STATE OF CALIFORNIA
The Resources Agency
DEPARTMENT OF FISH AND GAME

A REVIEW OF BUTTE CREEK FISHERIES ISSUES

by

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1992

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INTRODUCTION

Prior to 1965, Butte Creek supported an average of about 2,500 spring-run chinook salmon (Flint and Meyer 1977); however, over the last 26 years an average of only 349 spring-run chinook salmon have spawned in the creek . Steelhead once spawned and reared in Butte Creek as it flowed through mountain meadows and deep, cool canyon pools (Flint 1972). Two dams built in 1917 and now operated by Pacific Gas and Electric Company (PG and E) blocked these runs and limited their spawning and rearing areas (Brown, 1992b). Numerous other dams and diversions were built along the creek by private landowners to provide water for their agricultural crops and waterfowl. Water withdrawn through unscreened diversions in the spring primarily for rice growing and in fall for duck clubs conveys young salmonids from Butte Creek to the fields (Brown 1992a), and results in lack of adequate flows in the creek for passage, spawning, and rearing. Losses due to dam construction and operation, combined with sport fishing and poaching in Butte Creek and fishing in the ocean, have teamed with export pumping in the Sacramento-San Joaquin Delta (Stevens and Miller 1983) to threaten not only the continuation of a viable fishery but the continued existence of the spring-run chinook salmon in Butte Creek.

holding areas (DFG files; PG and E 1991). Water temperature in the summer holding canyons has been measured at different flows by PG and E.

The objective of this report is to identify issues related to successful salmon and steelhead reproduction, to summarize solutions recommended by other researchers, and to suggest new solutions that address these issues. Additional data are needed to implement some of these solutions. A separate report is being prepared to address additional study needs.

STUDY AREA

Butte Meadows Basin

Butte Creek originates from snow and rain that fall on the western face of the Sierra Nevada Mountains at about 1982 m (6500 feet) (Figure 1). It is formed by four small streams that flow into the Jonesville Basin in Lassen National Forest in an area dominated by species of pine, cedar, and fir. The creek gathers flow as it drops into Butte Meadows Basin (Figure 2). Softwoods cover the hills around the creek while alder and willows comprise much of the riparian overstory. Butte Creek flows through a series of wide meadows and is characterized by repeating sequences of pools and riffles. Riffle substrate is cobbles and gravel while coarse granitic sand covers the bottoms of slow areas in pools. The stream flows all year, but peaks in streamflow occur during storms and spring runoff. Stream temperatures remain cool all year and trout are the dominant species of fish (Leach and Van Woert 1967).

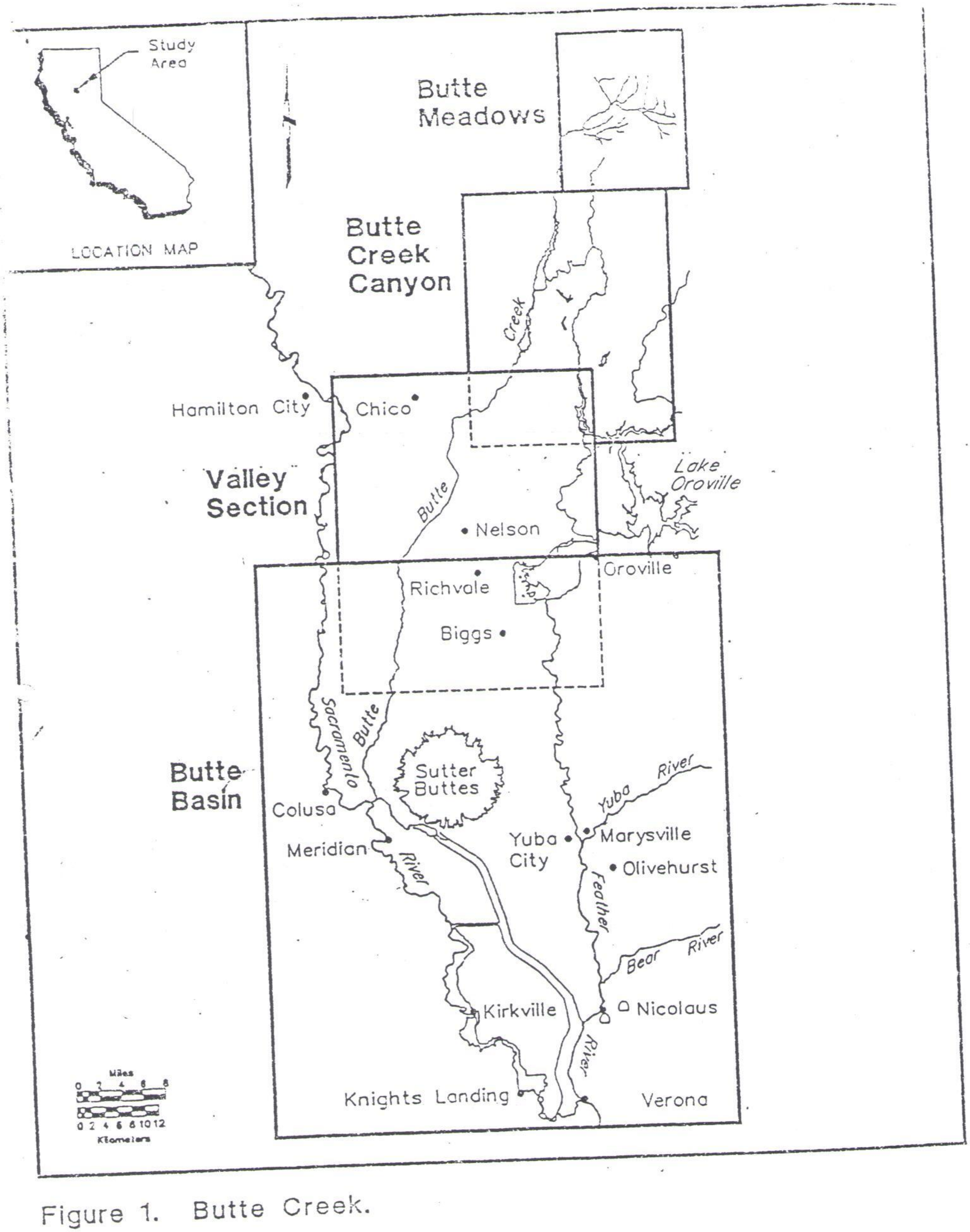

Figure 1. Butte Creek.

