State of California
The Resources Agency
Department of Water Resources

Final Report Juvenile Steelhead and Chinook Salmon Stranding in the Lower Feather River, 2001-2003
SP-F10, Task 3C

Oroville Facilities Relicensing
FERC Project No. 2100

AUGUST 2004

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REPORT SUMMARY

Since 2001, DWR has been conducting a juvenile stranding study on Chinook salmon and steelhead in the Lower Feather River. The objectives of the study were to identify potential ponding areas; determine the relative abundance of stranded salmonids; and determine the biological significance of stranding losses to the existing population of salmonids in the river. Empirical observations and historical aerial photos have led to the identification of over 30 areas that have potential to strand juvenile salmonids. The largest increase in ponded area appears to be associated with flow reductions below 2500 cfs and 1700 cfs. However, sampling of isolated areas revealed that relatively few juvenile salmon and steelhead become isolated. Furthermore, the proportion of stranded salmonids represent a very small percentage (<< 1%) of the estimated number of emigrants. Although this study did not experimentally evaluate ramping rates, the current ramping rates in the LFC of the Feather River are among the slowest for regulated rivers, and probably provide little, if any, incremental benefit over higher, more typical ramping rates.

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1.0 INTRODUCTION

Juvenile salmonids can become stranded on gravel bars or isolated in off-channel habitats as a result of flow fluctuations in rivers. Stranding has been reported to occur under both natural and controlled flow fluctuations, but significant stranding events have generally been associated with large, rapid flow reductions related to reservoir and hydropower operations (Hunter 1992). The incidence of stranding is related to several factors, including channel morphology, substrate type, species and life stage presence and abundance, time of year, river stage, and the magnitude, rate, and frequency of flow fluctuations. The vulnerability of fish to stranding is a function of their size and their behavioral response to changing flows, which depends on species, water temperature, time of year, and time of day. Newly emerged fry appear to be most vulnerable to stranding because of their limited swimming ability, their tendency to use the substrate as cover, and their preference for shallow river margins. As juveniles grow, they tend to move to deeper, higher-velocity water associated with main channel habitats where they are less susceptible to stranding (DWR 2004; Jones & Stokes 2002).

There are two general types of stranding, beach stranding and isolation basins. Beach stranding most often occurs in areas characterized by very low sloping channel margins (<5%) with larger substrates (e.g. small gravel, cobble, etc.). As the river channel recedes the substrate acts a sieve stranding fish within the interstices of the substrate. Isolation basins are typically inundated off channel ponds, side channels, or backwaters which become isolated after flow reduction. While slow, gradual ramping rates are important in minimizing gravel bar stranding, isolation of juveniles in off-channel habitats may occur regardless of ramping rate because of favorable rearing conditions, the distance of these habitats to the main river, and an apparent reluctance of juveniles to move away from protective cover (Bradford et al. 1995, Higgins and Bradford 1996, Bradford 1997, Jones & Stokes 1999). Do to the nature of beach stranding fish likely die quickly, but fish found in isolation basins can survive for long periods of time. For example, young salmon have been sustained in large, isolated backwaters along the lower Yuba River where significant subsurface flows maintain suitable habitat through the spring and summer (Jones & Stokes 1998, 1999). Factors that may influence fish survival in these off-channel habitats include the duration of reduced flows, water temperatures, food abundance, cover, and predator abundance.

Previous DWR investigations on the Feather River demonstrate that flow fluctuations cause some stranding. In January 1997, DWR temporarily reduced flows from 1800 cfs to 1600 cfs in the Feather River below the Thermalito Afterbay outlet. A subsequent survey found one pond with 47 juvenile salmon and four additional ponds that potentially had some stranding. A preliminary draft of the 2000-2001 season stranding survey calculated an estimated total of 2500 “spring-run sized” Chinook and 40 steelhead were stranded (DWR unpublished data).

