River upstream of Bellota Weir (Figure 20). Fall flows in Mormon Slough, following the end of the irrigation season, frequently are reduced to levels less than 20 to 30 cubic feet per second (cfs) and may prevent spawning migration (FFC 2004, as cited in Marsh 2006). Mormon Slough, the primary salmonid migration channel, still experiences dry periods during summer and early fall as it did under the pre-1964 unregulated hydrologic regime (Marsh 2006).

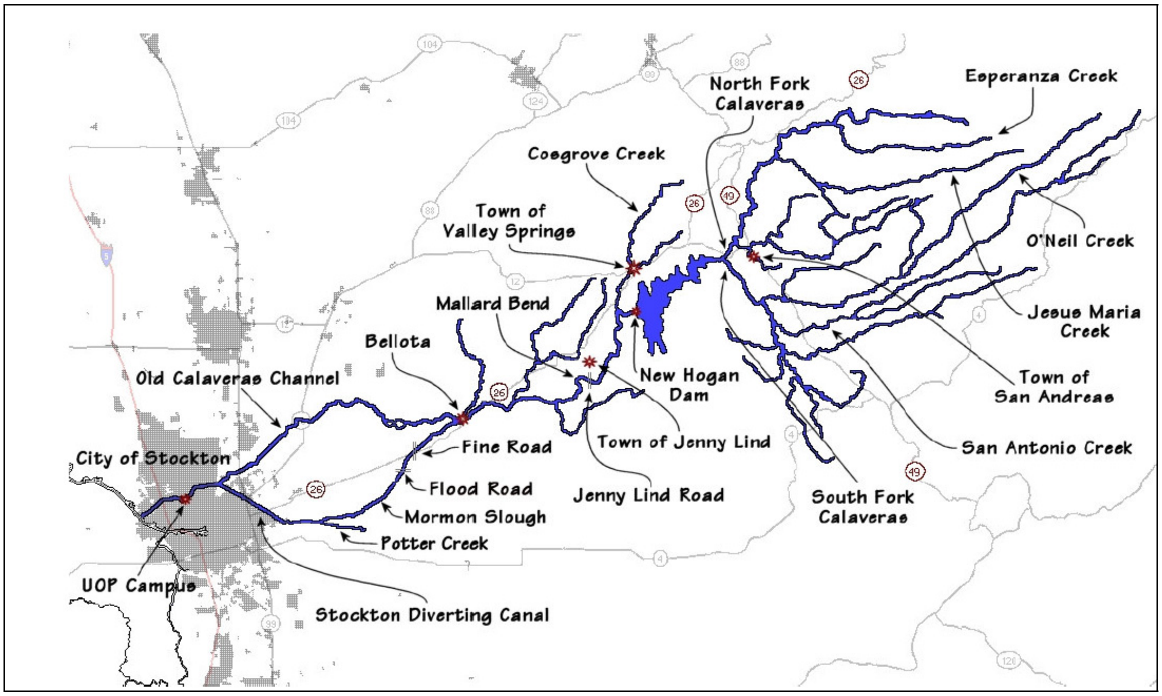

Figure 20. Primary barriers and features of the Calaveras River Watershed Source: Marsh 2006.

Historically, salmon and steelhead production in the Calaveras River was limited by low, intermittent flows during summer and fall. Chinook salmon have not been observed in the Calaveras River since 1984 (USFWS 1995). Although the duration and magnitude of peak winter/spring flows have been reduced due to reservoir operations, salmonids are able to opportunistically access the reach between the Bellota Weir and New Hogan Dam for spawning whenever adequate naturally occurring migration flows are available and no structural barriers are installed (i.e., flashboard dams). Upstream and downstream migration opportunities are currently limited to occasions between November and early April when passage conditions are created by substantial precipitation events that result in flood control releases and/or run-off events below the dam. In many years, precipitation events resulting in passage conditions do not begin until December because rainfall from initial storm events is generally absorbed into the ground through infiltration and run-off does not occur until the ground becomes saturated.

Currently, little data has been collected regarding the abundance, life-history preferences, and migration success of *O. mykiss* in the Calaveras River (Fishbio 2008). As reported by Marsh (2006), the Calaveras River does have the potential to support anadromous fish based on habitat qualities such as geomorphology (i.e., 22 feet per mile gradient, numerous riffles and pools), adequate spawning gravels, and a dense riparian canopy (USFWS 1993, CALFED Bay-Delta Program 2000, as cited in Marsh 2006). Spawning gravels occur in the lower Calaveras River in the first mile of river below New Hogan Dam and further downstream in the canyon and Jenny Lind reaches. In addition there are small areas of gravel riffles in Mormon Slough below Bellota Weir. Spawning gravels in the first mile below New Hogan Dam suffer from low permeability, but are adequate for several hundred pairs of salmon (USFWS 2003). Spawning gravels are similar in the middle reach between New Hogan Dam and the Bellota Weir. Below Bellota Weir the spawning gravels are limited and have poor permeability, but have produced some fry salmon in recent years. Several steelhead redds in this area in the spring of 2002 were likely unsuccessful as water temperatures reached lethal levels for trout eggs in the redds during the spring (USFWS 2003).

Adult steelhead entering the Calaveras River system are likely to move up the mainstem San Joaquin River channel before branching off into the channels of their natal rivers (NMFS 2008). Adult salmonid upstream passage problems include blockage at structural barriers and adequacy of stream flows for upstream adult migration (USFWS 2003). Juvenile salmonid downstream passage problems include structural barriers, lack of streamflow, and unscreened water diversions. Habitat concerns include: (1) instream flows for spawning and rearing; (2) adequacy of gravel spawning habitat; (3) adequacy of cool water rearing habitat; and (4) competition and predation by non-native warm-water fishes (USFWS 2003). There are many barriers to salmonid passage in the lower Calaveras River channels including several each in the Old Calaveras channel, the Diversion Canal, and Mormon Slough. Weirs at Bellota including one at the head of Mormon Slough, and one at the head of the Old River Channel are virtually impassable at many flows (USFWS 2003). However, two fish ladders have been placed at the Bellota Dam to assist with fish movement along the Calaveras River, and a hydraulic analyses of both ladders was conducted in 2005 (Fishery Foundation of California 2005).

Artificial structures (e.g., low-flow road crossings with culverts, low-flow road crossings without culverts, bridges, permanent dams and weirs, and flashboard dams with the flashboards removed) play a major role in reducing the Calaveras River's fisheries productivity (DWR 2007). Although the importance of the Calaveras River for steelhead production is currently unknown, opportunities to improve fish passage and aquatic habitat for anadromous salmonids have been identified at several locations, including the Mormon Slough flood control channel, the Old Calaveras River channel, and at the SEWD and the CCWD facilities (Fishbio 2008). SEWD and CCWD are working cooperatively with NMFS to improve the conditions for salmonids in the Calaveras River by including appropriate conservation measures and an adaptive management plan as part of this Calaveras River Habitat Conservation Plan. SEWD also is continuing to implement interim fish passage improvements until long-term fish passage and screening solutions are identified and put into operation (Fishbio 2008).

Steelhead

Although it is likely that steelhead once inhabited most of the San Joaquin River Basin streams used by Chinook salmon for spawning, they probably traveled farther upstream into smaller tributaries (Moyle *et al*. 1996). These passages are now blocked by dams. There is also little or no historic record of escapement available. Current annual escapements of steelhead in the San Joaquin River Basin, including the Calaveras River, are limited due to the long-term scarcity or absence of steelhead in the basin (Reclamation 2001)Lindley *et al*. (2006) concluded that several Calaveras River tributaries upstream of New Hogan Dam historically supported summer rearing habitat for steelhead and an independent population of steelhead. This conclusion is supported bythe collected anecdotal and documented information presented by Marsh (2006).

Flow is reported to be a principal factor currently limiting salmonids in general in the Calaveras River (CALFED Bay-Delta Program 2000, as cited in Marsh 2006). However, a small, apparently self-sustaining population of steelhead exists in the Calaveras River (NMFS 2008). Steelhead opportunistically use the watershed when sufficient flow provides suitable passage to spawning habitats. Surveys on the Calaveras River over the past several years indicate that small numbers of steelhead continue to run up the river with the first fall rains and during the winter (USFWS 2003).

The Calaveras River has historically experienced hatchery influences; *O.mykiss* have been stocked upstream and downstream of New Hogan Dam. In an analysis of the population genetic structure of Central Valley *O.mykiss*, Garza and Pearse (2008) reported that Calaveras River O.mykiss consistently grouped with "…the Junction Kamloops hatchery strain, possibly indicating some introgression from this strain into Calaveras River steelhead." Carcasses of several steelhead collected below Bellota Weir were too deteriorated to determine if the adipose fins were clipped (USFWS 2003).