flow as it drops into Butte Meadows Basin (Figure 2). Softwoods cover the hills around the creek while alder and willows comprise much of the riparian overstory. Butte Creek flows through a series of wide meadows and is characterized by repeating sequences of pools and riffles. Riffle substrate is cobbles and gravel while coarse granitic sand covers the bottoms of slow areas in pools. The stream flows all year, but peaks in streamflow occur during storms and spring runoff. Stream temperatures remain cool all year and trout is the dominant species of fish (Leach and VanWoert 1967).

Butte Creek Canyon

Butte Creek cascades from the mountains to the valley through steep canyons (Figure 3). Pine and fir dominate the flora at the head of the canyons, but as the stream reaches the valley floor oaks and willows are more common. PG and E owns two dams in the canyon. They were built in 1917. The first dam, Butte Creek Head Dam, diverts all but 0.48 cms (17 cfs) of Butte Creek for hydropower generation during wet and normal years and all but 0.2 cms (7 cfs) during dry years. Tributaries add flow to Butte Creek in the canyon. The second dam, Centerville Head Dam, diverts all but 1.13 cms (40 cfs) during wet and normal years and 0.28 cms (10 cfs) during dry years. When flows exceed amounts required at each diversion more water flows down the creek by overtopping the dams. About 1.13 to 3.40 cms (40 to 120 cfs) imported from the West Branch of the Feather River returns to the creek at Centerville

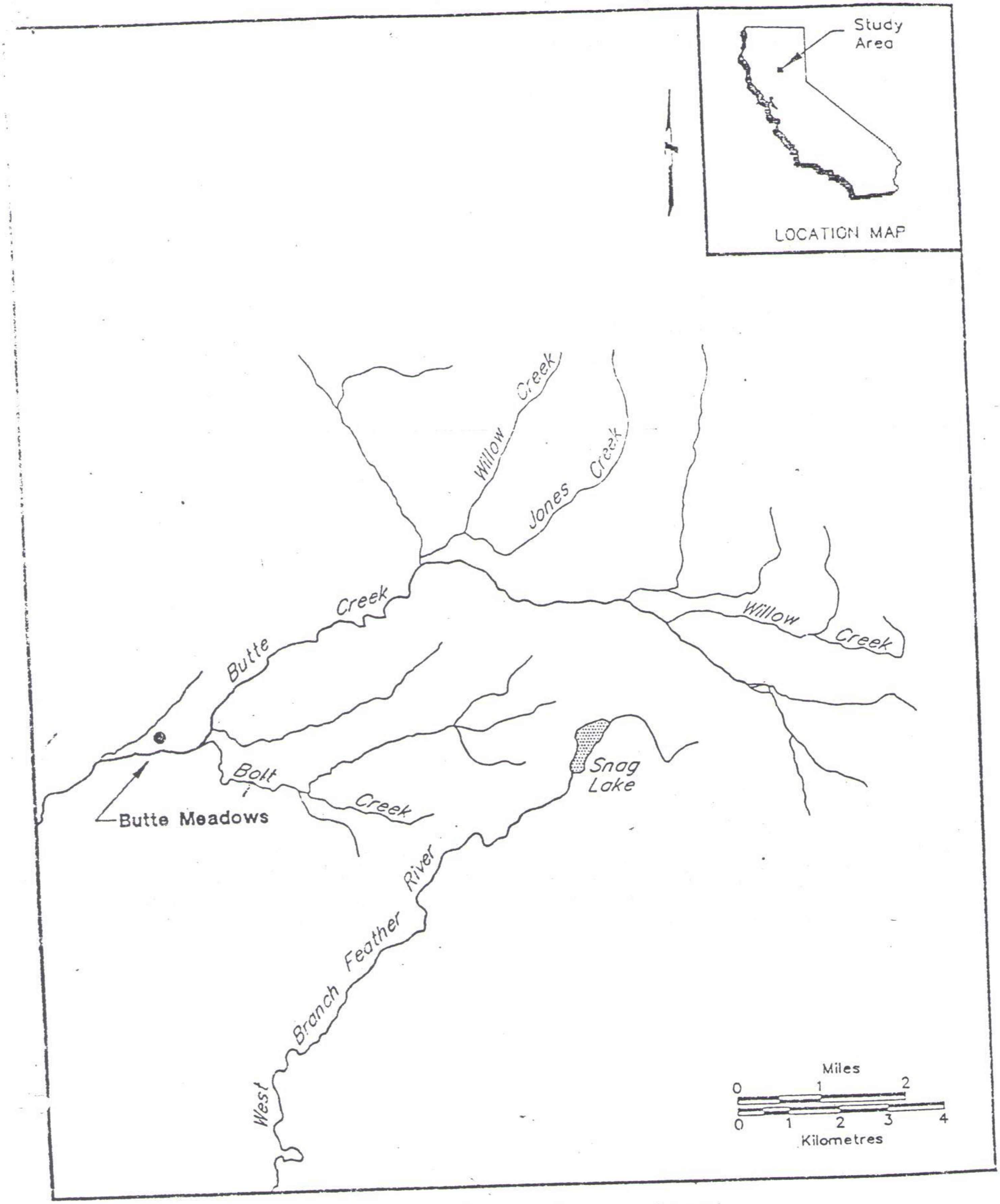

Figure 2. Butte Meadows Basin, Butte Creek.