Flow fluctuation criteria were developed in response to the 2000 Biological Opinion from NMFS to minimize the effect of flow fluctuations on the two salmonid species downstream of the Lake Oroville (Study Plan: Steelhead and Spring-Run salmon Redd Dewatering and Juvenile Stranding in the Lower Feather River, DWR 2000). Subsequently, a stranding monitoring program was developed by DWR and approved by NMFS. With the inception of FERC studies the stranding monitoring program became known as F 10 Task 3C. The goal of stranding studies was to evaluate project operation flow fluctuation effects on juvenile salmonid stranding. More specifically Task 3C had the following objectives: (1) quantify on-going impacts of juvenile stranding and evaluate ability of current flow fluctuation guidelines in minimizing stranding events and impacts; (2) quantify the amount of stranding potential area and resulting fish stranding that occurs during flow reductions between various flow levels; (3) determine the biological significance of the proportion of the juvenile salmonid population loss due to stranding.

1.2 DESCRIPTION OF FACILITIES

The Oroville Facilities were developed as part of the State Water Project (SWP), a water storage and delivery system of reservoirs, aqueducts, power plants, and pumping plants. The main purpose of the SWP is to store and distribute water to supplement the needs of urban and agricultural water users in northern California, the San Francisco Bay area, the San Joaquin Valley, and southern California. The Oroville Facilities are also operated for flood management, power generation, to improve water quality in the Delta, provide recreation, and enhance fish and wildlife.

FERC Project No. 2100 encompasses 41,100 acres and includes Oroville Dam and Reservoir, three power plants (Hyatt Pumping-Generating Plant, Thermalito Diversion Dam Power Plant, and Thermalito Pumping-Generating Plant), Thermalito Diversion Dam, the Feather River Fish Hatchery and Fish Barrier Dam, Thermalito Power Canal, Oroville Wildlife Area (OWA), Thermalito Forebay and Forebay Dam, Thermalito Afterbay and Afterbay Dam, and transmission lines, as well as a number of recreational facilities. An overview of these facilities is provided on Figure 1.2-1. The Oroville Dam, along with two small saddle dams, impounds Lake Oroville, a 3.5-million-acre-feet (maf) capacity storage reservoir with a surface area of 15,810 acres at its normal maximum operating level.

The hydroelectric facilities have a combined licensed generating capacity of approximately 762 megawatts (MW). The Hyatt Pumping-Generating Plant is the largest of the three power plants with a capacity of 645 MW. Water from the six-unit underground power plant (three conventional generating and three pumping-generating units) is discharged through two tunnels into the Feather River just downstream of Oroville Dam. The plant has a generating and pumping flow capacity of 16,950 cfs and 5,610 cfs, respectively. Other generation facilities include the 3-MW Thermalito Diversion Dam Power Plant and the 114-MW Thermalito Pumping-Generating Plant.

Thermalito Diversion Dam, four miles downstream of the Oroville Dam creates a tail water pool for the Hyatt Pumping-Generating Plant and is used to divert water to the Thermalito Power Canal. The Thermalito Diversion Dam Power Plant is a 3-MW power plant located on the left abutment of the Diversion Dam. The power plant releases a maximum of 615 cubic feet per second (cfs) of water into the river.

The Power Canal is a 10,000-foot-long channel designed to convey generating flows of 16,900 cfs to the Thermalito Forebay and pump-back flows to the Hyatt Pumping-Generating Plant. The Thermalito Forebay is an off-stream regulating reservoir for the 114-MW Thermalito Pumping-Generating Plant. The Thermalito Pumping-Generating Plant is designed to operate in tandem with the Hyatt Pumping-Generating Plant and has generating and pump-back flow capacities of 17,400 cfs and 9,120 cfs, respectively. When in generating mode, the Thermalito Pumping-Generating Plant discharges into the Thermalito Afterbay, which is contained by a 42,000-foot-long earth-fill dam. The Afterbay is used to release water into the Feather River downstream of the Oroville Facilities, helps regulate the power system, provides storage for pump-back operations, and provides recreational opportunities. Several local irrigation districts receive water from the Afterbay.

The Feather River Fish Barrier Dam is downstream of the Thermalito Diversion Dam and immediately upstream of the Feather River Fish Hatchery. The flow over the dam maintains fish habitat in the low-flow channel of the Feather River between the dam and the Afterbay outlet, and provides attraction flow for the hatchery. The hatchery was intended to compensate for spawning grounds lost to returning salmon and steelhead trout from the construction of Oroville Dam. The hatchery can accommodate 15,000 to 20,000 adult fish annually.