Restoration opportunities exist on the Calaveras River to improve fish passage and aquatic habitat for anadromous salmonids. Several have been identified at several locations, including the Mormon Slough flood control channel, the Old Calaveras River channel, and at the SEWD and CCWD diversion facilities (Fishbio 2008). SEWD and CCWD are working cooperatively with NMFS to improve the conditions for salmonids in the Calaveras River by including appropriate conservation measures and an adaptive management plan as part of the Calaveras River Habitat Conservation Plan. SEWD also is continuing to implement interim fish passage improvements until long-term fish passage and screening solutions are identified and put into operation (Fishbio 2008). Further instream and riparian habitat improvements such as an increase in shade and channel complexity, which over time could support better steelhead rearing.

Stanislaus River Watershed Profile

Listed Species Present in the Watershed

Central Valley steelhead

Listed Species that Historically Occurred in the Watershed

Central Valley spring-run Chinook salmon
Central Valley steelhead

Diversity Group

Southern Sierra Nevada

Key Stressors

Key stressors to steelhead in the Stanislaus River include but are not limited to the following:

- Passage impediments/barriers at Goodwin, New Melones and Tulloch dams affecting adult immigration and holding
- Flow conditions (i.e., low flows) associated with attraction and migratory cues into the Stanislaus River affecting adult immigration
- Physical habitat alteration associated with limited supplies of instream gravel, habitat suitability and spawning habitat availability affecting adult spawning
- Flow conditions (i.e., flow fluctuations), particularly during flood releases, affecting spawning and embryo incubation
- Flow dependent habitat availability affecting juvenile rearing and outmigration
- Changes in hydrology and channel morphology (e.g., reduced instream gravel recruitment, reduced channel complexity, increased predator habitats) affecting juvenile rearing and outmigration
- Loss of riparian habitat, floodplain and side-channel habitat, and instream cover affecting juvenile rearing and outmigration

Watershed Description

The habitat currently available to salmonids on the Stanislaus River has been severely limited and impacted as a result of human activities over the past hundred years. Because of the significant impacts to habitat on the Stanislaus River, spring-run Chinook and viable populations of steelhead have been extirpated from the watershed. Steelhead are present but only in low numbers. Installation of the Goodwin, Tulloch, and New Melones Dams has been the primary cause of depleted, degraded habitat. The dams are physical barriers between migrating adult salmonids and their historic spawning habitat as well as a physical barrier that impedes the natural downstream transport of spawning gravel. The operation of the dams has resulted in decreased and more uniform flow. This has resulted in many negative effects including degraded water quality, channel incision and a loss in habitat diversity due to inhibiting geomorphic processes, and a lack in connectivity to floodplain rearing habitat.

In addition to the installation and operation of the dams, other human impacts have an effect of the river. This would include gravel mining activities. Although this does not occur as frequently today in the watershed, remnant gravel mining pits provide warm-water refugia for non-native predators. This activity has also depleted gravel abundance needed to replenish spawning habitat downstream. In addition, gravel and gold mining activities have contributed to the Lower Stanislaus River's listing as an impaired water body for mercury (2006 Clean Water Act section 303(d) list). Agricultural and urban landscape runoff contribute pesticide, herbicide, and fertilizer pollutants into the watershed.

Some restoration has been occurring to address the dearth in good flow and good gravels. In the spring, the Vernalis Adaptive Management Program (VAMP) flows are designed to stimulate outmigration for juvenile fall-run Chinook salmon, and consequently steelhead, into the Delta. CVPIA funding has provided funding for gravel augmentation to the river; however, more gravel is needed to replenish past losses as well as maintain current annual losses (NMFS 2009a). Restoration actions that would restore viability: release of more flow to lower water temperature, dilute pollutants, and carry juveniles downstream to more suitable rearing habitat, and vary flow rates to provide more geomorphic function and increase habitat diversity. Restoration of riparian habitat in the lower river would also increase good habitat for steelhead and provide much needed refugia that is missing because of the off channel opportunities that are denied because of the lack of access to upper habitats.

Watershed Description

The Stanislaus River originates in the western slopes of the Sierra Nevada and is one of the largest tributaries of the San Joaquin River. The Stanislaus River is approximately 113 miles long and covers an area of approximately 1,075 square miles (USFWS 2008) (Figure 21).

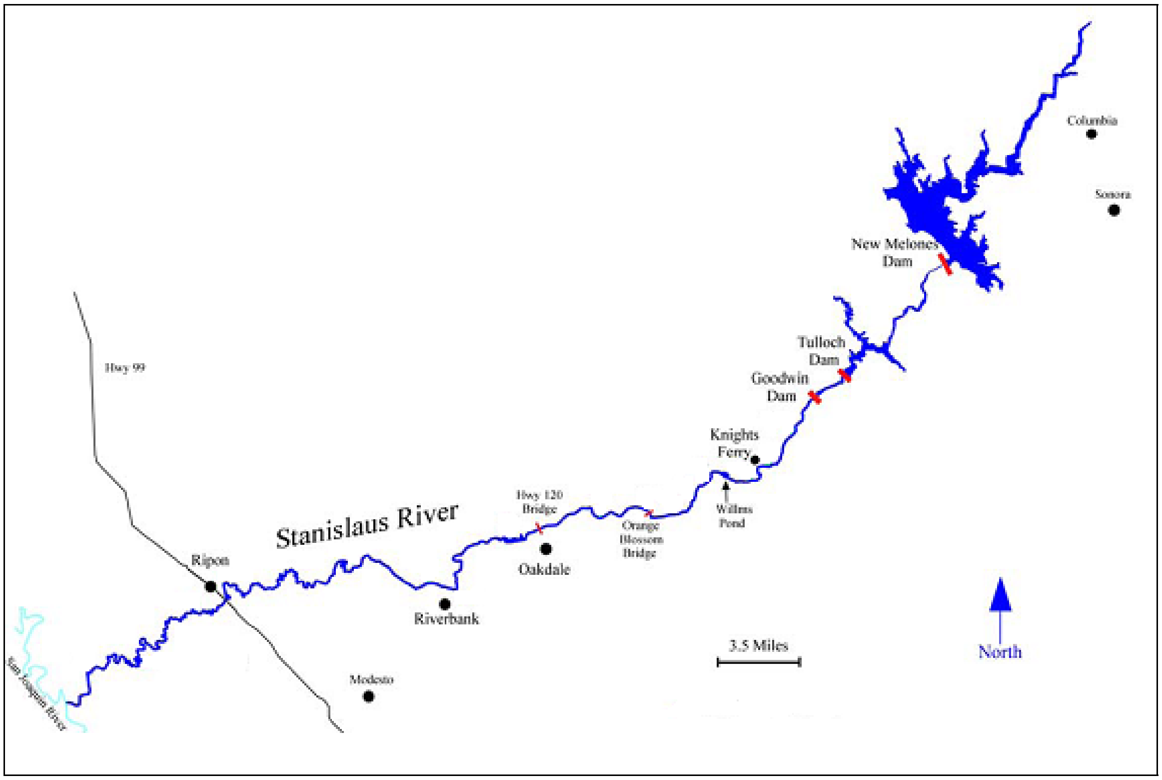

Figure 21. The Lower Stanislaus River between New Melones Reservoir and the San Joaquin River confluence Source: Modified from SRFG 2003

The Stanislaus River is extensively dammed and diverted. Donnells Dam on the middle fork forms Donell Lake, high in the Sierra Nevada. Downstream is Beardsley Dam, which forms Beardsley Lake. McKays' Point Diversion Dam diverts water on the north fork for hydroelectricity production and domestic use. The New Melones Dam blocks the river after the confluence of all three forks. Downstream from New Melones Lake, there is Tulloch Dam, which forms Tulloch Reservoir, and Goodwin Dam (RM 58), which is the first major barrier for anadromous fish on the Stanislaus River.

Geology

In the upper Stanislaus River watershed, the geology is primarily glaciated granite with mid-river reaches of metamorphic rock. Between Goodwin Dam and Knights Ferry, the rock is predominately volcanic. Below Knights Ferry, the river flows through Holocene alluvial deposits adjacent to late Pleistocene fill terraces.