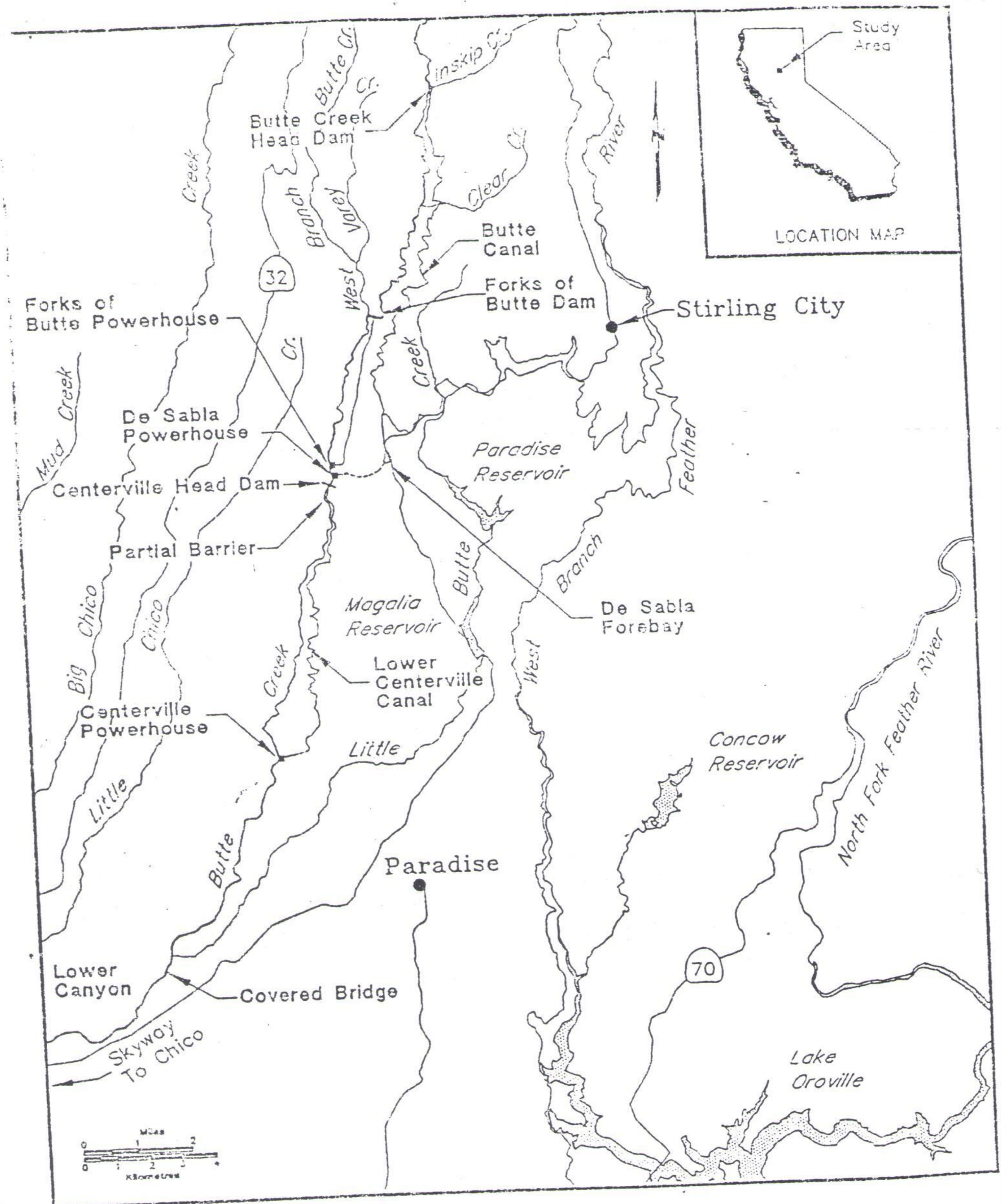

Figure 3. Butte Creek Canyon, Butte Creek.

Powerhouse. The stream in the canyon between and below the dams is characterized by deep pools and steep rocky banks. The stream gradient is steep through the canyon (Hansen et. al 1940). Little spawning size gravel for trout or salmon is available in the canyon above Centerville Head Dam, although salmon can not ascend the dam to spawn in this reach.

Salmon and steelhead migrated far into the canyons prior to construction of the dams in 1917. Steelhead probably went as far as Butte Meadows (Flint and Meyer 1977). They are now restricted to the lower reaches of the canyon and tributaries such as Dry Creek (Brown 1992b). Salmon now spend their summers between a natural barrier about 1.6 km (1 mile) below Centerville Head Dam and the Covered Bridge. Most gradually swim up to the barrier during summer. Some spawn near their holding pools, but many drop downstream to areas richer in suitable gravel. Young salmon rear in the canyon below Centerville Head Dam for up to one year. Summer flows of 1.13 cms (40 cfs) generally keep water temperature below 20 C (68 F) in the reach (Kimmerer and Carpenter 1989). Water temperature exceeds 24.4 C (76 F) in the canyon between the dams in July and August.

Valley Section

Butte Creek leaves the canyon and flows through a portion of the Sacramento Valley near Chico (Figure 4). Oaks, cottonwoods, and