The Oroville Facilities support a wide variety of recreational opportunities. They include: boating (several types), fishing (several types), fully developed and primitive camping (including boat-in and floating sites), picnicking, swimming, horseback riding, hiking, off-road bicycle riding, wildlife watching, hunting, and visitor information sites with cultural and informational displays about the developed facilities and the natural environment. There are major recreation facilities at Loafer Creek, Bidwell Canyon, the Spillway, North and South Thermalito Forebay, and Lime Saddle. Lake Oroville has two full-service marinas, five car-top boat launch ramps, ten floating campsites, and seven dispersed floating toilets. There are also recreation facilities at the Visitor Center and the OWA.

The OWA comprises approximately 11,000-acres west of Oroville that is managed for wildlife habitat and recreational activities. It includes the Thermalito Afterbay and surrounding lands (approximately 6,000 acres) along with 5,000 acres adjoining the Feather River. The 5,000 acre area straddles 12 miles of the Feather River, which includes willow and cottonwood lined ponds, islands, and channels. Recreation areas

include dispersed recreation (hunting, fishing, and bird watching), plus recreation at developed sites, including Monument Hill day use area, model airplane grounds, three boat launches on the Afterbay and two on the river, and two primitive camping areas. California Department of Fish and Game's (DFG) habitat enhancement program includes a wood duck nest-box program and dry land farming for nesting cover and improved wildlife forage. Limited gravel extraction also occurs in a number of locations.

