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FISH AND WILDLIFE SERVICE

AN ANALYSIS OF THE EFFECTIVENESS OF THE MITIGATION PLAN FOR SHASTA AND KESWICK DAMS

REGION ONE

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AN ANALYSIS OF THE EFFECTIVENESS OF THE MITIGATION PLAN FOR SHASTA AND KESWICK DAMS

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INTRODUCTION

The purpose of this report is to assess what the anadromous fish resources in the upper Sacramento River system were prior to construction of Shasta and Keswick Dams and to evaluate the effectiveness of mitigation measures designed to compensate for the loss of these resources. Information provided by this report is intended to assist the reader in answering questions regarding the specific nature and extent of mitigation requirements, including hatchery production goals and habitat maintenance. Such questions include:

> What mitigation goals were originally set forth for the Bureau of Reclamation's Shasta Dam and Keswick Dam projects?
>
> Can those mitigation goals be refined using newer information or analytical methods?
>
> Have the mitigation goals been reached?
>
> Are some components of the mitigation program for the projects truly enhancement?

The role of Coleman National Fish Hatchery and the Keswick Fish Trap are emphasized in this report as these are the only remaining features of the original mitigation plan identified for the construction and operation of Shasta and Keswick Dams.

BACKGROUND

Shasta Dam and its 4,500,OOO acre-foot capacity reservoir, Shasta Lake, are located on the Sacramento River near Redding, California. Immediately downstream from Shasta Dam is the smaller Keswick Dam and its 23,800 acre-foot reservoir which regulates flows in the Sacramento River. These facilities were authorized by the River and Harbor Act (Reclamation Project Authorization) of 1937. The act specified that Shasta Dam was to be a multiple purpose dam for navigation improvement, flood control, supplemental irrigation, salinity control in the lower Sacramento Delta region, and electric power generation.

Construction of Shasta Dam by the Bureau of Reclamation (Bureau) extended from 1938 to 1944. Construction of Keswick Dam commenced in 1941 and was not completed until 1950. By May 1942, fish migration upstream of Keswick had been significantly impacted by the construction of a cofferdam without adequate fish passage conditions. Shasta Dam itself became an impassable barrier to upstream migrating salmon on November 8, 1942.

Concurrent with the start-up of construction activities in 1938, the Bureau initiated studies to assess project effects on important fisheries resources, primarily chinook salmon (Oncorhynchus tshawytscha) and to develop plans for a salmon salvage program. From the outset, this program was constrained by (1) the lack of information on the kind and size of fish runs that would be impacted by the project, and (2) the time frame in which to select and implement an action plan.

Biological Investigations

Biological investigations in the project area began as early as 1937 when the California Division of Fish and Game (now the Department of Fish and Game) initiated fish counting at the Anderson-Cottonwood Irrigation Diversion Dam, about 10 miles downstream from the Shasta dam site. These counts were continued by the Bureau in 1938 and by the Fish and Wildlife Service (Service) from 1939 through 1942. An extensive study of the upper Sacramento River salmon resources was conducted in 1939 and was published as Special Scientific Report No. 10 (Hanson, Smith and Needham, 1940). This report summarized fish counts, spawning ground surveys, and other biological information on the Sacramento River and its tributaries in and downstream from the project area. Several plans were proposed for the salvage of salmon runs blocked or otherwise adversely impacted by the construction and operation of Shasta Dam. Biological investigations were continued during the ensuing salmon salvage operation (Needham, Hanson and Parker, 1943) and afterwards (Moffett, 1949; Azevedo and Parkhurst, 1956; Slater , 1963).

Plan Selection.

Selection of a final plan to offset salmon losses was based on the conclusions of a Board of Consultants appointed by the Bureau (Calkins, Durand and Smith, 1940). This Board, consisting of one expert each in the field of economics, engineering and biology, considered the findings of the Service's Special Scientific Report No. 10 and additional input from the Bureau of Reclamation and U.S. Bureau of Fisheries Seattle Office personnel including Fred J. Foster and Harlan B. Holmes. The plan selected was called the "Sacramento River, Battle Creek, Deer Creek Plan" and consisted of mitigation measures that included (1) improvement of natural spawning conditions in the Sacramento River, (2) artificial salmon propagation improvements in the Battle Creek system, and (3) trapping and transporting spring-run salmon to Deer Creek, a tributary of the Sacramento River.

The rationale behind this plan appeared to have been based on measures that could be undertaken economically and that would utilize the potential of existing facilities and habitats, and habitats anticipated once the project was in operation. It was expected that once the dam was operating and the transition period over, temperature conditions would improve and biological

productivity would increase in the main Sacramento River (Calkins et al., 1940). A salmon hatchery already existed ont Battle Creek (12,000,OOO egg/fry capacity), having been established by the State of California **in** 1895 **and** operated by the Service since 1896. A natural run of spring chinook occurred in Deer Creek, but there appeared to be a potential for this system to support additional fish based on gravel surveys and habitat improvements such as laddering barrier falls and reducing irrigation diversions. The rationale for plan selection is discussed in detail in the section of this report titled "The Shasta Salmon Salvage Plan".

Plan Implementation.

The salmon salvage plan was put into effect starting in 1941 and continued in part through 1946. A new **hatchery** was **built on** Battle Creek (Coleman Hatchery Station, now Coleman National Fish Hatchery) and fish racks were installed in Battle Creek to hold salmon spawners. Fish racks were also constructed on the Sacramento River at Balls Ferry and twelve miles upstream near Anderson. Measures were taken at these mainstem river racks to count fall-run chinook salmon and control their distribution in the river reaches below Keswick Dam. A temporary fish trap was constructed at the Balls Ferry Rack to provide fall-run spawners for artificial propagation at Coleman Hatchery. A permanent fish trap was constructed at Keswick Dam, primarily to capture spring-run chinook salmon. Nearly 16,000 spring-run salmon were hauled to Deer Creek between 1941 and 1946.

In 1943, the Service issued a status report (Special Scientific Report No. 26) titled "Supplementary Report on Investigations of Fish-Salvage Problems in Relation to Shasta Dam" (Needhan, Hanson and Parker, 1943). This report discussed modifications to the salmon maintenance plan and progress of ongoing salvage operations and fishery investigations.

Plan Evaluation and Subsequent Developments.

A report titled "The First Four Years of King Salmon Maintenance Below Shasta Dam, Sacramento River, California" by Dr. James Moffett of the U.S. Fish and Wildlife Service (Moffett, 1949) summarized the salmon salvage plan, discussed the relative success of the various plan features, and provided an assessment of overall conditions in the Sacramento River for anadromous fish production. Moffett pointed out the apparent failures of the Deer Creek adult transplanting program, the racks placed in the Sacramento River to control fish distribution, and development of an artificial propagation program for spring-run chinook salmon at Coleman Hatchery.

* The chinook salmon (Oncorhynchus tshawytscha) is commonly referred to as king salmon in California.

Moffett concluded that (1) “present ecological conditions in Sacramento River below Shasta Dam are greatly improved for the natural production of Salmonid fishes”, (2) “The main river spawning plan is producing large numbers of seaward migrant salmon and presumably adult salmon in some measure of abundance”, and (3) “The improvement in river conditions has compensated, as nearly as can be determined at present, for the loss of spawning grounds above Shasta”. Moffett qualified his conclusions by further stating that “Ultimate success of the program depends on the maintenance of presently favorable river conditions” and that “experience has been insufficient to establish definitely the success or failure of the salmon maintenance work and observations and studies need to be continued”.

Despite these concerns, a Memorandum of Agreement was signed on July 1, 1949 by the Commissioner of the Bureau of Reclamation and the Director of the Fish and Wildlife Service which formally (1) terminated the Bureau's obligation to carry out any further elements of the salmon salvage plan with the exception of maintaining the Keswick Fish Trap, and (2) transferred full custody of Coleman Hatchery and its facilities to the Service (including responsibility for all future operational funding). The total capital and operating costs to the Bureau of constructing and operating the Shasta Salmon Salvage Plan as of July 1, 1949, was $2,824,349.11.

The Service conducted subsequent studies to further determine Shasta Dam impacts on salmon and steelhead (Azevedo and Parkhurst, 1957; Cope and Slater, 1957; Slater, 1963). Modifications and improvements at Coleman Hatchery have occurred over the past 45-plus years. However, due to insufficient funding and the deterioration of many of the original facilities, operational goals have not been fully achieved (U.S.F.W.S., 1984a; Richardson, 1985).

The current production goal of Coleman Hatchery, with existing facilities, is a return escapement to the upper Sacramento River of approximately 18,650 fall and late-fall chinook spawners and 2,150 steelhead trout (U.S.F.W.S., 1984a). This goal is based on maximizing use of water supply and propagation facilities available to the hatchery. The return run of spawners anticipated is considerably less than the estimated 60,000-plus spring and fall-run chinook and the unknown numbers of winter-run and late fall-run chinook salmon that were produced in the river reaches blocked by Shasta and Keswick Dams.

PRE-SHASTA DAM FISHERY RESOURCES

There is little information in the literature regarding the magnitude of salmon runs in the upper Sacramento River prior to Shasta Dam, but various reports and documents do describe the distribution and general abundance of salmon runs. There is very little reference to steelhead trout. Perhaps the best evidence that significant salmon runs existed is from the early records of commercial salmon catches from the Sacramento River and egg collections from the upriver hatcheries.

Commercial Fisheries

Although the first commercial salmon fishery was established on the Sacramento River about 1850, even partial records of the catch were not available until 1864, and total catch records for the combined Sacramento-San Joaquin River fisheries were not maintained until 1874 (Clark, 1929).