Hydrology

The average unimpaired runoff in the watershed is about 1.2 million acre-feet (maf) (Reclamation 2008). The median historical unimpaired runoff is 1.1 maf per year, with a range of between 0.2 and 3.0 maf (USFWS 1995). Snowmelt contributes the largest portion of the flows in the Stanislaus River, with the highest runoff occurring in the months of April, May, and June (Reclamation 2008). Agricultural water supply development in the Stanislaus River watershed began in the 1850s and has significantly altered the basin's hydrologic conditions. The 32 dams within the Stanislaus River watershed large enough to be regulated by the Division of Safety of Dams have a total capacity of about 2.85 maf, or 237 percent of the average unimpaired runoff (SRFG 2003). The current hydrograph differs greatly from unimpaired flow conditions. Spring and summer flows are capped at 1,500 cfs (barring flood releases), while summer flows are increased to maintain downstream water quality.

Currently, New Melones Dam and Reservoir, completed by the Corps in 1979, is now the largest storage reservoir in the basin with a storage capacity of 2.4 maf, and was designed to control floods up to the 100-year-flood (Kondolf *et al*. 2001). New Melones Dam and Reservoir is located approximately 60 miles upstream from the confluence of the Stanislaus River and the San Joaquin River.

Another major water storage project in the Stanislaus River watershed is the Tri-Dam Project, a power generation project that consists of Donnells and Beardsley Dams, located upstream of New Melones Reservoir on the middle fork Stanislaus River, and Tulloch Dam and Powerplant, located approximately 6 miles downstream of New Melones Dam on the mainstem Stanislaus River (Reclamation 2008). New Spicer Reservoir on the north fork of the Stanislaus River has a storage capacity of 189,000 af and is used for power generation. Releases from Donnells and Beardsley Dams affect inflows to New Melones Reservoir. Under contractual agreements between Reclamation, the Oakdale Irrigation District (OID), and South San Joaquin Irrigation District (SSJID), Tulloch Reservoir provides afterbay storage to reregulate power releases from New Melones Powerplant (Reclamation 2008).

The main water diversion point on the Stanislaus River is Goodwin Dam, located approximately 1.9 miles downstream of Tulloch Dam. Goodwin Dam, constructed by OID and SSJID in 1912, creates a re-regulating reservoir for releases from Tulloch Powerplant and provides for diversions to canals north and south of the Stanislaus River for delivery to OID and SSJID. Water impounded behind Goodwin Dam may be pumped into the Goodwin Tunnel for deliveries to the Central San Joaquin Water Conservation District and the Stockton East Water District (Reclamation 2008).

Twenty ungaged tributaries contribute flow to the lower portion of the Stanislaus River, below Goodwin Dam (Reclamation 2008). These streams provide intermittent flows, occurring primarily during the months of November through April. Agricultural return flows, as well as operational spills from irrigation canals receiving water from both the Stanislaus and Tuolumne Rivers, enter the lower portion of the Stanislaus River. In addition, a portion of the flow in the lower reach of the Stanislaus River originates from groundwater accretions (Reclamation 2008).

The New Melones Reservoir flood control operation is coordinated with the operation of Tulloch Reservoir. The flood control objective is to maintain flood flows at the Orange Blossom Bridge at less than 8,000 cfs. When possible, however, releases from Tulloch Dam are maintained at levels that would not result in downstream flows in excess of 1,250 cfs to 1,500 cfs because of seepage problems in agricultural lands adjoining the river associated with flows above this level (Reclamation 2008).

As part of the East Side Division of the Central Valley Project (CVP), New Melones Dam and Reservoir are operated by the Bureau of Reclamation (Reclamation). Flows in the lower Stanislaus River serve multiple purposes concurrently. The purposes include water supply for riparian water right holders, fishery management objectives, and dissolved oxygen (DO) requirements per State Water Resources Control Board Decision (D)-1422. Issued in 1973, SWRCB D-1422 provided the primary operational criteria for New Melones Reservoir and permitted Reclamation to appropriate water from the Stanislaus River for irrigation and M&I uses. Under D-1422, Reclamation was required to release up to 98 thousand acre-feet (taf) of water per year from New Melones Reservoir to the Stanislaus River on a distribution pattern to be specified each year by CDFW for fish and wildlife purposes (SRFG 2003). In addition, water from the Stanislaus River enters the San Joaquin River where it contributes to flow and helps improve water quality conditions at Vernalis. D-1422 requires the operation of New Melones Reservoir include releases for existing water rights, fish and wildlife enhancement, and the maintenance of water quality conditions on the Stanislaus and San Joaquin rivers (Reclamation 2008).

More recently, CVP operations on the Stanislaus River have been guided by the New Melones Interim Plan of Operation (NMIPO) (Reclamation 2008). The NMIPO was developed as a joint effort between Reclamation and USFWS, in conjunction with the Stanislaus River Basin Stakeholders over a period of several years (SRFG 2003). The process of developing the plan began in 1995 with a goal to develop a management plan with clear operating criteria, given a fundamental recognition by all parties that New Melones Reservoir water supplies are overcommitted on a long-term basis, and consequently, unable to me*et al*l the potential beneficial uses designated as purposes (Reclamation 2008). Although meant to be a short-term plan, it continues to be in effect and defines categories of water supply and operations criteria for the annual planning to meet beneficial uses from New Melones Reservoir storage (Reclamation 2008).

Instream fishery management flow volumes on the Stanislaus River, as part of the NMIPO, are based on a combination of fishery flows pursuant to the 1987 CDFW Agreement and the USFWS AFRP in-stream flow goals (Reclamation 2008). Dedication of (b)(2) water on the Stanislaus River also provides actual in-stream flows below Goodwin Dam greater than the fish and wildlife requirements previously identified for the East Side Division, and in the past has been generally consistent with the NMIPO (Reclamation 2008). Actual in-stream fishery management flows below Goodwin Dam will be determined in accordance with the Decision on Implementation of Section 3406 (b)(2) of the CVPIA. Reclamation has begun a process to develop a long-term operations plan for New Melones Reservoir, which will be coordinated with B2IT members, along with the stakeholders and the public before it is finalized (Reclamation 2008).

The operating criteria for New Melones Reservoir are affected by (1) water rights; (2) in-stream fish and wildlife flow requirements; (3) SWRCB D-1641 Vernalis water quality requirements; (4) dissolved oxygen (DO) requirements on the Stanislaus River; (5) SWRCB D-1641 Vernalis flow requirements; (6) CVP contracts; and (7) flood control considerations. Water released from New Melones Dam and Powerplant is re-regulated at Tulloch Reservoir and is either diverted at

Goodwin Dam or released from Goodwin Dam to the lower Stanislaus River (Reclamation 2008).

Land Use

The lower Stanislaus River has been extensively developed to provide water, hydroelectric power, gravel, and conversion of floodplain habitat for agricultural and residential uses (SRFG 2003). While the upper reaches of the lower Stanislaus River (below Goodwin Canyon) remain relatively undeveloped, the river floodplain below Knights Ferry (with the exception of a narrow riparian border) has been converted to urban and rural development or used for agriculture (Wikert pers. comm. 2009). By 1994, it was estimated that approximately 50 percent of the riparian corridor along the lower Stanislaus River had been converted for agricultural, mining, and urban uses (USFWS 1995, as cited in KDH Environmental Services 2008).

Fisheries and Aquatic Habitat

The Stanislaus River historically had 113 miles of anadromous fish habitat (USFWS 2008), but currently only the lower 58 river-miles are accessible to anadromous fish, with access terminating at Goodwin Dam (KDH Environmental Services 2008). Historically, spring-run Chinook salmon were believed to be the primary salmon run in the Stanislaus River, but the fall-run population became dominant following construction of Goodwin Dam, which blocked upstream migration between 1913 and 1929 (in Yoshiyama *et al*. 1996). It is likely that hydraulic mining caused the initial decline of the salmon and steelhead runs in the Stanislaus River, because the early dams were too small to substantially affect flows and they did not completely block the salmon's upstream migration until Old Melones Dam was constructed in 1926 (SRFG 2003).

Although records on anadromous salmonids in the San Joaquin tributaries are sparse (Yoshiyama *et al*. 1998), the Stanislaus River still provides valuable spawning and rearing habitat for fall-run Chinook salmon and steelhead (NMFS 2004). Spawning is focused on the extensive gravel beds located from the town of Riverbank to Knights Ferry, with 95 percent of fall-run Chinook salmon spawning occurring from Orange Blossom Road to Knights Ferry (NMFS 2008). One mile upstream of Knights Ferry, spawning is concentrated at Two-Mile Bar (NMFS 2008).