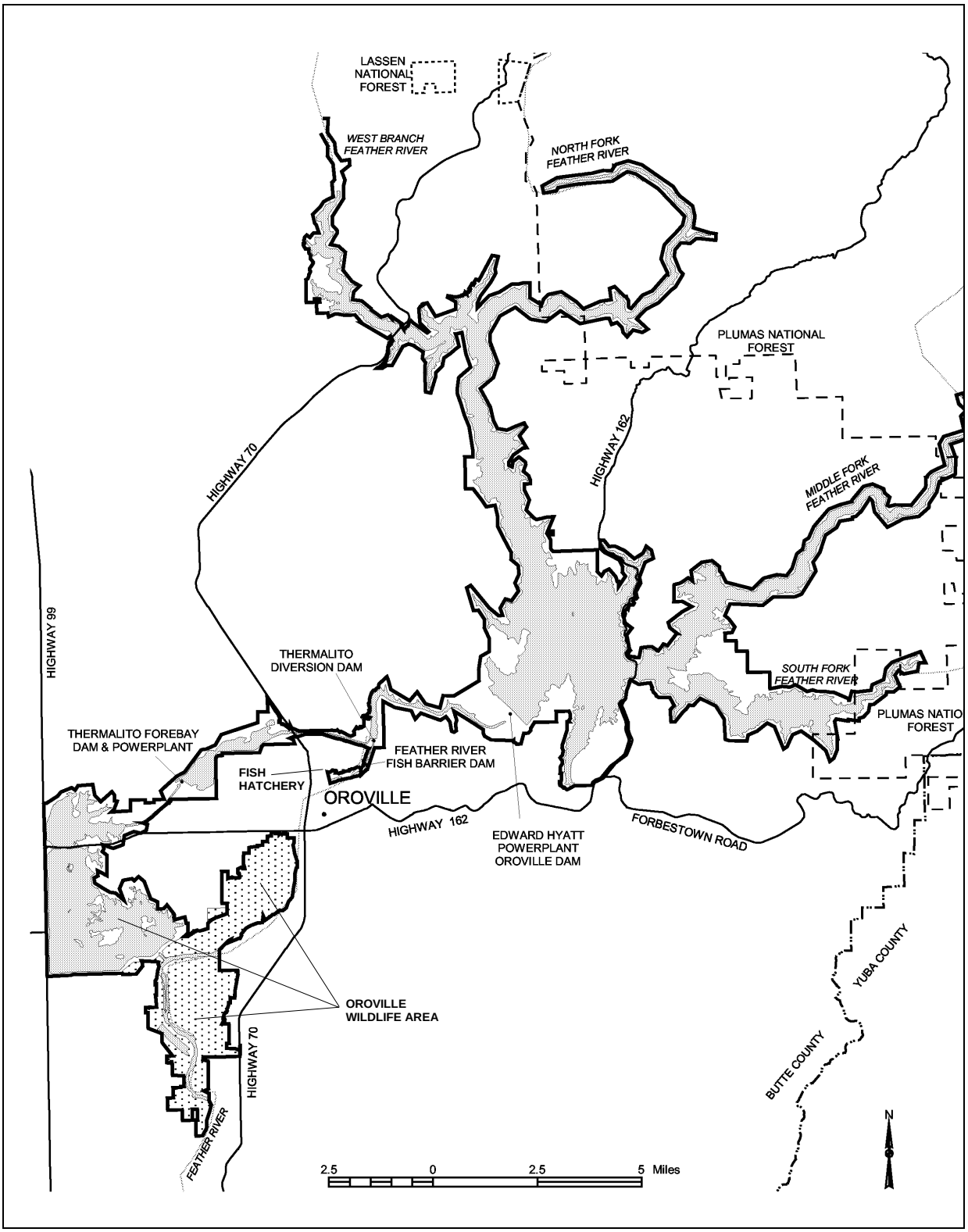


Figure 1.2-1. Oroville Facilities FERC Project Boundary

1.3 CURRENT OPERATIONAL CONSTRAINTS

Operation of the Oroville Facilities varies seasonally, weekly and hourly, depending on hydrology and the objectives DWR is trying to meet. Typically, releases to the Feather River are managed to conserve water while meeting a variety of water delivery requirements, including flow, temperature, fisheries, recreation, diversion and water quality. Lake Oroville stores winter and spring runoff for release to the Feather River as necessary for project purposes. Meeting the water supply objectives of the SWP has always been the primary consideration for determining Oroville Facilities operation (within the regulatory constraints specified for flood control, in-stream fisheries, and downstream uses). Power production is scheduled within the boundaries specified by the water operations criteria noted above. Annual operations planning is conducted for multi-year carry over. The current methodology is to retain half of the Lake Oroville storage above a specific level for subsequent years. Currently, that level has been established at 1,000,000 acre-feet (af); however, this does not limit draw down of the reservoir below that level. If hydrology is drier than expected or requirements greater than expected, additional water would be released from Lake Oroville. The operations plan is updated regularly to reflect changes in hydrology and downstream operations. Typically, Lake Oroville is filled to its maximum annual level of up to 900 feet above mean sea level (msl) in June and then can be lowered as necessary to meet downstream requirements, to its minimum level in December or January. During drier years, the lake may be drawn down more and may not fill to the desired levels the following spring. Project operations are directly constrained by downstream operational constraints and flood management criteria as described below.

1.3.1 Downstream Operation

An August 1983 agreement between DWR and DFG entitled, “Agreement Concerning the Operation of the Oroville Division of the State Water Project for Management of Fish & Wildlife,” sets criteria and objectives for flow and temperatures in the low flow channel and the reach of the Feather River between Thermalito Afterbay and Verona. This agreement: (1) establishes minimum flows between Thermalito Afterbay Outlet and Verona which vary by water year type; (2) requires flow changes under 2,500 cfs to be reduced by no more than 200 cfs during any 24-hour period, except for flood management, failures, etc.; (3) requires flow stability during the peak of the fall-run Chinook spawning season; and (4) sets an objective of suitable temperature conditions during the fall months for salmon and during the later spring/summer for shad and striped bass.

1.3.1.1 Instream Flow Requirements

The Oroville Facilities are operated to meet minimum flows in the Lower Feather River as established by the 1983 agreement (see above). The agreement specifies that Oroville Facilities release a minimum of 600 cfs into the Feather River from the

Thermalito Diversion Dam for fisheries purposes. This is the total volume of flows from the diversion dam outlet, diversion dam power plant, and the Feather River Fish Hatchery pipeline.

Generally, the instream flow requirements below Thermalito Afterbay are 1,700 cfs from October through March, and 1,000 cfs from April through September. However, if runoff for the previous April through July period is less than 1,942,000 af (i.e., the 1911-1960 mean unimpaired runoff near Oroville), the minimum flow can be reduced to 1,200 cfs from October to February, and 1,000 cfs for March. A maximum flow of 2,500 cfs is maintained from October 15 through November 30 to prevent spawning in overbank areas that might become de-watered.