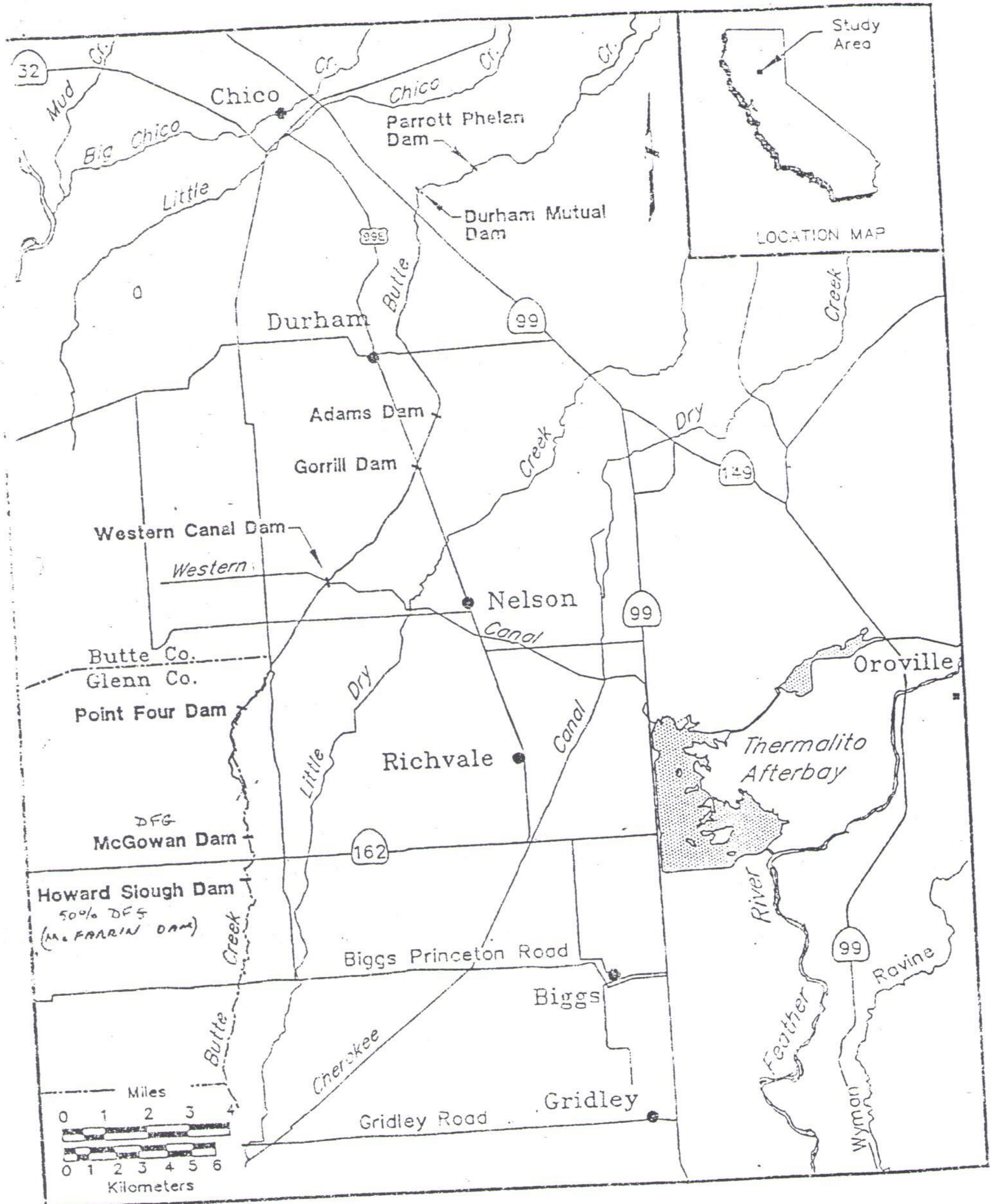

Figure 4. Valley Section, Butte Creek.

willows are common along the banks of the upper reaches in this section (DFG 1974). The creek is bordered by levees in most of the valley reach. Eight dams and numerous diversions in the valley section remove water to irrigate rice and orchards (McGill 1987). The upstream-most diversion, Parrott Phelan, takes water all year (winter diversions are small and are made with the dam boards out), but most divert in April through September in dry years and May through August in wet years. Fall-run chinook salmon spawn in this reach between Highway 99 crossing and Western Canal crossing in October and November. Adult spring-run chinook salmon pass through this reach in April, May, and June. Late running adults, however, may not be able to successfully ascend these eight diversion dams. Juvenile salmon from both races rear here in late winter and spring on their way to the Pacific Ocean.

Butte Basin

Butte Basin, Butte Sink, Butte Slough, and the Sutter Bypass is the final path of Butte Creek water before it joins the Sacramento River (Figure 5). Creek water flows through twin channels, the East and West borrow pits in summer and Butte Slough Outfall in the fall, winter, and spring. The borrow pits are regular, excavated channels on either side of Sutter Bypass. The creek gains flow here in wet years through the return of irrigation water. Gates on Willow slough and the East-West borrow pit diversion structure are used to control water levels in the East borrow pit