Compared to historic conditions, the area of suitable salmonid spawning and rearing habitats has been substantially reduced due to anthropogenic influences including dam construction, in-river aggregate mining, and the conversion of floodplain habitat for agricultural uses (KDH Environmental Services 2008). A series of dams in the Stanislaus River has blocked access to spawning habitat in the upper river, and has blocked the transport of gravel to downstream reaches (KDH Environmental Services 2008). Gravel recruitment was reduced by 92 percent following construction of Goodwin Dam in 1912 (KDH Environmental Services 2008). Mobilization of gravel and fines below Goodwin Dam was further reduced in 1981 when the expansion of New Melones Dam reduced the frequency and magnitude of flooding in the lower reaches (Kondolf *et al*. 2001, as cited in KDH Environmental Services 2008), inhibiting the flushing of fine particles from coarser bed materials (CDWR 1994, as cited in KDH Environmental Services 2008). Along most of the lower Stanislaus River, agricultural and urban encroachment has separated the river from its floodplain. As a result, the channel is incised, which prevents the river from developing and maintaining shallow spawning and rearing habitats necessary for salmonids.

Gold and aggregate mining also have had a detrimental effect on spawning and rearing habitats in the Stanislaus River (KDH Environmental Services 2008). Approximately 40 percent of historic gravel beds were excavated from the 13.6-mile reach between Goodwin Dam and Orange Blossom Bridge between the years 1939 and 1980 for gold and aggregate mining purposes (Mesick 2003, as cited in KDH Environmental Services 2008). Mining activities left instream pits and long, uniform ditches 5 to 10 feet deep and 100 to 165 feet wide in the active channel near Lover's Leap from RM 53.4 downstream to RM 51.8. Gravels entering the river from tributaries below Goodwin Dam, or mobilized in high flow events become trapped in these pits rather than replenishing downstream riffles (SRFG 2003). Furthermore, these ditches sustain large populations of predatory fish, but provide little habitat for salmonids (KDH Environmental Services 2008).

Isolation of floodplain and riparian habitats from the Stanislaus River by dikes also has had a negative impact on salmonid spawning and rearing habitats (KDH Environmental Services 2008). Dikes confine flood flows to the river channel, increasing the rate of scouring of gravel from spawning and rearing habitat (KDH Environmental Services 2008).

Reduced gravel recruitment, in-river gravel mining, and the loss of functional floodplain, have severely reduced the quality and quantity of the spawning and rearing habitat for anadromous salmonids in the lower Stanislaus River (KDH Environmental Services 2008). The limited riffle habitat that remains has become armored and shortened due to erosion and the blockage of gravel recruitment (Mesick 2001, as cited in KDH Environmental Services 2008).

Restoration actions conducted to date have been limited to spawning gravel augmentation and providing additional water to supplement Stanislaus River flows in accordance with Section 3406(b)(2) and 3406(b)(3) provisions of the Central Valley Project Improvement Act (CVPIA)[8]. Additional restoration work is needed to replace gravel lost to mining and dams, and to provide additional floodplain habitat to replace that which has been lost due to the flattening of the hydrograph (USFWS 2008).

In September 2007, the Lover's Leap Restoration Project was implemented in the lower Stanislaus River near Lover's Leap, and was intended to replenish spawning gravel at existing and new restoration sites and to restore riverbed topography (KDH Environmental Services 2008). The overall objective was to increase and improve steelhead (and Chinook salmon) spawning and rearing habitat by adding approximately 18,000 tons of cleaned spawning-sized

[8] Section 3406(b)(2) of the CVPIA directs the Secretary of the Interior to dedicate and manage annually eight hundred thousand acre-feet of Central Valley Project yield for the primary purpose of implementing the fish, wildlife, and habitat restoration purposes and measures authorized by the CVPIA. The 800,000 acre-feet of water dedicated by the CVPIA is referred to as "(b)(2) water."

gravels and roughly 7,000 tons of larger cobble to degraded areas within the 25.5 mile salmonid spawning reach. (KDH Environmental Services 2008) Increasing the area of suitable spawning habitat should increase the abundance and condition of Chinook salmon and steelhead by reducing the effect of density dependent factors such as redd superimposition and by decreasing the area of habitat available for predatory fish (KDH Environmental Services 2008).

Steelhead

Central Valley steelhead were thought to be extirpated from the San Joaquin River system. However, monitoring has detected small self-sustaining (i.e., non-hatchery origin) populations of steelhead in the Stanislaus River and other streams previously thought to be devoid of steelhead (McEwan 2001). In 2004, a total of 12 steelhead smolts were collected at Mossdale, which indicates steelhead production is occurring in the San Joaquin River tributaries (CDFW unpublished data).

A fish counting weir operated in the river near the town of Riverbank has documented the passage of large *Oncorhynchus mykiss* upstream. In the 2006-7 season 12 steelhead were observed passing through a Stanislaus River counting weir (Anderson *et al*. 2007). However, surveys have not been conducted to determine where steelhead spawn in the Stanislaus River, but it is presumed that a majority of spawning occurs between Goodwin Dam and the Orange Blossom Bridge (SRFG 2003). The potential spawning sites with holding and feeding habitat, and spawning-sized gravel where large adults are frequently caught with hook-and-line include the four gravel addition sites in Goodwin Canyon, eight of the Knights Ferry Gravel Replenishment sites near Lovers Leap, Horseshoe Road, and Honolulu Bar, and four riffles adjacent to deep mine pits near Frymire Ranch, "Willms Pond", and Button Bush Park. Although the abundance of steelhead is not surveyed in the Stanislaus River, the catch of adult steelhead using hook-and-line began to increase in 1997 and again in 1999 (SRFG 2003).

Juvenile salmonid monitoring has been conducted at Oakdale and/or Caswell on the Stanislaus River since 1995, and is used to estimate abundance of out-migrating fall-run juvenile Chinook salmon (*O. tshawytscha)* and Central Valley steelhead/rainbow trout (*O. mykiss)* to the San Joaquin River as part of the U.S. Fish and Wildlife Service's Anadromous Fish Restoration Program (AFRP) (USFWS 2008; USFWS 2008a). Steelhead smolts also have been captured in the rotary screw traps at Caswell State Park and Oakdale each year since 1995 (Cramer and Associates Inc. 2000; 2001). Studies by CDFW also have documented juvenile *O. mykiss* in the river with maternal anadromy using SR:Ca ratios. More recently, Zimmerman *et al.* (2008) has documented steelhead in the Stanislaus River based on otilith microchemistry, while nearly 90 percent of O. mykiss sampled were offspring of resident adults.

Based on surveys conducted during 2000 and 2001, Fisheries Foundation (2002 in SRFG 2003) reports that young steelhead began to emerge from the gravel in the upper spawning reaches by April, and they were abundant from May through September. Juvenile fish were most abundant at the upper Goodwin Canyon site and Two-Mile Bar and least abundant at Oakdale (the lowermost study site). Trout parr were observed downstream to Honolulu Bar by June, where they remained common throughout the summer and fall. Few juvenile fish were observed at Oakdale where water temperature was the highest, ranging between 64.4 and 68^{o}F (Fisheries

Foundation 2002 in SRFG 2003). Yearling and post-yearling trout were concentrated in the upper river for most of the 2000 and 2001 surveys at the upper Goodwin Canyon site and Two-Mile Bar (Fisheries Foundation 2002 in SRFG 2003). A few fish were observed in lower reaches whereas some were abundant at the experimental sites (Knight's Ferry, Lovers Leap, and Orange Blossom). Water temperatures rarely exceeded 59^{o}F in the upper reaches, whereas downstream temperatures were near or at stressful levels of 64.4 and 68^{o}F during most of the summer. Yearling trout were slightly more abundant in 2001 than in 2000 in downstream reaches as water temperatures were slightly lower with higher flows in 2001. Abundance at the upper Goodwin Canyon site and Two-Mile Bar appeared to increase over the summer, which may indicate a positive upstream movement of yearling trout to the cooler water below Goodwin Dam (Fisheries Foundation 2002 in SRFG 20030).