The first salmon cannery was established along the Sacramento River in Yolo County in 1864 and the industry grew rapidly until, by 1881, twenty canneries operated on the river. The estimated commercial catch for the Sacramento River, harvested primarily by gillnets, increased from approximately 215,000 fish per year in 1874 to over 500,000 per year during the 1880-82 period. The number of fish harvested annually is estimated from records on cases of canned salmon produced, or from pounds of fish landed. Following the early both commercial harvest and the number of canneries operating on the river declined significantly. The catch fell to only 103,000 fish in 1891, and averaged around 200,000 fish annually through 1898. With **more salmon** being sold fresh or salted (mild-cured), the canned salmon industry continued to decline until finally discontinued in 1919.

From 1899 the catch again rose slowly until reaching a high of 540,000 fish harvested in 1910. At that time, the numbers of fishermen (1,490), boats (842) and gillnets (750) were triple that occurring in the early 1880's. Also, seining and ocean trolling were beginning to increase. From that point, the Sacramento River gillnet fishery declined steadily, reaching a low of only 21,000 salmon caught in 1934. The average annual gillnet harvest during the 1930's was less than 50,000 salmon.

From 1940 to 1946 there was another increase in the catch of Sacramento River salmon. Approximately 342,000 salmon were harvested in 1946, the largest catch since 1910. However, catches again declined until a complete closure of the river gillnet fishery occurred in 1957. The present harvest consists primarily of ocean commercial troll and marine sportfish catch.

The Sacramento River salmon catch from 1874 through 1957 is summarized in Table 1. From these data, and assuming a one-to-one catch to escapement

ratio, it is estimated that peak chinook salmon runs in the Sacramento River may have been as large as 800,000 to l,000,000 fish, with an average run size of 600,000 prior to 1915 (USFWS, 1984b).

Table 1. Commercial Salmon Catch from the Sacramento River, 1874-1957 1/, 2/ 3/, 4/

YEAR	NO. OF FISH	YEAR	NO. OF FISH
1874	215,948	1919	239,782
1875	352,785	1920	204,370
1876	367,714	1921	132,942
1877	343,777	1922	93,445
1878	345,217	1923	118,797
1879	234,648	1924	139,770
1880	573,745	1925	147,115
1881	508,500	1926	66,800
1882	508,515	1927	48,748
1883	476,470	1928	29,317
1884		1929	30,785
1885		1930	64,254
1886		1931	49,850
1887		1932	63,794
1888	350,628	1933	24,049
1889	342,587	1934	21,048
1890	157,241	1935	47,055
1891	103,625	1936	50,251
1892	181,890	1937	51,610
1893	209,137	1938	88,326
1894	237,951	1939	26,308
1895	189,595	1940	80,237
1896	173,466	1941	44,734
1897	210,674	1942	135,156
1898	215,968	1943	68,581
1899	342,000	1944	172,860
1900		1945	289,481
1901		1946	342,172
1902		1947	178,967
1903	-	1948	102,695
1904	435,872	1949	47,599
1905		1950	63,683
1906		1951	71,109
1907	482,357	1952	39,075
1908	386,047	1953	42,866
1909	465,715	1954	47,689
1910	542,965	1955	122,863
1911		1956	60,331
1912		1957 5/	17,028
1913			
1914			
1915	183,792		
1916	182,689		
1917	210,467		
1918	314,399		

1/ Data prior to 1916 from Clark (1929) and Rutter (1902).
2/ Data from 1916 from Heimann and Carlisle (1970).
3/ Totals reduced 10% to exclude the San Joaquin River catch.
4/ Based on average weight of 17 lbs/fish.
5/ Commercial net fishing prohibited after 1957.

Hatchery Records

Several salmon hatcheries operated in the upper Sacramento River system, collecting eggs and either incubating them locally or shipping them back east, overseas, or to other hatcheries in the basin with suitable rearing facilities. The Bureau of Fisheries operated egg taking stations and hatcheries on the McCloud River (Baird Hatchery, established in 1872), Battle Creek (Battle Creek Hatchery, established in 1895) and Mill Creek (Mill Creek Hatchery, established in 1901). Many eggs taken at these hatcheries were shipped to the State of California hatchery near Sisson (Mt. Shasta Hatchery: established in 1885). Table 2 summarizes the annual operations of these hatcheries from 1896 through 1935 (Hedgpeth, 1941).

Nearly all of the juvenile fish from these eggs were released into receiving waters as unfed fry. It was commonly assumed that survival of the large numbers of artificially propagated fry far exceeded that which would otherwise have occurred from natural spawning. Unfortunately, in the endeavor to maximize egg collections, management of natural spawning populations were often neglected. Weirs and racks placed across the streams to collect spawners for artificial propagation adversely impacted the migration and numbers of salmon which spawned naturally. In the long-run, favorable results of such mass propagation and transfer of eggs were not evident in returns to the escapement (Clark, 1929; Hedgpeth, 1941; 1944). Additional information on these early hatcheries is provided in the following section on specific stream systems.

General Fish Distribution

Salmon runs occurred extensively in the various river reaches that were blocked by Keswick and Shasta Dams. These reaches included the Little Sacramento River extending upstream from the mouth of the Pit River, the Pit River and its tributaries, and the McCloud River.

The primary run ascending the river to the headwaters of the Little Sacramento, McCloud River, Hat Creek and even Fall River (on the upper Pit River system) was the spring run (Rutter, 1902). Rutter noted that these salmon, which generally spawn in August, spawned in the McCloud River as early as April 20. Subsequent investigations revealed that these early McCloud River spawners were actually the predecessors of the present-day winter run (Slater, 1963).

The fall run, according to Rutter, did not ascend the Sacramento River as far as the spring run, but for the most part turned into the lower tributaries or spawned in river. The river reach downstream of Redding (to Tehama) was an important spawning ground for fall-run salmon. However, considerable numbers of fall-run salmon did spawn in the Little Sacramento River and lower McCloud and Pit Rivers.

The fish resources of various stream systems that were impacted by construction and operation of Shasta Dam, including Battle Creek and Deer Creek, are discussed herein.

Little Sacramento River

Clark (1929) quotes Livingston Stone, founder of Baird Hatchery on the McCloud River in 1872, as saying that the Little Sacramento River is, with the exception of the McCloud River, the principal spawning stream for the Sacramento River system. Juvenile salmon were also found in abundance during the summer as far upstream as Sisson (present town of Mt Shasta) and, according to Rutter (1902), it was not at all uncommon to catch over a hundred at a time in seine hauls in many of the pools of the headwaters. According to Clark, the entire Little Sacramento River had wonderful spawning beds, but falls at Sims stopped many fish. The Little Sacramento River suffered extensive destruction of habitat and declines in fish runs during construction of the Southern Pacific Railroad in 1884-87.

A State hatchery was constructed on Spring Creek, a tributary of the Little Sacramento River at Sisson, where surplus salmon eggs from the Baird, Battle Creek and Mill Creek Hatcheries were hatched and reared. Hedgpeth (1941) provides annual records of salmon eggs sent to this hatchery from 1896 to 1935 (Table 2). Over 50,000,OOO chinook salmon eggs were shipped to the facility annually from the three federal hatcheries between 1903 and 1907, the record being 96,000,OOO eggs in 1905. Most of the fry from these eggs were released unfed into the upper Sacramento River.

TABLE 2

Chinook Salmon Hatchery Operations, Sacramento River. 1896-1935a

(All figures in thousands, i.e., 1,000 = 1,000,000)

Year	McCloud River (Baird)		Battle Creek		Mill Creek		Eggs sent to Mt. Shasta
	Eggs taken	Fry released	Eggs taken	Fry released	Eggs taken	Fry released	
1896	5,000	2,000	25,852	10,900			18,645
1897	9,194	6,916	48,527	44,230			6,255
1898	16,568	3,263	19,429				31,620
1899	6,415	4,729	1,610				1,905
1900	2,139	889	3,920				2,021
1901	8,932	2,115	10,059		2,561		17,149
1902	1,065	1,618	5,584		3,880		7,455
1903	27,352	2,350	3		15,891		58,624
1904	8,661	7,561			36,719		87,170
1905	25,743	3,488	49,032		33,110		96,190
1906	2,984	2,512	32,640		37,752		63,671
1907	10,442	4,780	36,379		18,132		56,493
1908	5,078	3,590	14,006		13,193		26,599
1909	7,331	2,286	7,358		15,849		27,214
1910	(Records for	1910 were not	published)				32,952
1911	60	7,243	11,090		9,547		16,254
1912	495	2,195	6,270		10,327		14,522
1913	3	3,011	Id.232	4,793	14,752		22,796
1914		2,875	19,969	5,001	21,669	3,740	34,301
1915		2,464	10,414	6,155	12,750	9,750	18,872
1916		3,702	14,293	5,695	7,026	4,853	7,027
1917		2,730	4,810	4,050	17,264		14,321
1918		2,280	5,384	4,509	17,284	3,498	11,802
1919	1,350	1,350	4,078	3,619	6,358	2,122	4,000
1920	1,349	1,465	2,450	1,781	5,460	1,347	3,000
1921		1,500	2,386	1,386	1,986	1,480	
1922	1,521	1,466	1,587	1,587	791	750	
1923	1,000	1,242	1,620	2,300	3,012	1,770	
1924	1,200	1,133	887	1,330	2,300	1,598	
1925	1,590	1,590	2,082	2,682	3,270	2,550	
1926	1,545	1,545	4,585	4,585	3,175	3,175	
1927		1,642	1,811	1,433	3,405	2,520	
1928	250	b1,211	2,347	2,189	2,350	1,312	
1929	500	b1,956	7,674	5,301	1,800	2,385	
1930	160	3,075	11,130	8,840	5,137	4,118	
1931	10,776	6,240	9,507	9,507	8,999	3,915	3,780
1932	857	857	3,417	3,417	1,667	1,667	
1933	30	1,158	1,379	1,379	2,309	1,277	
1934		1,495	3,492	3,492	4,000	2,389	
1935	5	1,509	8,500	4,055	4,500	4,761	

a Record of hatchery operations compiled from the tables "Hatchery Operations" and "Eggs Distributed." in Reports of U. S. Bureau of Fisheries, 1896-1936. In many cases it was necessary to arrive at the figures given in this table by addition or subtraction of published figures; hence a balance between eggs taken and fry released at a station indicates that the figure has been derived from the tables rod does not indicate a 100 per cent success in hatchery operations. In addition to the eggs sent to Mt. Shasta Hatchery, eggs were also sent to the Eel River (in 1898 and 1901 these were not separated from the Mt. Shasta figures) for many years, and several shipments were also made to the Brookdale Hatchery near Santa Cruz.

b The larger part of these fry were released below the Anderson-Cottonwood Irrigation District Dam. in the Sacramento River.