1.3.1.2 Temperature Requirements

The Diversion Pool provides the water supply for the Feather River Fish Hatchery. The hatchery objectives are 52°F for September, 51°F for October and November, 55°F for December through March, 51°F for April through May 15, 55°F for last half of May, 56°F for June 1-15, 60°F for June 16 through August 15, and 58°F for August 16-31. A temperature range of plus or minus 4°F is allowed for objectives, April through November.

There are several temperature objectives for the Feather River downstream of the Afterbay Outlet. During the fall months, after September 15, the temperatures must be suitable for fall-run Chinook. From May through August, they must be suitable for shad, striped bass, and other warmwater fish.

The National Marine Fisheries Service has also established an explicit criterion for steelhead trout and spring-run Chinook salmon. Memorialized in a biological opinion on the effects of the Central Valley Project and SWP on Central Valley spring-run Chinook and steelhead as a reasonable and prudent measure; DWR is required to control water temperature at Feather River mile 61.6 (Robinson's Riffle in the low-flow channel) from June 1 through September 30. This measure requires water temperatures less than or equal to 65°F on a daily average. The requirement is not intended to preclude pump-back operations at the Oroville Facilities needed to assist the State of California with supplying energy during periods when the California ISO anticipates a Stage 2 or higher alert.

The hatchery and river water temperature objectives sometimes conflict with temperatures desired by agricultural diverters. Under existing agreements, DWR provides water for the Feather River Service Area (FRSA) contractors. The contractors claim a need for warmer water during spring and summer for rice germination and growth (i.e., 65°F from approximately April through mid May, and 59°F during the remainder of the growing season). There is no obligation for DWR to meet the rice

water temperature goals. However, to the extent practical, DWR does use its operational flexibility to accommodate the FRSA contractor's temperature goals.

1.3.1.3 Water Diversions

Monthly irrigation diversions of up to 190,000 (July 2002) af are made from the Thermalito Complex during the May through August irrigation season. Total annual entitlement of the Butte and Sutter County agricultural users is approximately 1 maf. After meeting these local demands, flows into the lower Feather River continue into the Sacramento River and into the Sacramento-San Joaquin Delta. In the northwestern portion of the Delta, water is pumped into the North Bay Aqueduct. In the south Delta, water is diverted into Clifton Court Forebay where the water is stored until it is pumped into the California Aqueduct.

1.3.1.4 Water Quality

Flows through the Delta are maintained to meet Bay-Delta water quality standards arising from DWR's water rights permits. These standards are designed to meet several water quality objectives such as salinity, Delta outflow, river flows, and export limits. The purpose of these objectives is to attain the highest water quality, which is reasonable, considering all demands being made on the Bay-Delta waters. In particular, they protect a wide range of fish and wildlife including Chinook salmon, Delta smelt, striped bass, and the habitat of estuarine-dependent species.

1.3.2 Flood Management

The Oroville Facilities are an integral component of the flood management system for the Sacramento Valley. During the wintertime, the Oroville Facilities are operated under flood control requirements specified by the U.S. Army Corps of Engineers (USACE). Under these requirements, Lake Oroville is operated to maintain up to 750,000 af of storage space to allow for the capture of significant inflows. Flood control releases are based on the release schedule in the flood control diagram or the emergency spillway release diagram prepared by the USACE, whichever requires the greater release. Decisions regarding such releases are made in consultation with the USACE.

The flood control requirements are designed for multiple use of reservoir space. During times when flood management space is not required to accomplish flood management objectives, the reservoir space can be used for storing water. From October through March, the maximum allowable storage limit (point at which specific flood release would have to be made) varies from about 2.8 to 3.2 maf to ensure adequate space in Lake Oroville to handle flood flows. The actual encroachment demarcation is based on a wetness index, computed from accumulated basin precipitation. This allows higher levels in the reservoir when the prevailing hydrology is dry while maintaining adequate flood protection. When the wetness index is high in the basin (i.e., wetness in the

watershed above Lake Oroville), the flood management space required is at its greatest amount to provide the necessary flood protection. From April through June, the maximum allowable storage limit is increased as the flooding potential decreases, which allows capture of the higher spring flows for use later in the year. During September, the maximum allowable storage decreases again to prepare for the next flood season. During flood events, actual storage may encroach into the flood reservation zone to prevent or minimize downstream flooding along the Feather River.