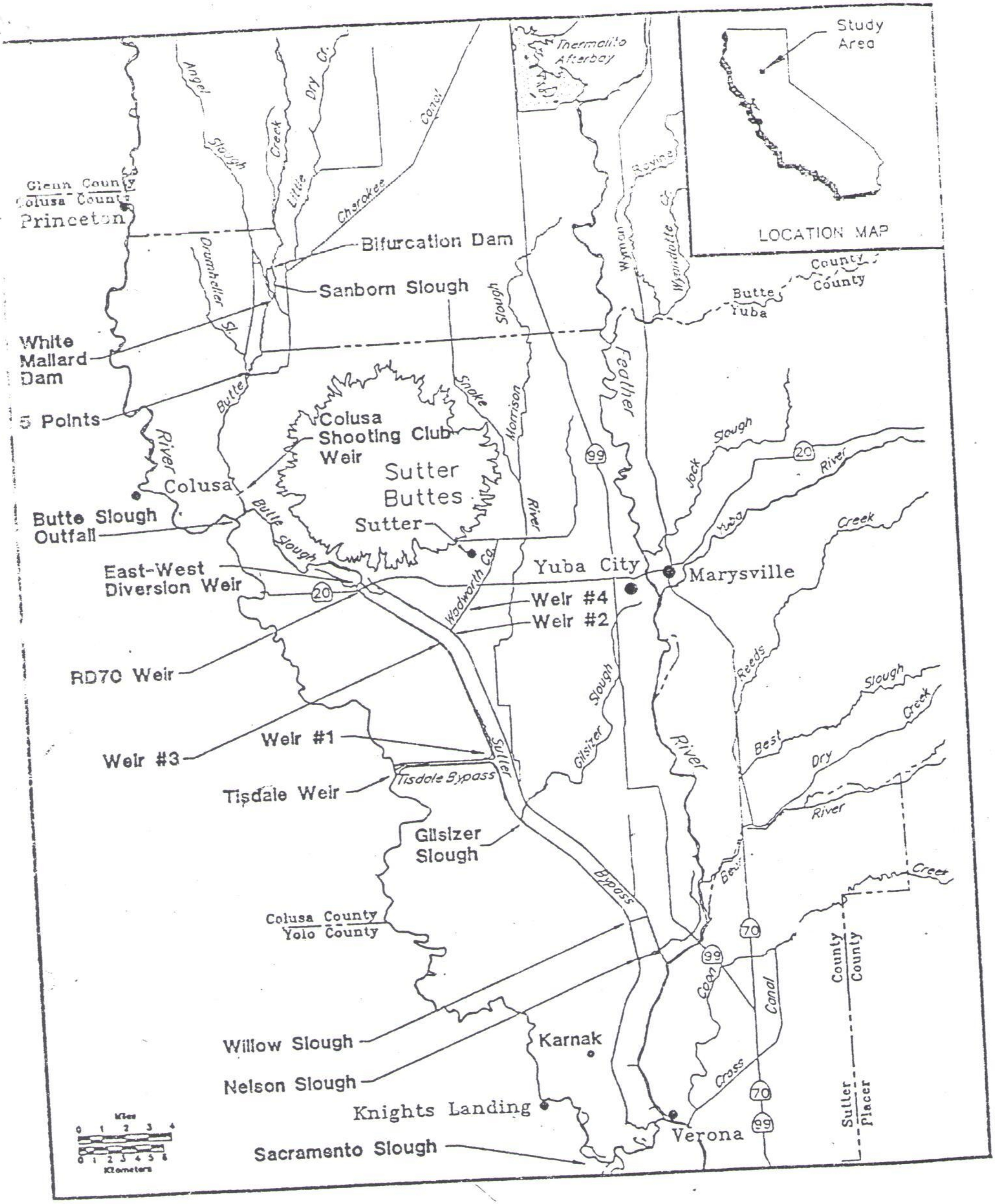

Figure 5. Butte Basin, Butte Creek.

(Slebodnick 1976). Dams also impound and divert water for duck clubs and rice growers. The dams include: Sanborn Slough, White Mallard Dam, East-West Diversion Weir, and weirs number 1 through 5. Willows are the dominant riparian plant species. Salmon and steelhead rear in these waters in spring and early summer, but so do the other species listed in Table 1. Some, such as squawfish, bass, and catfish could be significant predators on young salmonids here. High water temperatures 21.1-29.4C (70-85F) in late spring and summer also threaten the survival of salmon and steelhead in this reach.

METHODS

Memoranda from the Butte Creek files of the Department of Fish and Game (DFG), PG and E, and Department of Water Resources (DWR) were copied and reviewed. Other reports from DFG and DWR were also reviewed. General fisheries literature was searched for references on Butte Creek. Knowledgeable biologists and wardens with DFG, biologists with the U.S. Fish and Wildlife Service (FWS), and PG and E were interviewed. Statements in this report are derived from DFG memoranda unless a citation is listed.

Table 1. The Fishes of Butte Creek (Moyle 1976, Brown 1992b).

Common Name	Scientific Name
Pacific lamprey	*Lampetra tridentata*
Pacific brock lamprey	*Lampetra pacifica*
Chinook salmon	*Oncorhynchus tshawytscha*
Steelhead rainbow trout	*Oncorhynchus mykiss*
Brown trout	*Salmo trutta*
Brook trout	*Salvelinus fontinalis*
Hitch	*Lavinia exilicauda*
California roach	*Hesperoleucus symmetricus*
Hardhead	*Mylopharodon conocephalus*
Sacramento squawfish	*Ptychocheilus grandis*
Speckled dace	*Rhinichthys osculus*
Golden shiner	*Notemigonus crysoleucas*
Goldfish	*Carassius auratus*
Carp	*Cyprinus carpio*
Sacramento sucker	*Catostomus occidentalis*
Black bullhead	*Ictalurus melas*
Brown bullhead	*Ictalurus nebulosus*
Channel catfish	*Ictalurus punctatus*
Mosquitofish	*Gambusia affinis*
Threespine stickleback	*Gasterosteus aculeatus*
Bluegill	*Lepomis macrochirus*
Redear sunfish	*Lepomis microlophus*
Green sunfish	*Lepomis cyanellus*
White crappie	*Pomoxis annularis*
Black crappie	*Pomoxis nigromaculatus*
Largemouth bass	*Micropterus salmoides*
Smallmouth bass	*Micropterus dolomieui*
Spotted bass	*Micropterus punctulatus*
Bigscale logperch	*Percina marcolepida*
Tule perch	*Hysterocarpus traski*
Prickly sculpin	*Cottus asper*
Riffle sculpin	*Cottus gulosus*

RESULTS AND DISCUSSION

Salmon Life History

Spring-run Chinook Salmon

Adult spring-run chinook salmon begin to enter Butte Creek from the Sacramento River in late February. They attempt to pass diversion dams near Chico from early March through early June. Most pass these obstacles between mid-April and mid-May. The fish seek refuge in pools in the canyon (Sato and Moyle 1989) between a barrier about 1.6 km (one mile) below Centerville Head Dam and the Paradise Highway Bridge. They gradually move upstream from pool to pool throughout the summer. Spawning takes place in gravel beds near their summer refuge from mid-September through early October (Marcotte 1983). Prior to 1965, Butte Creek supported an average of 2,454 spring-run chinook salmon (based on expanded counts of carcasses and live salmon in September and October surveys); however, over the last 26 years an average of only 349 spring-run chinook salmon have spawned in the creek (Flint and Meyer 1977) (Table 2).