(from Hedgpeth, 1941)

Although there was some speculation that these large releases may have been instrumental in the high commercial catches recorded from 1907 through 1910, there was no significant increase in egg collections that might be attributed to a greater escapement (Hedgpeth, 1941). After 1920, except for one year (1931), there were no longer any surplus salmon eggs available to send to the Mt. Shasta Hatchery.

Spawning ground surveys conducted in 1938 indicated that no natural barriers occurred in approximately 55 miles of the Little Sacramento River upstream from the mouth of the Pit River to the vicinity of Cantara Loop (Hanson et al., 1940). Clark (1929) believed that the falls at Sims, 42.5 miles upstream from the Shasta damsite was impassable to salmon. However, Hanson et al. reported observing salmon nests upstream from the falls at Sims. Based on the calculated amount of suitable spawning gravel in the Little Sacramento River, Hanson et al. estimated that this reach had a potential utilization for 15,035 female salmon.

McCloud River

The McCloud River was also an important salmon spawning stream, and was two or three times the size of the Little Sacramento River above the mouth of Pit River. The first fish hatchery in the western United States (Baird Hatchery) was established on the McCloud River in 1872 (Hedgpeth, 1941). This station collected winter and spring-run eggs for local hatching and release as fry and for shipment of eggs to other areas as far away as New Zealand. Clark (1929) said Stone reported that the salmon came to the McCloud River in vast numbers.

Annual chinook salmon eggs taken at Baird Hatchery reached a high of over 27,000,OOO prior to 1910, but declined to a low of only l,OOO,OOO eggs by 1923 (Clark, 1929). These declines, and the corresponding declines in the commercial harvest (according to Clark), may have been due in part to the Anderson-Cottonwood Irrigation District Dam which was constructed near Redding in 1917. This dam, a major barrier to upstream migrating salmon and steelhead, is placed in operation at the beginning of the irrigation season each year (April) and maintained until the fall or early November. Although a fishway was mandated by the California Fish and Game Commission in 1922, completion of a suitable facility did not occur until 1927 (USBR, 1983). Clark (1929) reported that "for a number of years, the Anderson-Cottonwood Dam was such a barrier that it nearly exterminated the salmon run in that part of the river. Now (1928) there are quite a number of salmon that pass over the dam, but nothing to compare with conditions before the dam was constructed"

In any event, McCloud River salmon runs had declined significantly prior to the construction of the Anderson-Cottonwood Irrigation District Dam. Based on egg taking records at Baird Hatchery, Hedgpeth (1941) states that only

once after 1911 (in 1931) were more than a million and a half eggs taken, and that for many years the collections were negligible. He suggests that even though the Baird Hatchery claimed credit for the large commercial harvests that occurred during its early operation, the decline in salmon migration to the McCloud River may have been due to the nature of fish culture at that time (the taking of eggs to the point where natural spawning is adversely affected).

In 1939, salmon were seen spawning in the mouth of the McCloud River, a mile above the Baird Hatchery, at Big Springs, and several other places below the Lower Falls, approximately 46 miles upstream from the mouth (Hanson et al., 1940). Based on spawning gravel surveys, Hanson estimated that the McCloud River provided potential spawning space for 25,928 female salmon.

Pit River

Rutter (1902) reported that the Pit River was accessible to salmon for over 75 miles above its mouth, and that spring-run chinook salmon passing Pit River Falls spawned in Fall River. Spring-run chinook also ascended Hat Creek. Clark (1929) reported there was both a spring and fall run of salmon in the Pit River, with spawning beds occurring from the mouth of the river to the base of the Pit 4 Dam. According to Clark, Squaw Creek and two or three small tributaries of the lower Pit River also afforded suitable places for salmon to spawn.

Surveys conducted in 1938 (Hanson et al., 1940) in the lower 28 miles of the Pit River and its tributaries (the remaining area available to salmon migration at that time), indicated that sufficient spawning gravels existed for utilization by 18,061 female salmon.

Salmon and Steelhead Trout Spawning Populations upstream from Shasta Dam

There are no records of estimated salmon and steelhead trout population sizes or actual counts of these runs in the Sacramento River reaches above Redding until just prior to initiation of Central Valley Project investigations. In 1937, the California Division of Fish and Game estimated the total run to be 19,000 salmon based on partial counts of salmon passage at The Anderson-Cottonwood Irrigation District Dam (Hanson et al., 1940). In 1938, the Bureau of Reclamation counted a total of 13,885 fish and estimated an additional 5,500 passing the Anderson-Cottonwood Irrigation District Dam. In 1939 the total salmon run passing Redding, based on intensive counts at the Anderson-Cottonwood Irrigation District Dam by the Bureau of Fisheries (now the Fish and Wildlife Service), was 21,894 fish comprised of 16,108 fall-run and 5,786 spring-run salmon. Counting extended from April 17 to December 8, although dismantling of the dam commenced on November 16.

Very little information was obtained on winter-run salmon or steelhead trout during the Shasta fishery investigations. Hanson et al. (1940) state that "it is well known, however, that both salmon and steelhead migrate **in** the late fall, winter, and early spring into the upper Sacramento River." Needham et al. (1943) state that there is a winter run of salmon, but nothing is known about its size. During 1939, Needham et al. report that a total of 118 steelhead trout and 114 brown trout were counted at the Anderson-Cottonwood Irrigation District Dam between April **17** and October 18. It was concluded that the steelhead trout run was very small. This conclusion may have been misleading, however, as most steelhead trout in the upper Sacramento River migrate upstream to spawn after October 18 and prior to April 17 (Dave Vogel, USFWS and Dick Hallock, CDFG-retired; 1987, personal communication)

Although the actual count past Redding in 1939 was 21,894 salmon, Hanson et al. (1940) estimated that the total run to be salvaged might be estimated as 27,000 fish. This estimate included an additional 5,106 fish were believed to have passed upstream during a 130-day period in 1939 when counts could not be made, and was derived from the relationship between monthly commercial catch and fish counts and the allowance for a 'safety factor'. This number, according to Hanson et al., was to be used as the basis for calculating the size of the ponds and hatchery buildings that would be needed. However, this same report recorded the existence of spawning gravel areas in the upper river reaches blocked by Shasta Dam capable of supporting 59,024 female salmon or, assuming a one-to-one sex ratio, 118,048 total salmon spawners.

Based on Special Scientific Report No. 10 by Hanson et al. (1940), the Board of Consultants concluded that the salmon run at Redding consisted of approximately twenty to twenty-five thousand fish. This run included five to six thousand spring-run salmon and fifteen to twenty thousand fall-run salmon.

In 1940, the count of salmon at the Anderson-Cottonwood Irrigation District Dam from May 16 to October 31 was 40,248; nearly double that of the previous year, although made over a two-month shorter period (Needham et al., 1943). In 1941, the count was 44,856 salmon - also made over a two-month shorter period that 1939 (May 17 through October 31). In 1942, excessive high water in the spring and the lack of sufficient personnel precluded counting of all but a small part of the run.

Needham et al. (1943) concluded in their Scientific Report No. 26 that, comparing counts of the previous three years with that of 1939, the total run was about 60,000 fish per year. This did not include the winter run of salmon which for which there was no information, according to the report.

The number of salmon entering the upper Sacramento River varied considerably during the salvage operation from 1943 through 1945, but in

all years they exceeded the estimate of the Board of Consultants (Moffett, 1949). The total salmon run above Balls Ferry in 1944 was estimated at 83,286 while that for 1945 was approximately 55,979. The numbers of spring-run chinook salmon counted or handled in the Shasta Salmon Maintenance Program exceeded 6,000 in 1943 and 12,000 in 1944. Undoubtedly, many others reached Keswick but were not trapped. The much larger runs of salmon encountered during the salvage program confirmed that the Needham et al. 60,000-salmon estimate for runs above Redding reflected a closer estimation of true population size that the 25,000 total estiaated by the Board of Consultants in 1940.

Hedgpeth (1944) states that the the (Shasta) investigations revealed an unexpectedly large run of salmon passing the site **of Shasta Dam and, as** later counts indicated, the run was on the increase. According to Hedgpeth, the Central Valley Project could not have started at a more inopportune time as far as the salmon were concerned.

Battle Creek

Battle Creek was, and still is, an important salmon spawning tributary to the Sacramento River. Located near Balls Ferry, about 30 miles downstream from Redding this stream provides excellent fall-run salmon spawning gravels. Also, a small spring run of chinook salmon ascends the north and south forks of Battle Creek to spawn.