2.0 METHODOLOGY

2.1 STUDY AREA

The geographic area included in the existing stranding survey covers the Feather River from the Fish Barrier Dam down to the confluence with Honcut Creek. The area from Honcut Creek down to the confluence of the Sacramento River is not included in the present, on-going stranding survey. However preliminary evaluations were made in this area to identify potential locations for future, additional stranding monitoring. The Oroville Wildlife Area (OWA) is also not covered under the current survey scope as this area only becomes susceptible to stranding during severe flood control events.

2.2 JUVENILE STRANDING

Surveys were conducted in 2001, 2002, and 2003 for flow reductions occurring between January and May. Surveys were not conducted during summer months because emigration patterns of juvenile salmonids suggests there are relatively few rearing salmonids remaining in the Feather River beyond May (DWR 2003; DWR 2004). Isolation basin type stranding was the primary focus of this study. Beach stranding was not considered due to the following factors: (1) this type of stranding is generally believed to be only a minor component of overall stranding potential in the lower Feather River; (2) ramping rates are very low (roughly 1 inch stage change per hour) and should minimize beach stranding impacts; (3) problems with predation by birds before a survey could be conducted which would frustrate any effort at accurate beach stranding survey results; (4) this type of stranding would occur in intragravel spaces and therefore be very difficult to quantify in any reliable quantitative manner.

Most stranding areas were identified in surveys from previous years (e.g. DWR 2002). However, searches for new stranding areas were completed for flow ranges not observed in previous survey years. Physical measurements recorded for each pond included: river mile, river flow, average depth and total surface area. Additionally, specific sites were classified according to the following definitions:

Side channel (SC) – Secondary channels formed along the lateral margins of bars that are typically separated from the main channel at low flow.

Off-channel ponds (OCP) – Relatively large pools formed along the lateral margins of bars by sediment deposition, beaver dams, and other obstructions.

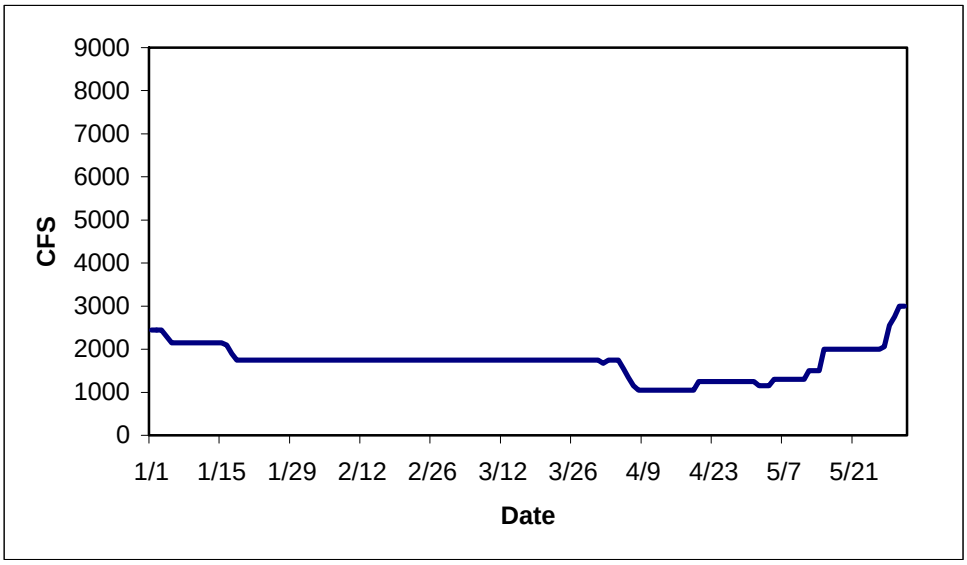
Pothole (PH) - Small, isolated depressions typically caused by local scouring around obstructions (e.g., woody vegetation) on bar surfaces.

Once ponding occurred, a sub-set of ponds from the Thermalito Afterbay Outlet downstream to Honcut Creek was sampled by beach seine or snorkeling based. Beach seining was used for ponds less than 1.2 meters (3.94 ft) deep and free of major obstructions. Snorkel transect surveys were used for ponds deeper than 1.2 meters (3.94 ft) or where obstructions precluded seining. Fish were identified and enumerated by species. The Fork Length (FL mm) of each species from snorkel surveys was estimated visually. Fish captured by beach seine were measured for up to 50 salmon and steelhead (and up to 20 individuals for non-salmonids). Fish were handled in accordance with the RST handling protocol documented in SP-F10, Task 4A. Run identification was based on a daily length table (Greene 1992) for Central Valley Chinook salmon. The proportion of spring run sized fish in the sub-sample was used to estimate the number of spring run sized salmon in the total catch.