Eggs hatch in the gravel in late fall. After a period of physical development the young salmon leave the protection of their gravel niches to rear and migrate downstream (Marcotte 1983). The first migrants passed the Parrott-Phelan Diversion in early January in 1991. They measured about 40 mm (1.6 inch) fork length. Fry and

Table 2. Estimates of spawning spring-run chinook salmon in Butte Creek, 1956-1991.

Year	Number	Year	Number
1956	3,000	1974	150
1957	2,192	1975	650
1958	1,100	1976	46
1959	500	1977	100
1960	6,700	1978	128
1961	3,100	1979	10
1962	1,750	1980	119
1963	4,600	1981	250
1964	600	1982	534
1965	1,000	1983	50
1966	80	1984	23
1967	180	1985	254
1968	280	1986	1,371
1969	830	1987	14
1970	285	1988	1,300
1971	470	1989	1,300
1972	150	1990	100
1973	300	1991	100

fingerling chinook salmon continued to migrate downstream through May. Their migration peaked in February (Brown 1992a). Several hundred young salmon remained in pools below Centerville Head Dam in spring and summer (Brown 1992b). Some of these probably emigrate during fall freshets as yearlings (Shapovalov and Taft 1954), while others leave during winter and spring storms (Brown 1992a).

Fall-run Chinook Salmon

Fall-run chinook salmon enter Butte Creek in October and November. Some begin spawning in late October but most spawning occurs in mid November. They usually spawn in gravel between Durham Mutual Dam and Western Canal (Slebodnick 1976). DFG has estimated that up to 1,000 spawn in the creek;. however, no count was made in most years. Their young migrate downstream from February through May (Richardson 1978).

Late Fall-run Chinook Salmon

Late fall-run chinook salmon enter Butte Creek December through February. They spawn in gravel above Parrott Phelan Dam in January, February and March. DFG has made no estimate of their numbers. Their young leave Butte Creek later than the fall run, usually April through June (Richardson 1978). Wardens have reported anglers catching late fall-run chinook salmon in Butte Creek in January during winters when flow is low.

Steelhead

Steelhead ascend Butte Creek in the late fall and winter. They spawn in tributaries such as Dry Creek (Brown 1992b) and in the main creek above Parrott-Phelan diversion in winter and spring. Their young may emigrate in spring or fall, or they may remain as resident fish for up to four years. Some are resident trout all their lives (Shapovalov and Taft 1954).

Steelhead have been reported in Butte Creek principally through reports by DFG wardens of angler catches. Steelhead smolts were caught in Dry Creek (Brown 1992b), but no steelhead was caught in studies of salmonid losses in agricultural diversions (Brown 1992a). We found no estimate of their numbers in Butte Creek in our review of the available literature.

Barriers to Successful Reproduction and Recruitment

Barriers to successful reproduction and recruitment of salmon and steelhead in Butte Creek include numerous diversion dams that divert young salmonids to die in flooded fields and block adult migration (Flint 1972, Slebodnick 1976), low flow releases from Butte Creek Head Dam and Centerville Head Dam that cause salmonid mortalities from warm water (Flint and Meyer 1977, Kimmerer and Carpenter 1989), losses of adults that wander into canals (DFG 1973), lack of spawning gravel, over harvest by sport fishing, and poaching.

Spring-run Chinook Salmon

Blockage- Adult salmon are delayed at diversion dams in the Valley section of Butte Creek (Figure 4)(Upper Sacramento River Council and Action Team 1979). During wetter years, irrigators delay diverting Butte Creek water until mid-May. Most salmon have passed the diversions by then and are resting in pools in the canyon. Some spring-run chinook salmon run late and those fish can be trapped in pools between 0.8 and 1.6 km (0.5 and 1.0 miles) downstream of the Highway 99 bridge. Those fish are usually rescued by DFG wardens and biologists. During dry years, diversions can literally dry up Butte Creek as early as February or March. Most of the run is then trapped behind one of the upper diversion dams. Mortalities are high from elevated water temperatures and poaching until DFG can rescue the remaining fish.

Centerville Head Dam has blocked the migration of spring-run chinook salmon and steelhead since its construction in 1917 (Flint and Meyer 1977). Anadromous salmonids are denied access to a spectacular canyon characterized by deep, cool pools, and steep rock walls (Hansen et. al 1940). The construction of the Butte Creek Head Dam also in 1917 has allowed P.G.E. and E. to divert most of the water from the canyon. Under current operations, water in the upper canyon is too warm for salmon in the summer (Hayes 1965). Water diverted at the Butte Creek Head Dam is returned at the De Sabla Power House to the creek with water diverted from the

Feather River. Most spring-run chinook salmon spend the summer in pools below a partially passible natural barrier (low flow barrier) located 1.6 km (1 mile) below Centerville Head Dam. About 1.13 cms (40 cfs) is released by PG and E to keep water temperature cool enough for salmon in the lower canyon pools in normal and wet years. About 0.28 cms is released during dry years (PG and E 1983). Salmon are forced to drop downstream to spawn in September because little gravel is available near their holding pools. Temperatures above 13.9 C (57 F) in these downstream spawning areas cause substantial pre-spawning mortality and kill many eggs.

Poaching- Loss to poachers is the largest threat to the continued existence of spring-run chinook salmon in some streams in California (Moyle et. al 1989). Heavy poaching and harassment, coupled with warm water in the summer holding areas, and increased agricultural diversions in the late 1960's and early 1970's has been cited as the probable cause of the sharp decline in spawning spring-run chinook salmon in Butte Creek. Poaching is common in areas where adult salmon are blocked; however, poaching is also a major threat in streams where adult salmonids have free access to summer holding areas, such as the Middle Fork of the Eel River. DFG estimated that 3,000 of 5,000 salmon estimated to have reached the summer holding area perished during the summer of 1988 largely due to poaching in Butte Creek. Although most poaching may occur in Butte Creek Canyon, poaching also occurs at White Mallard Spill Dam, pools below Highway 99, in water behind any of the other diversion dams, and at control structures in the Sutter Bypass.