In 1895 an egg station was established by the State of California in Battle Creek at which 10,000,000 eggs were taken from 2,000 female salmon (Clark, 1929). The Bureau of Fisheries took over the facility in 1896 and constructed an 18,000,OOO egg salmon hatchery. Excess eggs were shipped to other hatcheries including Baird and Mt. Shasta Hatcheries in the upper Sacramento River drainage. In 1897, nearly 50,000,000 eggs were taken which hatched into more than 40,000,OOO alevins (Rutter, 1902). The peak was reached in 1904 when over 50,000,000 eggs were taken from about 10,000 females. Another 49,000,000 eggs were taken in 1905. According to Clark, great quantities of eggs were taken at Battle Creek, reaching such numbers as few people had ever dreamed. Between 1913 and 1916. egg takes ranged from 10,000,000 to 20,000,OOO annually. After 1916, the number of eggs taken declined significantly with the total generally not exceeding 5,000,OOO annually thereafter through 1935 except for a brief period in 1929-31 (Hedgpeth, 1941). The hatchery, by that time having a reduced capacity of only 12,000,OOO eggs, was described by Hanson et al. (1940) as being old and in need of repair.

Salmon spawning habitat in Battle Creek was significantly impacted by dams and diversion of water into canals built by the Pacific Gas and Electric Company for hydroelectric power generation. These structures, constructed as early as 1900, adversely impacted salmon migration by blocking migration and reducing flows so low that, even with fish ladders, the

salmon were unable to migrate upstream (Clark, 1929). The lowermost power facility was only about five miles above the old Battle Creek fish hatchery. Their greatest impact appeared to be on spring-run salmon, according to Clark. Hanson et al. (1940) indicated that low flows and warm water temperatures limited salmon production upstream from Coleman Powerhouse.

In 1939, 15,444 salmon were counted at Battle Creek Hatchery between October 10 and December 15 (Hanson et al., 1940). Eighty-five percent of these fish were grilse or jacks. Surprisingly, gravel surveys in 1939 showed a potential utilization capacity for only 2,107 females in the 13-mile reach of Battle Creek from the junction of the North Fork and South Fork to the Sacramento River.

Deer Creek

Deer Creek flows into the Sacramento River near Vina and is accessible to salmon for a distance of approximately 40 miles to a barrier falls downstream from the Highway 32 bridge in the Lassen National Forest. A second barrier falls is located about 10 miles farther upstream. This system has a fall run of chinook salmon which spawns in the lower reach, and a spring run which ascends into the canyon and spawns farther upstream where cooler temperatures prevail during the summer.

Clark (1929) stated that salmon were very numerous in Deer Creek until irrigation diversions took most of the water from the creek. He pointed out that the spring run had never been successful because of warm water temperatures in the holding areas.

Hanson et al. (1940) determined from gravel surveys that there was potential spawning utilization for 3,758 female salmon for the 41 miles of accessible stream. They stated that it would be possible to restore the stream to something approaching its original state of salmon production were it not that most of the 50 to 70 cubic feet per second of the summer flow emerging from the canyon is used for irrigation. During migration of the 1939 fall run in Deer Creek, the water was only a few inches deep at the mouth and very few salmon entered the stream. These authors also stated in their Special Scientific Report No. 10 that the amount of natural spawning gravels could be increased to accommodate 135 additional redds if the lower falls were blasted out to make the stretch between the two falls available to migrating fish.

Counts of spring-run salmon **migrating into** Deer Creek were conducted in 1941) 1942 and 1943 (Needham et al., 1943) and continued through 1946 (Moffett, 1949). At the same time, spring-run salmon were trucked to Deer Creek from the Sacramento River fish traps at Keswick Dam and from the Balls Ferry Rack (Table 3). These counts were considered essential for learning the relative success of the rehabilitation program. were to be learned.

TABLE 3

Spring-run Chinook Salmon Counted or Handled at Deer Creek

Year	Salmon counted	Counting period	Salmon hauled	Hauling period
1941	635	5/20- 7/6	920	6/3 - 6/30
1942	1,108	5/5 - 7/3	none	
1943	812	2/20- 2/22 3/2 - 3/5 3/20- 6/16	5,245	6/1 - 6/29
1944	2,692	1/1 - 1/11 1/24- 1/26 1/30- 2/2 2/22- 2/25 2/28- 3/3 3/10- 6/30	8,034	4/22- 6/28
1945	3,563	4/13- 6/23	1,606	3/12- 6/15
1946	4,257	4/11- 6/29	167	5/6 - 6/15

In 1941, 635 salmon were counted from May 20 through July 6. This count was considered lower than the actual run which probably began migrating earlier. Also, according to Needham et al. (1943) many more salmon would have been counted through the weir if extremely high water temperatures had not caused considerable mortality of native-run salmon on the riffles below the weir.

In 1942, 1,108 salmon were counted during a similar period. However, this count was again considered low as salmon were observed at the weir site as early as March 26.

In 1943 the weir was installed on February 20 but was washed out several times and the total count only reached 812 salmon. However, the peak of migration occurred in April (178 salmon were counted on April 22 alone) which supported the previous contention that many salmon went uncounted in 1941 and 1942.

The counts during 1944, 1945 and 1946 were conducted over a longer period of time, including most of April, and were 2,692, 3,563 and 4,257 adult migrants, respectively.

Fyke net sampling at the mouth of Deer Creek, conducted during the 1941-1946 period, indicates that outmigration of juveniles begins in January,

peaks in March, then declines markedly but continues sporadically until mid-May (Moffett, 1949). Many seaward migrants produced in Deer Creek are lost to irrigation diversions which take practically all of the streamflow by the end of May each year.

THE SHASTA SALMON SALVAGE PLAN

A Salmon Salvage Plan to protect fish resources in the Sacramento River during construction of Shasta Dam and filling of the reservoir was proposed in 1940 by a Board of Consultants established by the Bureau of Reclamation. This Board consisted of three experts, one each in the fields of economics, engineering and biology (Calkins et al., 1940a). Their analysis, conclusions and recommendations were based on Service investigations and Special Scientific Report No 10, and on advice provided by the Bureau of Reclamation, Bureau of Fisheries staff, and the California Division of Fish and Game.

Notable among the Board of Consultants' nany conclusions were the following:

1. Approximately twenty to twenty-six thousand salmon arrive in the Redding area in two well marked runs, the spring run comprising five or six thousand fish, and the fall run comprising fifteen to twenty thousand.

2. The salmon run to Redding forms not more than half of the total run propagating in the Sacramento River system. The value of this run to the commercial fishery may vary from $51,000 to $81,000 (assuming that no more than half of the river fishery, or $28,000 of this, may be regarded as the value of fish derived from spawning above the Shasta Dam, and that probably no more than one third to one half of the California ocean catch is derived from the Sacramento River).

3. Artificial salmon propagation should strive to liberate young fish in accord with their natural habits, and that there appears to be adequate evidence to support the conclusion that the chief seaward migration of young salmon in the Sacramento River occurs in the spring, not long after the fry are free swimming and beginning to feed. The Board concluded that the most satisfactory results should occur if the young fish are liberated late in the winter or early in the spring, and that such release will result in a cost reduction in artificial feeding and (fish) care in fresh water.

4. A general analysis of the various plans proposed appears to indicate a distinct measure of advantage for the (combined) Sacramento River, Battle Creek, Deer Creek plan. However, the Deer Creek plan (hauling one fourth of the spring-run chinook to this tributary) should be deferred until further information becomes available on summer temperatures and the feasibility of providing pumped irrigation water needs in lieu of maintaining adequate instrean flows.

A Battle Creek plan was identified by the Board of Consultants which contemplated (1) the artificial propagation on this stream of the entire Sacramento River salmon run (presumably blocked or otherwise adversely impacted by Shasta and Keswick Dams), and (2) a combination of artificial propagation with transfer to other streams. The first variation, i.e., full compensation by hatchery propagation, would require:

1. Trapping at Keswick with trucks for transfer of trapped fish to Battle Creek.

2. A new hatchery downstream from the Coleman Powerhouse in substitution for the existing facilities on Battle Creek to provide capacity for 75,000,OOO eggs. This hatchery is intended to provide for fish transferred from the Sacramento River and for fall-run chinook occurring naturally in Battle Creek.

3. Holding and ripening ponds for spring-run chinook salmon at Darrah Springs (located near the junction of the North Fork and South **Fork** of Battle Creek) and a hatchery with capacity for about 30,000,OOO eggs.

4. Associated water supply systems, weirs, traps, etc. for trapping of spring-run fish for transfer to Darrah Springs and for leading fall-run migrants into holding and ripening ponds at the Coleman site.

The second variation of the Battle Creek plan involved major artificial propagation structures on Battle Creek, as described above, with transfer of spring-run salmon to Deer Creek for natural spawning.

The Board of Consultants report also addressed a Sacramento River plan which consisted of placement of fish racks on the Sacramento River upstream from the mouth of Battle Creek. These racks would be used for enumerating salmon spawning stocks and controlling their distribution in the upper River below Keswick and Shasta damsites. One of the racks would be equipped with a fish trap and facilities for transferring trapped fish to hauling trucks.

An alternative measure for handling spring-run salmon was the Deer Creek plan. This plan called for capture of spring-run chinook salmon at Keswick fish trap and hauling spawners to a major tributary of the Sacramento River such as Deer Creek which already had an established spring run. Deer Creek is located on the east side of the Sacramento Valley between Red Bluff and Chico.

The June 1940 report issued by the Board of Consultants recommended the following key elements for a salmon salvage plan associated with the construction and operation of Shasta and Keswick Dams:

1. Studies on conditions of the upper Sacramento River, including copper pollution, and on the results of artificial propagation of salmon as proposed in the report.

2. Approval of the general plan contemplating the use of the main Sacramento River and of Battle Creek, with the role of Deer Creek left open to be determined by further feasibility analysis.

3. Placement of three racks in the main Sacramento River, the lower one to be located just above the mouth of Battle Creek. Such racks would have fish counting functions and one would have a fish trap. These racks **would be designed to hold fall-run chinook in reaches below Shasta Dar, thus maximizing utilization of spawning area in the Sacramento River.**

4. Construction of holding ponds at Darrah Springs and at the new Coleman Hatchery, substantially as planned, with a reduction of the number of rearing ponds in Battle Creek from twelve to **eight. These** facilities would be scheduled for completion by 1942, and the existing fish propagation station on lower Battle Creek would be abandoned.