Tuolumne River Watershed Profile

Listed Species Present in the Watershed

Central Valley steelhead

Listed Species that Historically Occurred in the Watershed

Central Valley spring-run Chinook salmon (ESU) – *Oncorhynchus tshawytscha*
Central Valley steelhead

Diversity Group

Southern Sierra Nevada

Key Stressors

Key stressors to Central Valley steelhead in the Tuolumne River include, but are not limited to, the following:

- Passage impediments/barriers in the Tuolumne River at La Grange and Don Pedro dams affecting adult immigration and holding
- Flow conditions (i.e., flow fluctuations, low flows) affecting attraction and migratory cues for adult immigration and holding, spawning and embryo incubation, and flow dependent habitat availability affecting juvenile rearing and outmigration
- Physical habitat alteration associated with limited supplies of instream gravel, and suitability of available habitat affecting adult spawning
- Water temperature and water quality effects on adult immigration and holding, spawning, and juvenile rearing and outmigration

Watershed Description

Draining an area of about 1,900 square miles, the Tuolumne River originates in Yosemite National Park and flows southwest through Yosemite, Stanislaus National Forest and private lands to its confluence with the San Joaquin River, approximately 10 miles west of Modesto, California (SFPUC 2009; TRTAC 1999). With its headwaters above the 10,000-foot level in Yosemite National Park, the Tuolumne River is one of the largest rivers in California's Sierra Nevada mountain range. The mainstem of the river begins in Tuolumne Meadows at the confluence of streams descending from the slopes of Mt. Lyell (13,100 feet) and Mt. Dana (13,155 feet). From there the river descends through the steep Yosemite wilderness, including the Tuolumne's own "Grand Canyon," before its flow is impounded by the O'Shaughnessy Dam in Hetch Hetchy Valley (3,500 feet). Similar to most major rivers in the Sierra Nevada, the Tuolumne River is dammed in several locations, principally to provide reliable water supplies for

California's farms and cities. La Grange Dam marks the upstream extent of currently accessible anadromous salmonid habitat. From La Grange Dam, the Tuolumne River flows in a westerly direction for approximately 50 miles before entering the San Joaquin River.

Geology

At higher elevations, the watershed is composed primarily of granitic bedrock that was scoured by glaciers during glacial periods down to the location of O'Shaughnessy Dam, resulting in mountainous terrain, patchy forests, and a variety of steep canyons and mountain meadows. The middle portion of the watershed from Don Pedro Reservoir to above Hetch Hetchy Reservoir is characterized by deep canyons and forested terrain. Near the town of La Grange, the river exits the Sierra Nevada foothills and flows through a gently sloping alluvial valley that is incised into Pleistocene alluvial fans (SFPUC 2009).

Hydrology

As reported by USFWS (1995), the median historical unimpaired runoff is 1.8 million acre-feet (maf), with a range of 0.4 maf to 4.6 maf. About 60 percent of the Tuolumne River flow occurs between April and June, when warm weather melts the Sierra snowpack. Similar to most other California rivers, flows in the Tuolumne River vary widely with annual precipitation. In about one out of every four years, the annual flow is less than 1.1 million acre-feet.

The Don Pedro Project is the largest reservoir located above the spawning reach on the Tuolumne River. Don Pedro Reservoir is owned by the Turlock Irrigation District (TID) and the Modesto Irrigation District (MID) and is licensed by the Federal Energy Regulatory Commission (FERC). TID and MID jointly regulate the flow to the lower river downstream of Don Pedro Reservoir, which has a gross storage capacity of 2.0 maf. In addition to providing power and irrigation, water storage in Don Pedro Reservoir is also managed to prevent the Tuolumne River from flooding Modesto and surrounding areas.

The river above Don Pedro Reservoir is regulated by three reservoirs (Cherry Lake, Lake Eleanor, and Hetch Hetchy Reservoir) owned and operated by the City and County of San Francisco. These reservoirs have a combined storage capacity of 800 thousand acre-feet (taf) or more. During each of the past 10 years, approximately 220 taf of Tuolumne River water has been annually exported to San Francisco. Hetch Hetchy Reservoir, with 360,000 acre-feet of storage capacity, is the largest reservoir in the upper watershed. Other small impoundments in the watershed include Modesto Reservoir (29 taf) and Turlock Lake (45.6 taf). LaGrange Dam, located downstream of Don Pedro Dam, diverts approximately 900 af per year for power, irrigation, and domestic purposes. LaGrange Dam is the upstream barrier to salmon migration (USFWS 1995).

Land Use

Agriculture, ranching, mining, and tourism dominate the region, and many people depend on the river for their sustained livelihoods (TRTAC 1999). The lower Tuolumne River has an extensive history of gold mining, municipal and agricultural water storage, power generation, agriculture, and recreation. Large dredges were used for gold mining and in recent years, the dredger tailings have been mined for gravel.

Fisheries and Aquatic Habitat

The San Joaquin River and its tributaries (e.g., Tuolumne River) once supported populations of both spring and fall-run Chinook salmon and steelhead (Yoshiyama *et al*. 1996, 1998, as cited in SRFG 2003). Spring-run Chinook salmon were extirpated from the San Joaquin Drainage by the late 1940's and it was believed that steelhead had been extirpated as well. Since then, fall-run salmon have declined by more than 90 percent and the populations remaining are in jeopardy of further decline (USFWS 2004). In recent years, a few confirmed reports of steelhead in the San Joaquin River drainage have been received, suggesting a viable but very small population (USFWS 2004).

Historically, the Tuolumne River Watershed is reported to have contained about 99 miles of anadromous fish habitat, and currently contains about 47 miles of habitat for fall-run Chinook salmon and steelhead (USFWS 2008). The lower Tuolumne River once hosted an extensive track of this riparian forest much of which has been removed due to growing urban settlement and extensive agriculture in the area (Tuolumne River Trust 2009). Past gravel-mining operations have reduced the low flow and bank-full channel capacity and changed the channel morphology of the Tuolumne River. In 1998, efforts to restore the lower Tuolumne River were initiated to restore the channel to its “pre-mining” condition.

Constructed in 1893, the La Grange Dam (RM 52.2) presents an impassable barrier to upstream migrating anadromous salmonids and marks the upstream extent of currently accessible steelhead habitat in the Tuolumne River. Dam construction ended the coarse sediment supply from the Tuolumne River Watershed upstream of the town of La Grange, and sediment transported during high flows has come from the bed itself or limited floodplain deposits (USFWS 2008a). Elimination of upstream sediment supply also has caused bed particle coarsening in the spawning reach near La Grange.

The Chinook salmon runs of the Stanislaus, Tuolumne, and Merced Rivers are perhaps the southernmost in the species range, and summer water temperatures appear to be among the primary factors determining the life-history strategies of these population, as well as those of steelhead (Hume 2005). Permanent upstream fish passage impairment dates back to dams constructed in the 19th century, eliminating access to cold-water refugia above the present dams. Unanticipated effects have resulted in the reduction of the timing window available for Chinook salmon and steelhead spawning because: (1) elevated water temperatures in the Delta, the San Joaquin River, and lower reaches of the tributaries usually prevent young salmon from migrating out of the tributaries much after May; (2) elevated water temperatures in the lower and middle reaches of the tributaries limit the effectiveness of life-history strategies which require over-summering by adults or juveniles; and (3) elevated water temperatures in the lower reaches of the tributaries usually prevent adult returns from spawning much before October (Hume 2005).

One of many stressors identified in recent studies on the Tuolumne River that limit salmonid populations are the aggregate extraction pits, which are a byproduct of extensive in-stream and off-channel mining (Turlock Irrigation District 2001). Many of these instream and off-channel pits have negatively impacted salmonid populations by stranding juveniles in ponds and fostering large populations of non-native predator fish (bass). Additionally, spawning and rearing habitats have been negatively impacted by either complete removal during aggregate extraction, degradation by channel encroachment from dikes along mining pits, or fine sediment infiltration. Many of the off-channel pits have only a small berm of undisturbed native material separating them from the river. Common floods (e.g., 1983, 1986, 1995, & 1998) of less than 8,000 cfs regularly breach some of these berms resulting in entrapment of salmon fry and smolts (Turlock Irrigation District 2001).

Given the large potential to make significant improvements in wild salmon production and the success of the TRTAC in promoting river-wide restoration goals, the CALFED – ERP has designated the Tuolumne River as one of three “Demonstration Streams” in the Central Valley. The problems that are the focus of the Tuolumne River restoration program fall into two major categories: (1) impairment of geomorphic and ecosystem processes caused by flow regulation, gold and aggregate mining, and land uses, and (2) reduction in fall-run Chinook salmon population abundance and resiliency (Turlock Irrigation District 2001).

Over the past several years, the Anadromous Fish Restoration Program (AFRP) has been working with the Tuolumne River Technical Advisory Committee (TRTAC) and the FERC Settlement Agreement framework to develop restoration and monitoring strategies (USFWS 2008). These strategies include utilizing an integrative approach to reestablish critical ecological functions, processes and characteristics that, under regulated flow and sediment conditions, promote recovery and maintenance of a resilient, naturally reproducing salmon population and the river's natural animal and plant communities (USFWS 2008). Initial priorities include: (1) continue to develop and fund the remaining two segments within the 6-mile Mining Reach; (2) complete restoration of two large in-channel pits; (3) develop a sediment management plan that will protect and restore critical spawning and rearing areas in the upper Tuolumne River; (4) work with agriculture and municipal interests in the lower river to establish and restore a riparian corridor for river function; and (5) continue to work with local interests and the U. S. Army Corps of Engineers (Corps) on a flood protection strategy (USFWS 2008). The AFRP also is working with the TRTAC to finalize river-wide and project-specific monitoring strategies that will guide adaptive management and allow the TRTAC to evaluate efficacy of FERC Settlement Agreement actions (USFWS 2008).