Fish density (number of fish per area swept) was used to estimate species abundance for an entire pond. Mean fish density across all ponds was computed and multiplied by the total ponded area to estimate the number of salmonids stranded in the study area. The incidence of stranding was compared with emigration estimates from rotary screw trap operations to determine the stranding losses relative to the population of juvenile salmon in the river. In order to determine the role of fish size and stranding potential, the distribution of fish sizes in isolated basins versus the range of sizes found in the main channel will be compared. Additionally, the relative magnitude of stranding was evaluated amongst pond type (SC, OCP, and PH), river mile, and month. The relationship between cumulative amounts of stranding area per reduction in river flow was also investigated.

3.0 STUDY RESULTS

There were four major flow reductions in the HFC of the Feather River over three survey years (Figure 3.0-1 thru 3.0-3). Flows ranged between a minimum of 1,050 cfs and a maximum of 8,000 cfs. Releases to the LFC largely remained at 600 cfs during this period. However, LFC flows were increased to 1,800 cfs for two days in August 2003 as part of instream flow study. Review of existing data, including aerial photos from 1998 and 1999, revealed 19 areas susceptible to stranding (flows between 1,000 and 8,000 cfs) from the Thermalito Afterbay Outlet to Honcut Creek. Ground surveys confirmed 17 of these areas as subject to isolation. Another 17 areas below Honcut Creek were also identified as potentially susceptible to isolation (RM 43 – 0). However, a March 18, 2003 aerial survey of this area following a major flow decrease showed only two locations were actually isolated. The two ponded areas were located at Shanghai Bench (RM 25) and at RM 35. Estimated surface area and flow at which all confirmed ponded areas isolate from the main river are provided in (Table 3.0-1).



Source DWR

Figure 3.0-1. Discharge for the HFC of the Feather River 2001.