A supplemental report was issued by the Board of Consultants in October 1940, which addressed suggestions proposed by the State of California (Calkins et al., 1940b). The State's suggestions included: (1) provision for supplemental flow in Stillwater Creek by pumping from Shasta Reservoir, (2) experimental transport of adult salmon above Shasta Dam, (3) provision for expanding hatchery facilities on Battle Creek, and (4) additional trucks for transporting trapped salmon. The Board ruled that the Stillwater Creek plan, although favored in the Service's Special Scientific Report No. 10, was not acceptable as it would involve pumping costs. The Board recommended that fourteen rearing ponds be constructed at Battle Creek Hatchery instead of the eight previously recommended and that natural holding ponds in Battle Creek be **used** for adult salmon.

Plan Implementation

The Board's plan was put into operation essentially as proposed with minor revisions based on further field investigations and experimental work from 1940 through 1942 (Needham et al., 1943).

In June 1941, spring-run salmon were transferred experimentally to Deer Creek from the Sacramento River. Evaluations indicated that they would distribute themselves similar to native-run salmon and spawn in that stream. Based on gravel surveys in Deer Creek, and a plan to ladder the lower falls (thus making an additional four to five miles of stream available), it was recommended that 10,000 spring-run chinook salmon be transferred from the Sacramento River to Deer Creek in 1943 (The number of

native-run salmon in Deer Creek, estimated from partial counts, was 635 in 1941, 1,108 in 1942, and 812 in 1943). It is also stated in Needham's report that Deer Creek had a suitable flow (for salmon) except during the irrigation season when it was almost dry for the lower several miles. The upper reaches, however, were considered suitable for natural salmon propagation.

Construction of Coleman Hatchery and facilities commenced in 1942. These facilities were ready to handle spring-run salmon by the early summer of 1943 (Figure 1). The hatchery had a capacity for about 58,000,000 eggs or advanced fry, approximately 29,000,OOO fingerlings **averaging** 1.5 **inches,** and an unspecified number of larger fingerlings (Needhaa et al., 1943). Five racks were provided in main Battle Creek for holding and ripening pools for adult fish transferred from the Sacramento River. **Also,** twenty-eight outdoor ponds, each 20-feet wide by 120-feet long, were constructed. The station plan called for (1) receiving 20,000 spring, summer, and early fall-run salmon between June 1 and October 10, (2) spawning fish between October 1 and December 31, and (3) caring for eggs and fry and planting the majority of fry between January 1 and June 1.

Construction of a fish rack and trap near Balls Ferry, just upstream from the mouth of Battle Creek, commenced in September 1941, but was discontinued in December because of high water. It was operable by late spring 1943, and was used intermittently through 1945 (Figures 2 and 3). The fish trap, installed as part of the rack, was an elaborate structure consisting of a holding pen, fish hopper and gantry designed for loading large numbers of salmon into tank trucks (Figures 4 and 5).

Construction of the "Middle Sacramento River Rack", approximately 12 miles upstream near Anderson, occurred in the fall of 1942, but the rack could not be made fish-tight (Figures 6, 7 and 8). Nevertheless, this rack was used off and on through 1945.

Attempts to install the "Upper Rack" were abandoned because of the difficulties encountered at this site and the problems experienced at the two lower fish racks.

Keswick Dam construction commenced in November 1941. However, completion of the dam and fish trap was delayed because of construction halt orders by the War Production Board. The trap was not operable until June 1, 1943, during the peak of the spring run. Fish blockage, however, occurred as early as May 1942. **A** fish ladder was constructed at the Keswick site that year but the downstream end was undermined and it is doubtful that any fish were able to enter (Needham et al., 1943). Needham also reported that the long delay in completing the Keswick Fish Trap resulted in serious losses to the 1943 spring run. Many salmon confined below the dam during the delay were badly bruised from jumping against rocks and the base of the dam. Heavy losses of spring-run chinook occurred when trapping operations commenced on June 1, 1943. Of 5,245 salmon trapped and transferred to Deer

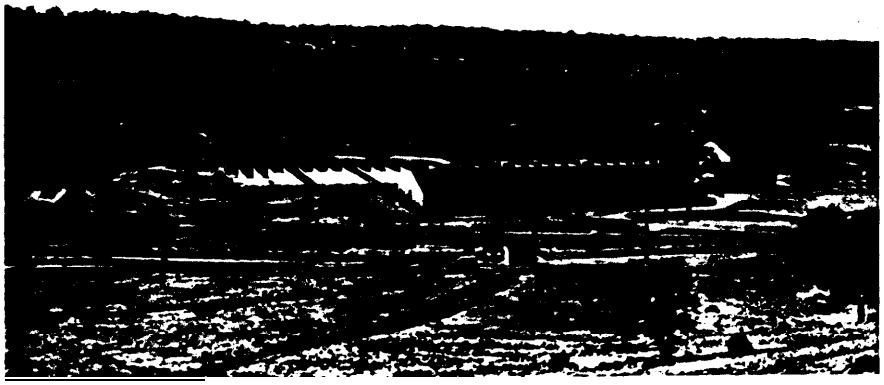

Figure 1. New Coleman Fish Hatchery on Battle Creek (November 1944)

Figure 1, New Coleman Fish Hatchery on Battle Creek
(November 1944)

Figure 2 Balls Ferry Rack on Sacramento River just downstream from Balls Ferry Bridge (May, 1944)

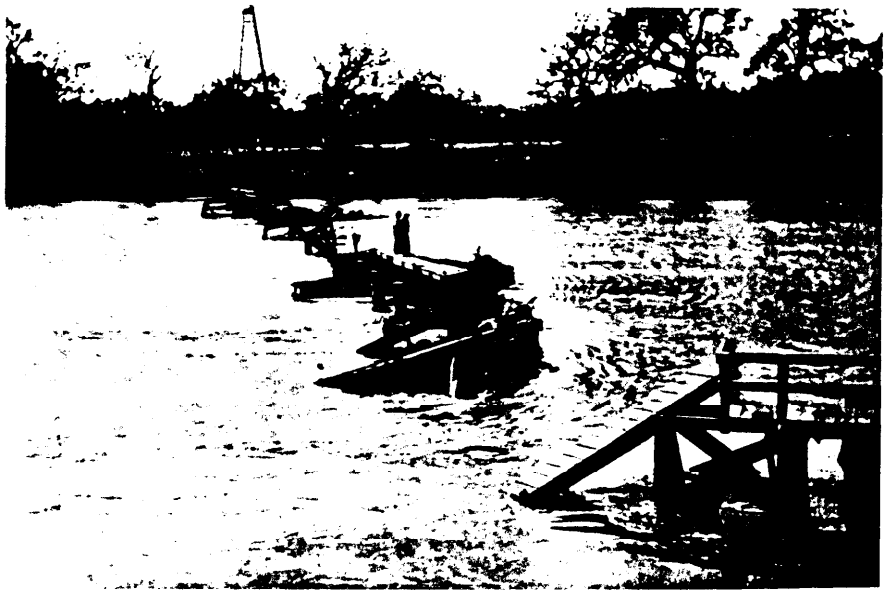

Figure 3 Balls Ferry Rack following high water, November 10, 1944

Figure 4. Fish Trap at Balls Ferry Rack.(1944)

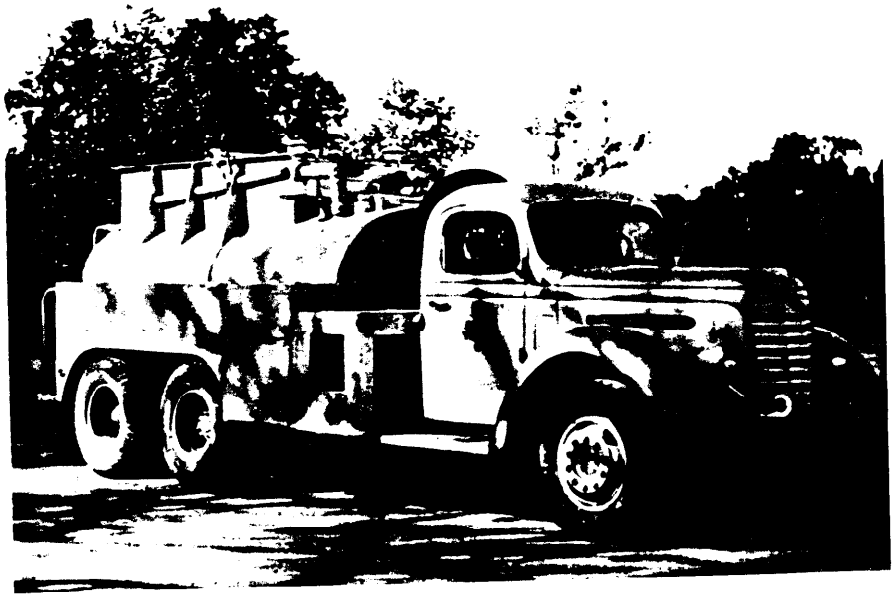

Figure 5. Fish tank truck used for transporting salmon from Balls Ferry Rack and Keswick Fish Trap. (1944)

Figure 6. Middle Sacramento River Fish Rack located near Anderson. Looking toward east bank. (circa autumn, *1942)*

Figure 7. Middle Sacramento Fish Rack following high water- Looking tow rds west bank Fall, 1942