Steelhead

The California Department of Fish and Wildlife (CDFW) has conducted fall-run Chinook salmon spawning surveys on the Tuolumne River since 1971, as required under the cooperative fish study program for the Don Pedro Project FERC license (TID/MID 2009). Incidental catches and observations of juvenile steelhead have occurred on the Tuolumne River during fall-run Chinook salmon monitoring activities (Good *et al.* 2005).

Although some steelhead reportedly persist in the Tuolumne River, debate over historical distribution and less emphasis on commercial value have shifted the primary focus of restoration efforts from steelhead to fall-run Chinook salmon in the Tuolumne River Basin (McBain and

Trush 2000). However, more recent fisheries monitoring for the Don Pedro Project (FERC Project No. 2299) by the TID and MID has documented the presence of *Oncorhynchus mykiss* in the lower Tuolumne River (TID/MID 2005). Additionally, as part of the April 3, 2008 FERC Order on Ten-Year Summary Report Under Article 58, TID and MID were required to start conducting *O. mykiss* population estimate surveys during the summer (June/July) and winter (February/March) of 2008 to determine population abundance by habitat type. The purpose of the *O. mykiss* population surveys is to provide population size estimates over several sampling seasons of differing environmental conditions to determine habitat use and needs within the lower Tuolumne River. Reportedly, a total of 135 young-of-the-year (YOY)/juvenile (< 150 mm FL) and 45 adult (> 150 mm FL) (180 total) *O. mykiss* were observed from RM 51.8 to RM 41.1 within the study reach extending down to RM 39.6 (TID/MID 2009a). Most juveniles were found in riffles and the upstream end (heads) of run habitat, while adults mainly were found within pool heads and riffles. Using a bounded counts population estimator, approximately 3,096 *O. mykiss* were estimated within the survey reach, with 95% confidence bounds of 1,905–3,047 and 325–914 YOY/juvenile and adult size classes, respectively (TID/MID 2009a).

Merced River Watershed Profile

Listed Species Present in the Watershed

Central Valley steelhead

Species that Historically Occurred in the Watershed

Central Valley spring-run Chinook salmon (ESU) – *Oncorhynchus tshawytscha*
Central Valley steelhead

Diversity Group

Southern Sierra Nevada

Key Stressors

Key stressors (i.e., identified as "Very High") to Central Valley steelhead in the Merced River include, but are not limited to, the following:

- Passage impediments/barriers at the Crocker Huffman, McSwain, Merced Falls and New Exchequer dams blocking/impeding adult immigration
- Flow conditions (i.e., low flows) associated with attraction, migratory cues, flood flows and the attraction of non-natal fish into the Merced River affecting adult immigration and holding
- Physical habitat alteration associated with limited supplies of instream gravel, habitat suitability and spawning habitat availability affecting spawning
- Water temperatures affecting adult immigration and holding, and spawning
- Flow fluctuations affecting spawning and embryo incubation
- Changes in hydrology affecting juvenile rearing and outmigration
- Flow dependent habitat availability affecting juvenile rearing and outmigration
- Loss of riparian habitat and instream cover affecting juvenile rearing and outmigration

Watershed Description

The Merced River is a tributary to the San Joaquin River in the southern portion of California's Central Valley. The Merced River originates in Yosemite National Park and drains an area of 1,276 square miles as it flows down the western slope of the Sierra Nevada range into the Central Valley, eventually joining the San Joaquin River about 87 miles south of Sacramento, California (Figure 22). Elevations in the watershed range from 4,000 m at its headwaters to 15 m at the San Joaquin River confluence (USFWS 2007).

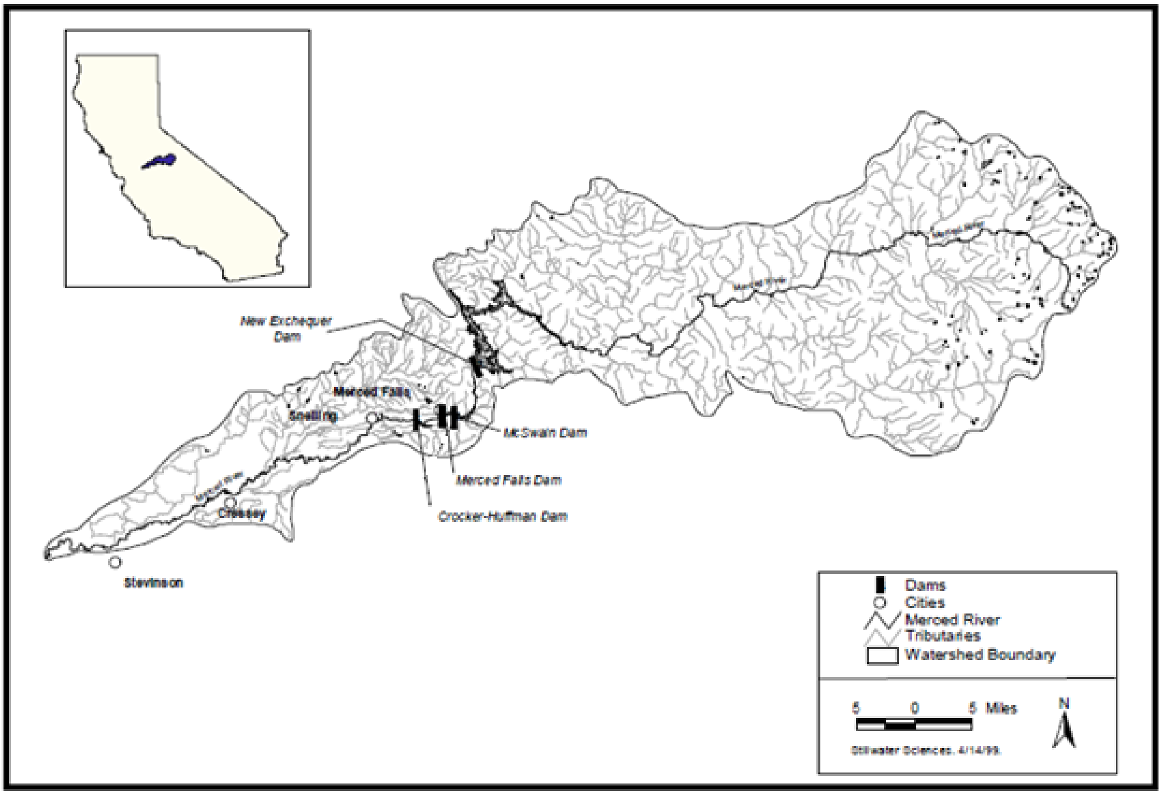

Figure 22. The Merced River Watershed Source: Modified from Stillwater Sciences 2001

The upper Merced River watershed encompasses approximately 700,000 acres from the headwaters near Triple Divide Peak to the New Exchequer Dam on Lake McClure, the main storage reservoir on the river (capacity 1 million acre-ft.). A significant part of the Merced River headwaters lies within Yosemite National Park (312,334 acres), while about 272,000 acres lie within the jurisdiction of lands managed by the United States Forest Service and the Bureau of Land Management. Downstream of New Exchequer Dam, the floodplain extent and connectivity in the Merced River have been affected by both flow regulation and levee construction. Flow regulation has reduced flood magnitude and, thus, reduced the extent and frequency of floodplain inundation. In addition, in the reach from Crocker-Huffman Dam to Shaffer Bridge, the river has been converted from a multiple-channel system to a single-channel system, and remnant sloughs have been converted to irrigation canals and drains.

Prior to the arrival of European pioneers and explorers, steelhead trout occurred throughout the upper Merced River drainage, occupying aquatic habitat as far upstream as Yosemite Valley on the mainstem, and probably, as far upstream on the South Fork, beyond Wawona, and most of its lower elevation tributaries (such as Skeleton Creek) as reported by Miller 2008. Currently, steelhead are present in the Merced River and spawn between Crocker Huffman Dam (RM52) and Highway J59 Bridge Crossing (RM42). Steelhead populations in the Stanislaus, Tuolumne, Merced, and Calaveras rivers are considered to be non-viable at this time (Lindley *et al*. 2007). The Merced River in particular is considered to be the most impacted of these southern rivers in terms of loss of flow, good gravels for steelhead, as well as poor water quality as a result of development and agriculture, so much habitat and hydrologic restoration is needed to ever see viable populations of steelhead again in the lower Merced River.