Diversions- Each water diversion in Butte Creek can divert outmigrant salmon and steelhead into rice fields, orchards, and waterfowl areas. Those that take the heaviest toll include Parrott-Phelan (Brown 1992a), Western Canal, Sanborn Slough, and White Mallard (DFG 1974). Brown (1992a) estimated that 6,004 fry and 47 yearling spring-run chinook salmon were lost from being diverted into Parrott-Phelan diversion during a sampling period that lasted from December through June, 1991. Most salmon were caught in Parrott-Phelan diversion in February. Sampling was also conducted during spring at the Durham Mutual, Adams, and Gorrill diversions. An estimated 350 salmon fry and smolts were lost at Durham Mutual. Most were caught in February. An estimated 263 were lost at Adams; most were caught in May and June. No yearling was caught at Durham Mutual or Adams, and no salmon was caught at Gorrill. Other sampling for outmigrant loss in diversions has been brief, lasting less than two months (Hallock and VanWoert 1959). Although no studies have been conducted to estimate losses of outmigrants at Western Canal, Sanborn Slough, or White Mallard over the entire migration period (DFG 1973), they are likely to be major sources of loss of salmon based on the portion of outflow they divert (Hallock and Van Woert, 1959) for ducks and agricultural crops during December through June.

Adult spring-run chinook salmon are lost as they attempt to ascend Butte Creek in the spring. Spring-run chinook salmon have been reported to be stranded after following the Western Canal to Thermalito Afterbay outlet (Figure 4) (Hallock and VanWoert 1957). Salmon are also drawn by relatively high irrigation return flows at Five Points and Drumheller Slough (Figure 5) where they are stranded (Flint 1972). Some late running spring-run salmon are drawn to irrigation spill water at White Mallard Spill Dam (Figure 5). Many fall prey to poachers and natural predators when they are stranded here (DFG 1974). Salmon are also attracted into the Cherokee Canal (Figure 5) by high flows. They may find their way back to Butte Creek through Sanborn Slough (Figure 5), but many are thought to be lost in the channels and fields of the adjacent duck clubs (Flint 1972).

Surplus irrigation water from White Mallard Diversion is released at Five Points and constitutes an attraction flow that lures adult salmon to their deaths. Migrating adults are attracted to this flow and are unable to pass barriers that are outfall structures. Salmon stay in the area until they are lost to poachers or predators (DFG 1974).

<u>Sport Fishing</u>-Sport fishing is allowed in Butte Creek all year below the Highway 99 bridge crossing south of Chico with a limit of 2 salmon or 5 trout in combination. Sport fishing is also allowed from February 1 through March 31 from the Highway 99 road bridge

crossing south of Chico to the Centerville Head Dam with a limit of 1 salmon or trout. In the California Fish and Wildlife Plan, DFG estimated that about 400 spring run salmon were caught each year and that "anglers took a substantial toll of migrating salmon" in years prior to 1965 (DFG 1965). We assume that fewer salmon are caught now because the runs are much smaller, but the risk of anglers catching a substantial portion of the run persists. Regulations permitting fishing in the summer holding areas even for the months of February and March may allow anglers to catch yearling spring-run chinook salmon rearing there.

Other-Flint (1972) has described the Butte Sink as the "greatest single hazard to downstream migrants on Butte Creek." Butte Slough outfall gates may cause losses in juvenile and adult salmon. DWR opens the gates to control flooding in winter and early spring and adult and juvenile salmon can pass freely from Butte Creek to the Sacramento River during this period. Reclamation District 70 closes all of the gates later in the spring and in summer to retain water in the Butte Slough for irrigation. Young salmon are also diverted down Butte Creek into Butte Slough and may be lost to agricultural diversions when the Butte Slough outfall gates are closed.

Young spring-run chinook salmon are lost as they migrate down the Sacramento River and through the Sacramento-San Joaquin Estuary. Their numbers are reduced by agricultural diversions in the Sacramento River, predators in the river and estuary, and by state and federal export pumps in the estuary (Stevens and Miller 1983).

Fall-run Chinook Salmon

Fall-run chinook salmon suffer from lack of water for passage and spawning, poor quality spawning gravel, inadequate flow for juvenile outmigration, losses from agricultural diversions, predation in lower reaches of Butte Creek, and poaching.

Blockage- Adult salmon are delayed or blocked at diversion dams in the Valley section of Butte Creek (Figure 4). Duck clubs and waterfowl areas divert most of the flow of Butte Creek in the fall, leaving little or no water in the creek bed. Salmon are trapped in pools between the Highway 99 crossing and Adams Dam in wetter years. In drier years no fall-run chinook salmon ascend the creek.

Diversions- Juvenile fall-run chinook salmon migrate in late spring. Losses are higher than for spring-run chinook salmon because agricultural diversions are in full operation as the fall-run juveniles attempt to leave their natal gravel. DFG suspects these young salmon suffer heavy losses from diversions in the middle and lower reaches of Butte Creek, especially through the Western Canal, Sanborn, and White Mallard diversions.

Outmigrant fall-run chinook salmon that survive the major diversions are passed into the Butte Slough because the gates at the mouth of Butte Creek are closed to bypass water for agricultural diversions. Salmon that reach the twin borrow pits bordering Sutter Bypass are subject to high water temperatures and concentrations of very active predatory fishes such as largemouth bass, green sunfish, and squawfish. They are also drawn into irrigated fields by diversions from the borrow pits.

Poaching- Like spring-run chinook salmon, migrating fall-run chinook salmon are suseptible to poachers. They are especially vulnerable because they swim upstream during periods of very low flows. They reach dead ends and congregate near outfalls from agricultural diversions.

Other- Migrating adult salmon that reach spawning areas above Highway 99 crossing find that spawning gravel is scarce and of poor quality. Low flow forces them to choose areas of marginal or poor quality toward the center of the channel to spawn.

Young fall-run chinook salmon are also lost as they migrate down the Sacramento River and through the Sacramento-San Joaquin Estuary. Like the spring run, their numbers are reduced by agricultural diversions in the Sacramento River, predators in the river and estuary, and by state and federal export pumps in the estuary (Stevens and Miller 1983).