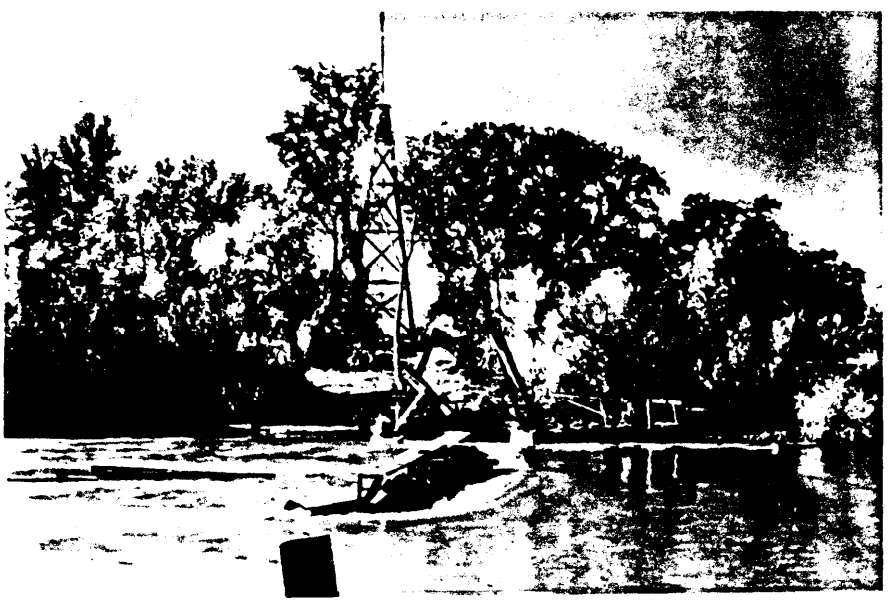

Figure 8 Middle Sacramento River Fish Rack *following high* water *(Fall 1942) West bank.*

Creek between June 1 and 29, 1,273 or 14 percent died unspawned. An additional 375 salmon died in the Keswick Trap facility. Among the early fish transferred to Deer Creek were many winter-run salmon (Needham et al., 1943).

The Needham et al. report makes no mention of propagation facilities for spring-run salmon at Darrah Springs. It may be presumed that in the course of investigations during the three-year period following the Board of Consultants' 1940 report, a decision was made to abandon the Darrah Springs recommendation in favor of hauling more spring-run spawners to Deer Creek.

Counts of chinook salmon passing the Anderson-Cottonwood Irrigation District Dam in Redding from 1940 through 1942 indicated that the annual run size to be blocked by Shasta Dam that had been identified in the Board of Consultants' 1940 report (20,000 to 25,000 spawners of all races) was underestimated by a factor of 3 or more. Based on six years of counts, Needham et al. (1943) estimated that the total run probably exceeded 60,000 salmon annually, and concluded that there was also a winter run of unknown size. His report stated: "it must be apparent that the salvage plan must be adjusted to great fluctuations in numbers of salmon and that no count to date has established the maximum numbers of salmon that may have to be handled." However, by the time of the Needham report, Coleman Hatchery and its facilities were already completed. There is no mention in the literature that the Salvage Plan was modified in scope to address the larger numbers of fish encountered.

Artificial and Natural Propagation

The provision for a hatchery in the Shasta Salmon Maintenance Program was deemed necessary by the Board of Consultants for the perpetuation of the spring-run segment of the salmon population in the Sacramento River (Moffett , 1949). A hatchery operation was vital during 1943 and 1944 when water temperatures in the main Sacramento River below Keswick Dam were too warm for natural spawning to be successful (Shasta Reservoir was filling and cold water releases were unavailable). Therefore, survival depended on transfer of these fish into a cold-water environment.

Although spring-run salmon were transferred to Deer Creek for natural spawning and some were successfully propagated at Coleman, mortality of trapped fish was excessive. Over 12,000 spring-run salmon were trapped at Keswick and Balls Ferry Rack in 1944, and an unknown number never entered the traps. In 1945, there was a significant decrease in the number of spring chinook at Keswick Fish Trap (less than 1,000 salmon were trapped between February and August 1945, and between May and August 1946). This may have been due to the cooler water temperatures that prevailed below Keswick Dam by this time. It may also have reflected the blockage of parent spawning runs at Keswick and Shasta starting in 1942. In any event, spring-run salmon were no longer trapped at Keswick and transported to Deer Creek for natural propagation after 1946. Likewise, this race has never been propagated in significant numbers at Coleman Hatchery because of high pre-spawning mortality caused by warm water temperatures at the holding facilities. This hatchery is used primarily to propagate fall-run and late fall-run chinook salmon.

Based on observations at the spawning grounds and considering the favorable water temperatures in the Sacramento River below Keswick Dam, Moffett

(1949) concluded that "the spring run can be perpetuated in the river without difficulty as long as present conditions prevail. (emphasis added by author). Conditions considered favorable for this race include (1) water temperatures not exceeding 56 degrees F. in September and October, the critical spawning and egg incubation period for this race, (2) good water quality, especially during the sensitive egg incubation and sac-fry development period from October through December (when toxic acid mine discharges often pollute the upper Sacramento River), (3) an abundance of properly sized spawning gravels, and (4) stable flow conditions during the egg incubation and sac-fry development period.

Sacramento River Spawning Control Plan

The success of the Sacramento River spawning control effort, involving racks at three sites in the upper river to control spawning distribution in specific reaches downstream from Keswick Dam, remains questionable. The upper river rack proposed near Redding was never built due to the lack of a suitable location and demonstrated need. The middle river rack and Balls Ferry Rack never functioned satisfactory, either repeatedly washing out or by failing to be fish-tight. The numbers of fish counted were undoubtedly far below actual population levels. Studies of salmon spawner carcasses and downstream juvenile migrants collected at these structures indicated that spawning in the Sacramento River between Balls Ferry and Keswick Dam was successful under most conditions. However, Mof fett (1949) reported heavy mortalities of adult fish from toxic pollution (copper leachate from abandoned mine tunnels) based on examination of carcasses lodging on the middle and Balls Ferry racks following the first heavy rain of the winter season in early November 1944.

It appears that this scheme was useful as a management tool in monitoring salmon response to the changes resulting from Shasta Dam, but never provided any compensation for lost or adversely impacted fish habitat.

Deer Creek Fish Transfer Plan

The Deer Creek element of the Salvage Plan is considered by most biologists to have been a complete failure (Dick Hallock, California Dept. of Fish and Game, retired: personal communication, 1987). Losses of transferred fish were often very heavy due to stress induced by holding and trapping conditions at Keswick Dam, by the several-hour haul between Keswick Dam and Deer Creek, and by receiving conditions in Deer Creek itself. In 1943, mortality of transported spring chinook salmon exceeded 24 percent. In 1944, the mortality was 16 percent, primarily due to water temperatures in Deer Creek as high as 82 degrees F. where the fish were released. Of primary concern was insufficient water for upstream and downstream migration in lower Deer Creek, where flows were greatly impacted by irrigation diversions. Despite the recommendation of the Board of

Consultants that additional flow be provided by paying groundwater pumping for irrigators, such measures were not implemented. Subsequent returns of spring-run chinook salmon to Deer Creek following the trucking program between 1941 and 1946 did not yield any significant population increase beyond that of naturally-occurring levels. The only actual improvement realized was the laddering of Lower Deer Creek Falls which added a small amount of available habitat.

Moffett (1949) summed up the results of this fish transferring effort when he concluded that a population exists at its maximum level at all times, considering all environmental factors, except for periods of adjustment usually established by activities of man. Without adjustment of controlling factors limiting salmon populations in Deer Creek, stocking vast numbers of fish beyond the creek's carrying capacity appears to have been a waste of time, money and effort. These limiting factors, mainly insufficient instream flows for both adult and juvenile migration, are responsible for the low levels of spring-run chinook salmon in Deer Creek in the 1940's and still today. The runs in Deer Creek currently average about 500 spring-run chinook annually, having declined dramatically during the last two decades (Vogel, 1987).

Other Analyses

The amount of chinook salmon and steelhead trout habitat lost upstream from Keswick and Shasta Dams was tremendous. Hanson et al. (1940) determined from extensive gravel surveys that over 2,360,OOO square feet of spawning habitat in 187 miles of accessible rivers and streams were blocked to anadromous fish by the project. This area provided substrate for natural propagation for approximately one half of the total Sacramento River salmon run (Calkins et al., 1940; Van Cleve, 1945; Azevedo and Parkhurst, 1957).

Evaluation of the size and condition of salmon and steelhead trout runs in the upper river were continued following cessation of salmon salvage operations and the transfer of Coleman Hatchery to the Fish and Wildlife Service in 1949 (Azevedo and Parkhurst, 1957). These studies were conducted under the Upper Sacramento River Salmon Maintenance Program during the eight-year period, 1949 through 1956. This program consisted of:

1. Allowing spring-run chinook salmon to spawn naturally in the main Sacramento River and upper tributary streams below Shasta Dam.

2. Trapping fall-run and winter-run salmon at Keswick for artificial propagation at Coleman Hatchery and subsequent release of yearlings into Battle Creek and the main Sacramento River.

3. Diversion of fall-run spawners from Battle Creek into Coleman Hatchery for artificial propagation, with the progeny liberated into Battle Creek and the Sacramento River.

4. Collection of information on factors causing annual fluctuations in the abundance of salmon

Based on these studies and associated observations, Azevedo and Parkhurst generally concluded that the fall run of salmon in the upper Sacramento River had been favored by increased flows and reduced water temperatures, and that there appeared to be a moderately increasing trend in their abundance. The average annual fall runs spawning in the main stem of the Sacramento River during this eight-year study was 86,000 salmon (range; 31,000 to 134,000), of which 86 percent spawned upstream of Iron Canyon (just downstream from Bend).

Azevedo and Parkhurst also reported that a winter run of salmon had developed which contributed significantly to the river sport fishery. They noted that increased numbers of winter-run fish were encountered during the late fall-run spawn-taking operations at Coleman Hatchery during the period from 1949 through 1956.