At this time, there are three obstructions to migrating fish: Crocker Huffman irrigation diversion near Snelling, McSwain, Merced Falls Dam, and New Exchequer. The direct and cumulative effect of these dams is that access to greater than 96% of the original historically available spawning and rearing habitat on the Merced River for *O. mykiss* (Steelhead trout) and other anadromous fishes (spring-run, fall-run and late fall-run Chinook salmon, lamprey) has been eliminated by impassable barriers and/or inundation. (Martin 2008, Schick *et al* 2005). Suitable *O. mykiss* and *O. tshawytscha* spawning and juvenile rearing habitat is now restricted to the Merced River reach between Crocker-Huffman Diversion Dam (RM 52) and the Highway J59 Bridge Crossing (RM 42). Reduction and modification of seasonal flow from the operation of the Project dams has adversely impacted the restricted *O. mykiss* accessible spawning and rearing habitat in this reach through interference with spawning gravel replenishment and armoring of gravel beds and instream flow regimes.

Little is known about steelhead numbers and current habitat uses in the southern sierra diversity group. Lindley *et al*. (2007) recommend that in order to assess the risk of extinction or develop effective recovery actions for steelhead in the Central Valley, determining the distribution of steelhead and assessing the relationship between resident and anadromous forms of *O. mykiss* is a fundamental need. Lindley *et al*. (2007) stress that any quantitative assessment of population viability would be inadequate unless the role resident fish play in population maintenance and persistence of *O. mykiss* in the Central Valley is known.

How will the Merced River help to buffer the negative effects of climate change for salmonids in the Central Valley?

Under the expected climate warming of around 5°C, substantial salmonid habitat would be lost in the Central Valley, with significant amounts of habitat remaining primarily in the upper Feather and Yuba rivers, and remnants of habitat in the upper Sacramento, McCloud, and Pit rivers, Battle and Mill creeks, and the Stanislaus River (Lindley *et al*. 2007). Under the less likely but still possible scenario of an 8°C warming, spring-run Chinook salmon habitat would be found only in the upper-most reaches of the north fork Feather River, Battle Creek, and Mill Creek (Lindley *et al*. 2007).

In addition, while warming may pose as a key threat to spring-run Chinook salmon in the Central Valley, suitable water temperature conditions should persist longer in areas where fish can reach higher altitudes (Williams 2006). Some existing or potential habitat should also remain for some time below various dams that currently release cool water through the summer (Williams 2006).

Geology

The following information on geology in the Merced River is taken directly from the *Merced Wild and Scenic Revised Comprehensive Management Plan and Supplemental EIS* (National Park Service 2005).

The Merced River gorge begins at the west end of Yosemite Valley where the gradient of the Merced River abruptly increases and the river enters the gorge. The gorge has remained an incised, V-shaped feature because the most recent glacial events did not extend down the Merced River beyond Yosemite Valley. The transition from the U-shaped, glaciated Yosemite Valley to the steep-gradient, V-shaped, incised Merced River gorge, is identified a feature of the geologic Outstandingly Remarkable Value.

The granitic rocks within the Merced River gorge consist primarily of tonalite; the Bass Lake tonalite is the dominant bedrock feature. Among some of the oldest rocks found in the Sierra Nevada are those just east of El Portal, in the walls of the Merced River gorge. These rocks are metamorphic and remnants of ancient sedimentary and volcanic rocks that were deformed and metamorphosed, in part by granitic intrusions (Huber 1989). This metamorphosed sedimentary rock (which includes banded chert) was once part of the ocean floor that covered the region about 200 million years ago (Huber 1989). The transition from igneous to metasedimentary rocks is identified as a feature of the geologic Outstandingly Remarkable Value in the El Portal segment of the river.

The soils in relatively flat topographic positions in the Merced River gorge and El Portal form from glacial and alluvial sediment deposition processes originating in Yosemite Valley, or by alluvial and colluvial deposition occurring locally within the gorge or near El Portal. Soils that formed in old river channels consist of alluvial boulders, cobbles, river wash, and loamy sands.

Hydrology

The overall climate in the Merced River Basin is temperate, with hot, dry summers and cold, wet winters. The average annual precipitation in Yosemite Valley is 36.5 inches. Annual precipitation decreases to 25 inches in El Portal (2,000 feet) and increases to 70 inches in the red fir forest at 6,000 to 8,000 feet (Eagan 1998, as cited in National Park Service 2005). At elevations above 5,000 feet, 80 percent of the annual precipitation falls as snow.

Similar to other rivers originating from the west side of the Sierra Nevada mountains, flow in the Merced River is typified by late spring and early summer snowmelt, fall and winter rainstorm peaks and low summer base flows (Stillwater Sciences 2001). Snowmelt drives the peak stream flows that occur in May and June, and minimum river flow is observed in September and October (National Park Service 2005). About 85 percent of precipitation falls between November and April, and the highest average precipitation generally occurs during December, January, and February (National Park Service 2005).

Four mainstem dams affect flow conditions in the lower Merced River. The two largest dams are New Exchequer Dam (which impounds Lake McClure) and McSwain Dam (which impounds Lake McSwain) (USFWS 2007; USFWS 1995; Stillwater Sciences 2001). These dams, which are known collectively as the Merced River Development Project, are owned by Merced Irrigation District (Merced ID) and are licensed by the Federal Energy Regulatory Commission. Merced Falls Dam and Crocker-Huffman Dam are low diversion dams which divert flow into the Merced ID Northside Canal and Main Canal, respectively. Merced Falls Dam is owned by Pacific Gas and Electric; Crocker-Huffman Dam is owned by Merced ID. Three additional small dams (i.e., MacMahon, Green Valley, and Metzger) are located on tributaries upstream of the New Exchequer Dam. These dams have a combined reservoir capacity of 835 acre-feet. Also, Kelsey Dam impounds a small (972 acre-feet) reservoir on Dry Creek, the only major tributary to the Merced River downstream of the mainstem dams (Stillwater Sciences 2001).

The New Exchequer Dam (located at RM 62.5) controls runoff from 81 percent of the basin and creates the largest storage reservoir in the system, Lake McClure. The maximum reservoir storage capacity at Lake McClure is 1,024,600 acre-feet, equivalent to 103 percent of the average annual runoff from the basin (as measured below Merced Falls Dam, near Snelling). The New Exchequer Dam provides agricultural water supply, power generation, flood control, recreation, and environmental flows including in-stream fisheries flows and flows to the Merced National Wildlife Refuge (Stillwater Sciences 2001).

McSwain Dam (RM 56) is located 6.5 river miles downstream of the New Exchequer Dam, and is operated as a re-regulation reservoir and hydroelectric facility. Storage capacity in Lake McSwain is 9,730 acre-feet.

The Merced Falls Dam (RM 55) and the Crocker-Huffman Dam (RM 52) are low-head irrigation diversion facilities. The Merced Falls Dam diverts flow into the Merced ID’s Northside Canal (capacity = 90 cfs) to the north of the river and generates electricity. The Crocker-Huffman Dam diverts flow into the Merced ID's Main Canal (capacity = 1,900 cfs). In addition to the Merced ID diversions, the Merced River Riparian Water Users maintain seven riparian diversions between Crocker-Huffman Dam and Shaffer Bridge. Between Crocker-Huffman Dam and Shaffer Bridge, Cowell Agreement and riparian water users divert up to approximately 94,000 acre-feet annually and have maintained seven main channel diversions since about the 1850s (Stillwater Sciences and EDAW 2001). These diversions are small wing dams consisting of rock and gravel, which can be transported downstream during high winter river flows. In addition to these diversions, CDFW has identified a large number of diversions, primarily pumps, in the 52 river miles between the Crocker-Huffman Dam and the San Joaquin confluence. During field surveys, CDFW recorded 244 diversions, which are predominantly used to supply water for agricultural use (206 diversions) (Stillwater Sciences and EDAW 2001).

Land Use

The Merced River Watershed has been significantly modified by dams and flow regulation, flow diversion, gold and aggregate (sand and gravel) mining, levee construction, land use conversion in the floodplain, and clearing of riparian vegetation (Stillwater Sciences 2001). As reported by USFWS (1995), agricultural development began in the 1850s, and significant changes have been made to the hydrologic system since that time. As early as the 1870's, large canal systems were built to divert Merced River water for agricultural uses including, row crops, cattle grazing and orchard crops. Mining for gold and aggregate downstream of the dams has been extensive, leaving tailings and numerous pits within the river corridor (USFWS 2001). Today, the lands within watershed are comprised of rural and privately owned areas, and the primary land use is agricultural and aggregate mining. Many tracts are under active cultivation with orchards and vineyards, and several actively grazed annual grassland pastures abut the river’s edge. There is also an expansive gravel mining plant on the north section of the lower Merced River (USFWS 2001).