Late Fall-run Chinook Salmon

Little is known of the late fall-run chinook salmon in Butte Creek. They typically migrate in mid-winter and spawn in the gravel upstream from Parrott-Phelan Dam. Their young emigrate in late May and June when they are especially susceptible to diversions in the Valley section of Butte Creek and in the Butte Basin. They share many of the same risks as the fall run.

Steelhead

Dams have eliminated steelhead spawning and rearing areas in Butte Meadows and Butte Creek Canyon. The few that presently swim up Butte Creek to spawn find their way to pools below Centerville Head Dam and small tributaries in the Valley reach. Surveys of Dry Creek showed that habitat was good for steelhead in winter and spring, but low flow and warm water temperatures limited production in the summer (Brown 1992b). Steelhead would have to leave these streams as fingerlings or find cooler water higher in the watershed. The main limiting factor for steelhead in Butte Creek is the Centerville Head Dam that blocks them from reaching favorable habitat.

Potential Solutions to Problems

Human activities have altered the flow of Butte Creek and reduced the number of anadromous fish that return to Butte Creek.

Just as construction activities have nearly destroyed the salmon and steelhead runs, other similar actions could help restore the runs. Better ladders over dams, eliminating some dams, finding alternative sources of water, improving spawning gravel, improving spawning and rearing flows, reducing poaching, and modifying fishing regulations are a few of the ways we could intervene to improve salmonid runs in Butte Creek. Each of the suggestions in this section was located in file memos from DFG. Solutions are listed in priority.

1. Release enough water from upstream diversions to cool late September through November flows to 13.9 C (57 F) or cooler at spawning sites from the canyon to the covered bridge to minimize egg loss and pre-spawning mortality.

2. Place spawning-size gravel below summer holding pools. Gravel could be placed by helicopter. This would allow spring-run chinook salmon to spawn closer to their summer holding pools in cooler water.

3. Controll poaching and harassment of salmon by stationing uniformed scientific aides in salmon holding areas during the late spring and summer. By patrolling the area frequently they can reduce the take of salmon by poachers (Jones 1980).

4. Screen Sanborn, White Mallard, and Parrott Phelan diversions. Siphon Western Canal water under Butte Creek. These diversions are a source of loss of outmigrant salmon in Butte Creek. Flow should be adequate below each diversion to allow salmon that are still in the creek to swim downstream in the channel of Butte Creek (DFG 1974).

5. Close Butte Creek to salmon fishing. Closing the salmon fishery in conjunction with habitat restoration could help salmon runs to rebuild to a level of 2,000 spring-run chinook salmon. The fishery could then be reopened on a limited basis. About 2,000 salmon was identified as the capacity of the holding and spawning areas with habitat improvements by biologists in DFG memos. Closing an imperiled run of salmonids that run in the spring and spend summer in pools in canyons has been applied to the Middle Fork Eel River (Puckett 1975). DFG closed the spring-run steelhead fishery when numbers of steelhead dropped (Jones 1980). The fishing closure has been responsible for the preservation of a viable population of spring-run steelhead on the Eel River (Weldon Jones, California Department of Fish and Game, personal communication).

6. Build lateral canals from Western Canal to provide farmers water for rice. Augment flows with water from Oroville. Let Butte Creek water flow down the creek. The DWR and DFG are negotiating with owners of Point Four Dam to provide water to irrigate rice from Western Canal through lateral canals in exchange for the

removal of Point Four Dam and abandonment of that diversion from Butte Creek. Other canals could be built to provide water to irrigators upstream and downstream from Western Canal . Water could also be provided to some landowners by pumping groundwater in exchange for water left in Butte Creek during low flow periods when salmon are migrating (Upper Sacramento River Council and Action Team 1979).

7. Adams and Gorrill diversions could be combined and one dam could be removed. An improved fish ladder could be installed in the remaining dam. Both dams have been identified as barriers to salmon migration at low flows (Upper Sacramento River Council and Action Team 1979).

8. Butte Slough outfall gates could be operated to accommodate the needs of spring-run chinook salmon. Gates should remain open later in the spring to allow outmigrants to pass and adults to ascend Butte Creek at this more favorable location in terms of avoiding mortalities associated with Sutter Bypass such as diversions, delays, predation, and poaching.

9. As already described, fall-run chinook salmon often face very low water conditions below Adams and Gorrill dams in late October. As part of a plan to supply upstream water users with alternate sources of water (such as annexation to Western Canal

Water District or augmenting flow with groundwater), flows could be increased in this reach. Gravel, which is currently scarce, should be added to riffles as an additional means of increasing survival of the fall run. Gravel that has been placed on these riffles should be protected from removal by gravel miners.

10. Operations at Five Points should be modified to reduce the trapping effect of current operations. This trap is a serious source of loss to upstream migrants. Return flows should be limited to 0.14 cms (5 cfs) or less at Five Points. Multiple return points or sub-creek bed return could help.

11. Place grids on canal discharges (Hallock 1987). Adult salmon are lost in rice fields and orchards when they swim up irrigation canals such as Western Canal and Cherokee Canal. These fish are stranded in fields or killed by predators or poachers.

12. Modify the low flow barrier below Centerville Head Dam. Modifying this velocity barrier would allow salmon that congregate in pools below the barrier to ascend the creek to occupy 1.6 km (1 mile) of additional holding habitat. This step would also allow salmon and steelhead access to a ladder that could be built over Centerville Head Dam to open habitat salmon historically occupied in Butte Canyon. Barriers above the dam should be modified to allow salmon to pass and additional flow to bring minimum flow up to at least 1.14 cms (40 cfs) should be allowed to pass Butte Creek Head

Dam to cool water in the canyon during late spring, summer, and early fall. Gravel should be added to riffles in this reach to replace gravel blocked by the dam. This action could increase numbers of spring-run chinook salmon and help restore the steelhead fishery decimated by these dams (Flint and Meyer 1977).

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