However, the spring run of salmon during this period neither materially increased nor decreased, with the total spawning population (mainstem river and tributaries) fluctuating around 14,000 fish annually. The average annual spawning population estimate in Deer Creek during the study period was approximately 2,200 spring-run chinook.

Reasons for the relative scarcity of spring-run chinook, according to Azevedo and Parkhurst (1957) were (1) limited amount of spawning area, (2) high water temperatures, particularly in the tributaries, (3) irrigation diversions in the tributaries, (4) mining pollution, and (5) failure of attempts to artificially propagate the run.

The report stated that since the construction of Shasta Dam, there had been a marked increase in the magnitude of the steelhead trout runs into the upper Sacramento River, primarily due to improved summer habitat conditions. No population estimates were given. The reported steelhead trout catch in 1951, 1953 and 1954, based on voluntary registration data from fishing resorts in the upper river, was 1,400, 1,200 and 2,400 fish, respectively.

An analysis of impacts of construction and operation of Shasta and Keswick Dams on winter-run chinook salmon indicated that these runs were small and had been adversely affected by construction conditions, particularly high water temperatures, and by the salvage activities which placed emphasis on saving spring-run salmon (Slater, 1963). These fish had apparently been adapted to spring-fed tributaries upstream from Shasta Dam, primarily the McCloud River. There is little evidence, however, that this run was distributed widely or that it was very large.

Slater indicated that ripe winter-run salmon were inadvertently trapped and hauled to Deer Creek in 1943, and that most died unspawned and the eggs from the few that did spawn probably perished due to warm water temperatures. However, those that were forced to spawn below Keswick Dam in 1943 probably fared no better as June-July water temperatures at Redding ranged from 62-73 degrees F., considered lethal for salmon egg incubation and yolk-sac fry development.

By 1944, water temperatures below Keswick were in the 52-61 degree F. range during the same period, affording some survival, and by 1945, water temperatures did not exceed 55 degrees F. until mid-September. Soon afterward, the winter run recovered and, based on increased catches of this race, it became apparent that a sizable run was present (Smith, 1950). General observations through 1962-63 indicated that the winter run of salmon had become much more abundant than the spring run in the Sacramento River (Slater, 1963).

An evaluation of the contribution of the Coleman Hatchery to the commercial gillnet fishery in California was conservatively estimated to be 18.91 percent for the period 1947 through 1952, based on the recovery of marked fish (Cope and Slater, 1957). This equates to an average of 15,857 salmon if one applies this percentage to the gillnet catch shown in Table 1. However, this contribution does not include the ocean troll catch, the sport fishery catch or the return of spawners to the hatchery.

DISCUSSION

The original mitigation goals as set forth in the Bureau of Reclamation's Shasta Salmon Salvage Plan were to salvage and maintain the runs of salmon blocked by Keswick and Shasta Dams. This would be accomplished, according to a final plan selected by a Board of Consultants, by (1) establishing natural spawning populations of fall-run chinook in the Sacramento River below Shasta Dam where improved post-project water flow and temperature conditions would provide better habitat, (2) salvaging and maintaining early fall-run chinook salmon in the river by trapping and hauling fish (from a rack to be located on the Sacramento River upstream from the mouth of Battle Creek) to a new hatchery on Battle Creek for artificial propagation, and (3) salvaging and maintaining existing populations of spring-run chinook salmon by trapping and hauling spawners (from fish traps at Keswick Dam and Balls Ferry Rack) to hatchery propagation facilities on Battle Creek and/or to natural spawning areas in Deer Creek.

The goal in respect to numbers of fish was grossly underestimated - approximately 26,000 total salmon based on one year of counting (1939) at the ACID Dam. Further counting from 1940 through 1942 indicated this goal should be increased to 60,000 salmon. This was confirmed by trapping

records at Keswick Dam and at the Balls Ferry Rack where the numbers of fish far exceeded the original estimate. Very few changes in the Salvage Plan were made to accommodate these additional fish, particularly in the sizing of propagation facilities.

In examining the literature and documentation of salvage efforts conducted from 1943 through 1946, and ensuing evaluations which followed, it appears that proper mitigation goals were not established for the loss of habitat and fish runs upstream from Keswick and Shasta Dams. These goals can be refined using newer information, analytical methods and fish culture technology.

The loss of anadromous fish habitat upstream from the dams can probably never be fully compensated because there is not 187 miles of similar streams and creeks in California available for rehabilitation. However, redefining the mitigation goal to improve existing but adversely impacted spring-run chinook habitat is a viable alternative. This goal would not merely include transplanting fish, but would ensure that natural production would be achieved. Deer Creek is still there with the same basic problems that impacted spring-run salmon production nearly 50 years ago. Mill Creek offers similar rehabilitation potential. These streams still have rudimentary but rapidly dwindling runs of genetically distinct spring-run chinook salmon similar to those runs blocked by Shasta and Keswick Dams. What is needed is maintenance of favorable instream flows necessary for both upstream and downstream migration.

The loss of anadromous fish runs (but not habitat) may be compensated by artificial propagation. Back in 1940, a collection goal of 60,000,OOO fall-run and 30,000,OOO spring-run chinook salmon eggs was identified as that necessary to produce a return run of approximately 26,000 adult spawners to the upper river. Assuming the run was actually 60,000 adults, as it appears to have been, this would have required over 200,000,000 eggs based on the same calculation of survival of unfed fry to returning adult. By rearing juvenile salmon to a larger release size and improving physical and biological controls of the hatchery environment (including adult holding and juvenile rearing), a much greater production can be realized. Therefore, a mitigation goal of 60,000 adult salmon can be achieved using present technology with less than 50,000,000 eggs.

As to whether the mitigation goals of the Shasta Salmon Salvage plan, and the Maintenance Program which followed, were reached, it is clear that, to a large extent, they were not. Some authorities believe that as elements of the Plan failed, they were simply abandoned and those particular groups of fish to be salvaged were just “written off” (Hallock, 1987).

There were some gains which may have offset losses at the beginning, such as improved water flows and temperatures in the Sacramento River downstream from Keswick Dam. In 1949 the Service perceived these improved conditions as mitigation for the tremendous loss of habitat blocked by the project

dams, as long as conditions at that time prevailed (Moffett, 1949). However, conditions in 1949 did not prevail and any initial gains have been negated by long-term impacts including lack of gravel recruitment, armoring of riffles in the upper river reaches, dewatering of redds from winter flow reductions, increased summer and early fall temperatures as use of Shasta Reservoir yield is maximized, and continued fish mortality from insufficient dilution of acid mine discharges.

Gains

Although the project dams blocked access to an estimated half of the available salmon and steelhead trout spawning and rearing habitat in the upper Sacramento River system, habitat conditions in the mainstem Sacramento River below Keswick Dam were generally improved by project releases. Flows were increased during the summer and early fall and water temperatures were reduced. These improved habitat conditions downstream from the project dams generally favored the production of fall-run chinook salmon inasmuch as spawning could occur earlier in the fall and farther downstream in the Sacramento River.

The old Battle Creek Hatchery, which had been operated by the Fish and Wildlife Service since 1896, was replaced with an updated (by 1943 standards) facility with increased rearing capacity - the present-day Coleman National Fish Hatchery. This hatchery has been operated and maintained exclusively with Service funding since transfer from Bureau of Reclamation authority in 1949.

The winter run of chinook salmon increased to over 100,000 adults annually following construction of Shasta Dam (Hallock and Fisher, 1985). Favorable flows and temperatures through the 1960's were provided by the project which apparently duplicated historical conditions in spring-fed tributaries upstream from the project dam sites. However, subsequent events, including fish passage problems at Red Bluff Diversion Dam, the 1976-77 drought, and degraded habitat conditions in the upper river resulting from Central Valley Project operations, have reduced the size of this run to only a few thousand fish. The winter run was recently considered for listing as a threatened species under the Endangered Species Act of 1973.

Conditions in the mainstem Sacramento River below Keswick Dam appear to have been made more favorable for the production of steelhead trout and resident rainbow trout. Little information is available for comparison with pre-project trout populations in the area upstream from Shasta Dam other than the general statement that trout were plentiful (Wales, 1939).

Losses

Over 187 miles of streams affording an estimated 2,360,000 square feet of spawning habitat capable of supporting a maximum run of 118,000 salmon were blocked by Shasta Dam (Hanson et al., 1940). The estimated run to this

habitat at the time of project construction was 60,000 salmon (Needham et al., 1943). However, the Shasta Salmon Salvage Plan goal, including artificial propagation objectives, was established at only 25,000 to 26,000 in the Board of Consultants 1940 report. The difference between the current production goal for Coleman National Fish Hatchery (18,650 return spawners as identified in the 1984 Coleman Station Development Plan) and the actual pre-Shasta run (60,000 spawners) is 41,350 salmon.

Perhaps the greatest loss of fish resources attributable to the Shasta and Keswick Dams was inflicted on spring-run chinook salmon. The salvage of this race was the main justification for construction and operation of the Keswick fish trap. Although the Salvage Plan called for construction of propagation facilities for handling up to 30,000,OOO spring-run chinook eggs at Darrah Springs, alternative (and less expensive) measures were ultimately chosen: propagating spring-run chinook salmon at Coleman Hatchery and hauling trapped spawners to Deer Creek. These mitigation measures failed completely due to (1) unsuitable water temperature for holding spawners at Coleman, and (2) the habitat conditions which limited salmon populations in Deer Creek.

Inasmuch as any gains in fish resources that were realized by the Shasta and Keswick **Dam** Projects were either offset by project-induced habitat degradation or were realized for only a short duration, any hoped-for enhancement was never realized. In the opinion of the Fish and Wildlife Service, enhancement can only be realized after full compensation for project impacts has taken place. Based'on the Fish and Wildlife Service's analysis of the mitigation plan for Shasta and Keswick Dams, compensation has not been achieved.