Fisheries and Aquatic Habitat

Historically, the Merced River supported spring and fall-run Chinook salmon, and occasionally steelhead trout. Over time, the manipulation of the Merced River has led to loss and degradation of native habitat. With the building of dams, access to spawning grounds upstream has been lost and gravel recruitment is greatly reduced in reaches below the dams. The large in-stream ponds left by mining create habitat for introduced predator fish species that prey upon juvenile salmon (USFWS 2005). Despite this loss and degradation of riverine habitat, the Merced River has supported a large population of fall-run Chinook salmon in the San Joaquin Valley. Steelhead have been largely extirpated from the project area, but sporadically use the Merced River for spawning and rearing (USFWS 2000).

Both the Merced Falls Dam and the Crocker-Huffman Dam are equipped with fish ladders, but the ladders were blocked by CDFW in the early 1970s in association with the Merced ID’s construction of an artificial salmon spawning channel immediately downstream of Crocker-Huffman Dam. As reported in Stillwater Sciences (2001), anadromous fish generally do not pass upstream of Crocker-Huffman Dam, although some fall Chinook salmon may surmount the dam during high flows. Thus, the Crocker-Huffman Dam presents an impassable barrier to upstream migration, and demarcates the upstream extent of currently accessible steelhead habitat. Salmon spawn in the 24-mile reach between Crocker-Huffman Dam and the town of Cressy (USFWS 1995), with the primary spawning reach occurring between RM 32 and RM52) (Stillwater Science 2001). Rearing habitat extends downstream of the designated spawning reach, requiring the protection of the entire tributary from Crocker-Huffman Dam to its mouth (USFWS 1995).

Thermographs are used by CDFW to record temperature at several points along the river. Downstream of Crocker-Huffman dam substrate is dominated by gravel and cobble with downstream fining to eventual sand and silt below the lowest spawning area (USFWS 2007.)

Water resource demands and flood control issues on the Merced River will largely determine the extent and types of restoration implemented in the corridor (Stillwater Sciences and EDAW 2001). The Merced River is heavily allocated for agricultural water use. The Merced ID holds pre-1914 appropriative water rights to divert flow from the river. In addition, riparian water users divert flows through seven diversion channels between Crocker-Huffman Dam and Shaffer Bridge and numerous riparian pumps throughout the river. Minimum instream flow requirements in the river are defined under Merced ID’s current licenses and agreements and are intended to provide adequate flows for Chinook salmon and for the Merced River Riparian Water Users Association diversions. In addition, under current U.S. Army Corps of Engineers flood control operations rules, the maximum allowable release to the Merced River from New Exchequer Dam is 6,000 cfs. For the above reasons, restoration projects developed within the Merced River Corridor Restoration Plan must, therefore, be designed to function within the current minimum flow requirements and this 6,000 cfs flood control limitation (Stillwater Sciences and EDAW 2001).

There are many opportunities for improving geomorphic and riparian ecosystem conditions in the Merced River. As reported in the Geomorphic and Riparian Vegetation Investigations Report for the Merced River Corridor Restoration Plan (Stillwater Sciences 2001), the major constraints to restoring geomorphic and riparian ecological processes and attributes in the Merced River include: (1) drastic reduction in the flood magnitude, frequency, and duration and the resulting reduction in bedload transport under current dam operations; (2) elimination of floods exceeding 6,000 cfs that will likely continue due to the Corps of Engineers limit to flood releases; (3) the presence of vulnerable structures (such as the City of Livingston sewage treatment plant) and vulnerable land uses in the floodplain; (4) lack of coarse sediment supply due interception of bedload by the large dams; (5) limits to channel migration caused by reduced flows, bank revetment, and development in the floodplain; (6) the extent of bedload impedance reaches throughout the Gravel Mining 1 and Gravel Mining 2 reaches; and (7) chronic fragmentation and clearing of riparian vegetation for floodplain development. To date, numerous projects to restore and protect floodplain function, as well as channel and riparian habitat have been initiated or completed on the Merced River as a result of the CVPIA and the Merced River Corridor Restoration Plan; however, consistent monitoring of juvenile Chinook salmon and steelhead emigration has been lacking (Stillwater Sciences 2001; USFWS 2007).

The Merced River Fish Hatchery (RM 52), operated by CDFW, is located immediately downstream of Crocker-Huffman dam. Crocker-Huffman Dam is the upstream terminus of fish migration on the Merced River. (USFWS 2007).

Steelhead

Prior to 2007, incidental catches and observations of steelhead juveniles have occurred on the Merced (and Tuolumne) rivers during fall-run Chinook salmon monitoring activities (Good *et al.* 2005). Zimmerman *et al.* (2008) also has documented Central Valley steelhead in the Merced River based on otilith microchemistry.

During 2007, Cramer Fish Sciences began juvenile Chinook salmon and *O. mykiss* population monitoring on the Merced River at George Hatfield State Park (RM 2) under contract with Anadromous Fish Restoration Program. The monitoring effort continues previous work by CDFW at Hagaman State Park (RM 12), and uses rotary screw traps, an established method for measuring juvenile out-migration abundance, to capture juvenile salmonid species while monitoring environmental variables (USFWS 2007). The new site was established to obtain a more accurate estimate of fish contribution to the San Joaquin River. Result from surveys conducted during 2007 indicate that out-migration timing of natural fish strongly coincided with hatchery releases upstream, and weaker associations were observed with temperature and lunar cycle (USFWS 2007). Observations during the 2007 appear to indicate poor natural production of Chinook salmon, however subsequent monitoring of population trends over several seasons is required before conclusions or management decisions can be made (USFWS 2007). No *O. mykiss* were captured during the 2007 sampling season. A more thorough understanding of *O. mykiss* populations on the Merced River may by necessary to explain the lack of out-migration observed during the 2007 season (USFWS 2007).

Upper San Joaquin River Watershed Profile

Listed Species Present in the Watershed

Currently unoccupied

Species that Historically Occurred in the Watershed

Central Valley spring-run Chinook salmon (ESU) – *Oncorhynchus tshawytscha*
Central Valley steelhead

Watershed Description

CV spring-run Chinook salmon and CV steelhead no longer occur in the San Joaquin River south the of the Merced River. According to DFG (1998), the San Joaquin River once supported a very large population. Clark (1929) wrote that in the late 1800s, salmon were very numerous, and Fry (1961) estimated a run of 56,000 spring-run in 1945. The extent of steelhead presence in the San Joaquin River is not well known.

The upper San Joaquin River, a 153-mile stretch of river from the Merced confluence upstream to Friant Dam, has been significantly altered over the past century due to changes in land and water use. The historical populations of Central valley spring-run salmon were extirpated due to several changes caused by development including the building of Friant dam that blocked fish passage to upper San Joaquin River habitats. As well, major agricultural water diversions were built in the last 150 years which lowered the water quality and quantity and caused areas of entrainment, further reducing the population of spring-run salmon and steelhead to the level of extirpation.

Because of these developments, which caused the extinction of the San Joaquin spring-run salmon population, several legal actions were taken which resulted in a Settlement in October of 2006 that was reached in the case of *NRDC et al. v. Kirk Rodgers et al.*, and was termed: the San Joaquin River Restoration Program (SJRRP). The following restoration goals were produced from this settlement:

Restoration Goal – To restore and maintain fish populations in "good condition" in the mainstem San Joaquin River below Friant Dam to the confluence with the Merced River, including naturally reproducing and self-sustaining populations of salmon and other fish.

Water Management Goal – To reduce or avoid adverse water supply impacts to all of the Friant Division long-term contractors that may result from the Interim Flows and Restoration Flows provided for in the Settlement.

The Settlement establishes a framework for accomplishing the Restoration and Water Management goals that will require environmental review, design, and construction of projects over a multiple-year period. To achieve the Restoration Goal, the Settlement calls for a combination of channel and structural modifications along the San Joaquin River below Friant Dam, releases of water from Friant Dam to the confluence of the Merced River, and the reintroduction of Chinook salmon. With these actions, the prognosis for spring-run populations to returns is high. However, for steelhead, since the main channel San Joaquin does not have suitable habitats that fulfill life history requirements for steelhead such as good off channel and side channel habitats as well as smaller spawning gravels, more restoration will need to be focused on these life history requirements before steelhead would reoccur.

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