REFERENCES

Azevedo, R.L., and Z.E. Parkhurst. 1958 The Upper Sacramento River Salmon and Steelhead Maintenance Program, 1949-56. U.S. Fish and Wildlife Service Office Report, 96 p.

Calkins, R.D, W.F. Durand and W.H. Rich. 1940. Report of the Board of Consultants on the Fish Problems of the Upper Sacramento River. Report to the U.S. Bureau of Reclamation on recommended fish salvage measures associated with the Shasta Dam project. Stanford University, June 21, 1940. 50 pp w/ maps.

Calkins, R.D, W.F. Durand and W.H. Rich. 1940. Supplemental Report, Salvage of Salmon, Upper Sacramento River. Memo report to the Commissioner of Reclamation from the Salmon Salvage Committee, October 5, 1940. 12 p.

Clark, G.H. 1929. Sacramento-San Joaquin Salmon (Oncorhynchus tshawytscha) Fishery of California. Bureau of Commercial Fisheries, Division of Fish and Game of California. Fish Bulletin No. 17. 73 pp.

Cope, O.B., and D.W. Slater. 1957. Role of Coleman Hatchery in Maintaining a King Salmon Run. Fish and Wildlife Service Research Report No. 47. 22 pp.

Hanson, H.A. O.R. Smith, and P.R. Needham. 1940. An Investigation of Fish Salvage Problems in Relation to Shasta Dam. U.S. Fish and Wildlife Service, Special Scientific Report No. 10. 1940. 200 pp.

Hallock, R.J., and F.W. Fisher. 1985. Status of Winter-Run Chinook Salmon, (Oncorhynchus tshawytscha), in the Sacramento River. California Department of Fish and Game, Anadromous Fisheries Branch Off ice Report, January 25, 1987. 28 pp.

Hallock, R.J. 1987. Sacramento River System Salmon and Steelhead Problems and Enhancement Opportunities. A report to the California Advisory Committee on Salmon and Steelhead Trout. June 22, 1987. 92pp.

Hedgpeth, J.W. 1941. Livingston Stone and Fish Culture in California. California Fish and Game. 27(3): pp 126-148.

Hedgpeth, J.W. 1944. The Passing of the Salmon. The Scientific Monthly, Vol. LIX. November, 1944. pp 370-378

Moffett, J.W. 1949. The first Four Years of King Salmon Maintenance Below Shasta Dam, Sacramento River, California. California Fish and Game. 35(2): pp 77-102.

Needham, P.R., O.R. Hanson, and L.P. Parker. 1943. Supplementary Report on Investigations of Fish Salvage Problems in Relation to Shasta Dam. U.S. Fish and Wildlife Service, Special Scientific Report No. 26. June 30, 1943. 52 pp.

Richardson, T.H. 1985. Coleman National Fish Hatchery and Keswick Fish Trap. A Report of the U.S. Fish and Wildlife Service on Problem A-6 of the Central Valley Fish and Wildlife Management Study, Prepared for the Bureau of Reclamation. 50 p.

Rutter, C. 1902. Natural History of the Quinnat Salmon. A Report of Investigations in the Sacramento River, 1896-1901. U.S. Fish Commission. Bulletin No. 22, 1902. pp. 65-141.

Rutter, C. 1908. The Fishes of the Sacramento-San Joaquin Basin, with a Study of Their Distribution and Variation. U.S. Fish Commission, Bulletin Vol 27, Doc. 637. pp 103-152.

Smith, S.H. 1950. Upper Sacramento River Sport Fishery. U.S. Fish and Wildlife Service, Special Scientific Report-Fisheries No. 34. 44p.

Slater, D.W. 1963. Winter-Run Chinook Salmon in the Sacramento River, California With Notes on Water Temperature Requirements at Spawning. U.S. Dept. of the Interior, Fish and Wildlife Service, Special Scientific Report--Fisheries No. 461. 9 p.

U.S. Bureau of Reclamation, 1983. Fishery Problems at Anderson-Cottonwood Irrigation District Diversion Dam, Sacramento River, California. Central Valley Fish and Wildlife Management Study Element No A-3, Special Report. July, 1983. 27 p. and appendices.

U.S. Fish and Wildlife Service, 1984a. Coleman National Fish Hatchery Station Development Plan. Region 1, U.S. Fish and Wildlife Service, Office Report. 64 p.

U.S. Fish and Wildlife Service, 1984b. Evaluation Report of the Potential Impacts of the Proposed Lake Red Bluff Water Power Project on the Fishery Resources of the Sacramento River. Office report prepared by the U.S. Fish and Wildlife Service (Division of Ecological Services, Sacramento) and the U.S. Bureau of Reclamation, Mid-Pacific Region. 89 p. and appendices.

Van Cleve, R. 1945. A Preliminary Report on the Fishery Resources of California in Relation to the Central Valley Project. California Division of Fish and Game, California Fish and Game 31(2): pp 35-52.

Vogel, D.A. 1987. Estimation of the 1986 Spring Chinook Salmon Run in Deer Creek, California. Fisheries Assistance Office, Red Bluff Office Report No. FRI/FAO-87-3. January, 1987. 10 p.

Wales, L.H. 1939. General Report of Investigations of the McCloud River Drainage in 1938. California Fish and Game, Vo1.25, No.4. pp 272-309.

APPENDIX A

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

MEMORANDUM OF AGREEMENT BETWEEN THE
BUREAU OF RECLAMATION AND THE FISH AND WILDLIFE SERVICE

Pertaining to the custody and future operation of the Coleman Fish Hatchery and other fishery maintenance facilities of the Upper Sacramento River, Central Valley Project, California.

WHEREAS, the Bureau of Reclamation, hereinafter referred to as the Bureau, has constructed, as a part of the Central Valley Project; fish trapping facilities below Shasta Dam; the Coleman Station fish hatchery; water supply and control houses for operating personnel; and other facilities for the protection and preservation of the migratory fish which spawned in the upper Sacramento River Basin prior to construction of the Shasta Dam; and

WHEREAS, the Fish and Wildlife Service, hereinafter referred to as the Service, has directed and conducted the operation of these facilities since their construction, with funds transferred to the Service from the Bureau; and

WHEREAS, the Bureau and the Service are agreed that as a result of the salmon maintenance program and the operation of Shasta Dam with a regard for the welfare of the fishery, the salmon runs above Shasta Dam appear to have become established below the dam in numbers equal to the numbers existing before the dam was built, and

WHEREAS, the Service has the authority and there is necessity for further investigation, protection, improvement, and conservation of fish in the Sacramento River Basin and for continued operation of Coleman Hatchery and related facilities, and

WHEREAS, the continued maintenance of the Sacramento River salmon runs is recognized as one of the purposes of the Central Valley Project in operating Shasta Dam, and

WHEREAS, the continuous release of not less than 2,500 cubic feet of water per second from Keswick Dam is considered to be the minimum flow necessary to maintain the fishery, and 3,000 cubic feet per second is considered the preferable low release, and

WHEREAS, water temperatures between 50° and 65° Fahrenheit are considered to be best suited to the welfare of the fishery

NOW, THEREFORE, the Bureau and the Service, subject to the approval of the Secretary of the Interior, do hereby mutually agree as follows:

1. That the current agreement "covering biological investigations for the salvage of migratory fish, and for the operation and maintenance of Coleman hatchery and holding ponds, and other facilities on the Sacramento River, Deer Creek, and Battle Creek, in the Central Valley Project, California" made and entered into as of the 30th day of June, 1947, between the Bureau and the Service, effective for the fiscal year ending June 30, 1948, and approved by Assistant Secretary of the Interior William E. Warne on July 11, 1947, is extended to be effective for the fiscal year ending June 30, 1949.

2. That the Bureau, effective July 1, 1949, shall transfer, and the Service shall accept full custody, jurisdiction, and responsibility for the facilities described in Exhibit A attached hereto and made a part hereof, subject to restoration and supplementing of such facilities by the Bureau as follows:

   a. Repair and revision of the Coleman rearing ponds and water supply systems to satisfactory operating condition;
   b. The construction of adult fish holding ponds; and
   c. The alteration of the Coleman sewage disposal system to insure satisfactory operation.

3. That for the fiscal year 1950 and thereafter the Service will request funds by direct appropriation for operation of the Coleman hatchery and appurtenant facilities described in Exhibit A.

4. That the Bureau shall retain responsibility for the facilities listed in Exhibit B attached hereto and made a part hereof, which facilities are a necessary part of the Sacramento River salmon maintenance program, and that the Bureau shall transfer funds annually to the Service in amounts mutually agreed upon as necessary for the operation of these facil

itics and for the necessary services and biological studies in connection therewith,

5. **That** in operating Shasta Dam, the Bureau sha3.1 make every effort to maintain flows and temperatures in the Sacramento Rive which are necessary for fishery maintenance and shall *consult* with the Service when critical fishery conditions *are anti*cipated.

The total cost of constructing the migratory fish control facilities was $2,013,750.52. The Bureau's cost of operating and maintaining the facilities, as of July 1, 1949, will have been $810,643.49. Under existing law, the total sum of $2,824,394.11 is included in the reimbursable costs of the Central Valley Project. However, it is agreed that in accordance with the policies set by the Act of August 14, 1946 (10 Stat. 1080), the total cost to the Bureau, as stated herein and as accruing from year to year, should at some future time be declared to be non-reimbursable.

This agreement shall become effective as previously stated herein and shall remain in force until otherwise directed by the Secretary of the Interior, or until legislation inconsistent herewith is enacted by Congress.

Bureau of Reclamation

By: /s/ G. E. Tomlinson
Acing Commissioner

Fish and Wildlife Service

By: /s/ Albert M. Day
Director

Attachments:

Exhibit A
Exhibit B

I approve

/s/ R. C. Price

Approved: September 21, 1948

/s/ William E. Warne
Assistant Secretary of the Interior