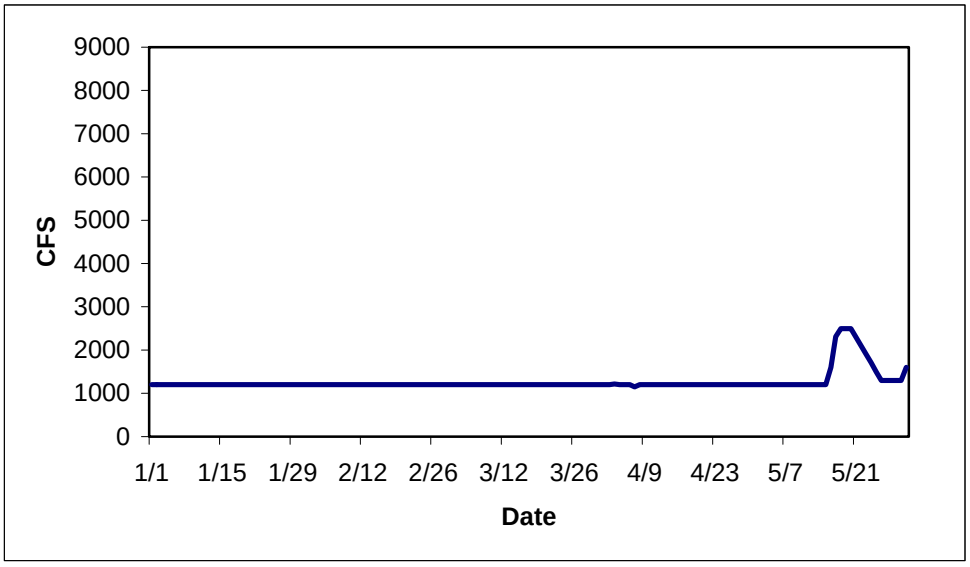


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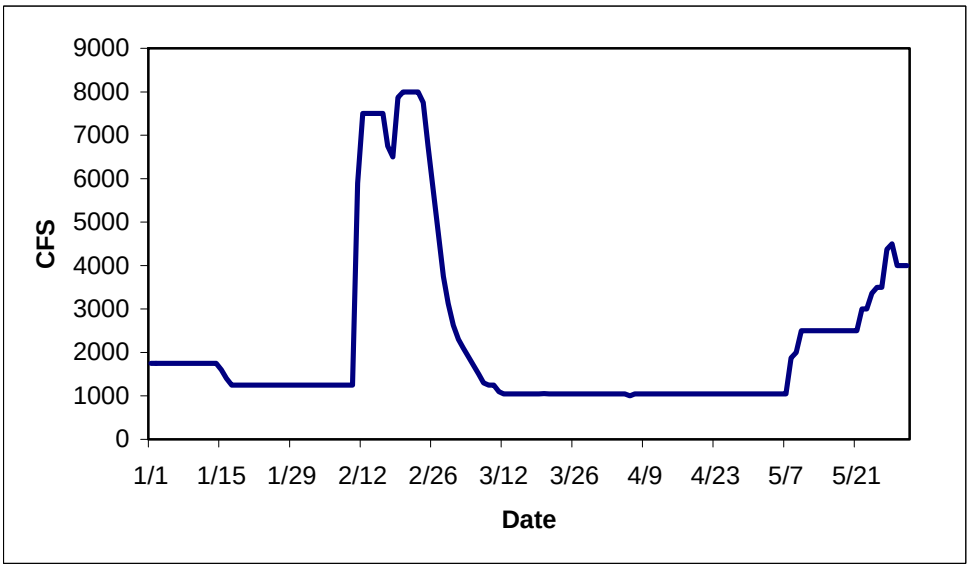
Figure 3.0-2. Discharge for the HFC of the Feather River 2001.



Source DWR

Figure 3.0-3. Discharge for the HFC of the Feather River 2001.

Table 3.0-1. Estimated pond surface area of confirmed isolated basins.

Location	River Bank	River Mile	Pond Area (m^2)
Thermalito Bar	L	59.0	520
G95 South Island (1)		57.2	216
G95 South Island (2)		56.9	190
Upper Hour Island		56.3	735
Lower Hour Island		56.1	1,530
Hour Bars	L	55.9	4,700
Goose Riffle	L	54.8	153
Big Bar	R	53.4	1,800*
Upper Macfarland	R	52.6	784
Lower Macfarland	R	52.4	6,746*
Gridley Side Channel (1)	L	49.5	384
Gridley Side Channel (2)	L	49.5	1,922
Gridley Riffle	R	49.2	13,296*
Shallow Riffle	R	47.0	312
Herringer Side Channel (1)	R	46.5	518
Herringer Side Channel (2)	R	46.5	16,109
Herringer Riffle	L	45.2	10,686*
RM 27.5	R	27.5	4,200
RM 19.0	L	19.0	1,200

** Estimated range based on historical aerial photos.*

3.1 JUVENILE STRANDING

In January of 2001 flow was reduced in the HFC from 2,450 cfs to 1,750 cfs, resulting in approximately 2,400 m^2 (25,834 ft^2) of ponded area. Subsequent sampling resulted in an estimated 4,213 juvenile fall run Chinook salmon and 193 spring run Chinook salmon. Another flow fluctuation in April 2001 reduced flow from 1,750 cfs to 1,050 cfs. This resulted in approximately 21,000 m^2 (226,044 ft^2) of additional isolated area. This reduction stranded an estimated 42,785 fall run Chinook salmon. Only 5 spring run Chinook salmon and 2 steelhead were captured, accordingly there abundance in the isolated areas was not expanded.

In 2002, flow was maintained at 1,200 cfs throughout the survey season, therefore stranding data was not collected. However, the 2003 survey had the highest magnitude of flow fluctuation to date. In February 2003 flow was increased to 8,000 cfs and subsequently reduced to 1,050 cfs in March. This resulted in approximately 42,755 m^2 (460,215 ft^2) of ponded area corresponding to an estimated 84,092 fall run Chinook

salmon that were potentially stranded. There were 8 spring run Chinook salmon and 1 steelhead captured; no expansion to the stranding estimates was made for these species. There was also a smaller event in January (1,750-1,250 cfs) which resulted in the capture of only one fall run Chinook salmon despite an estimated 3,021 m^2 (32,518 ft^2) of ponded area. Also of note, in August 2003, discharge to the LFC was increased to 1,800 cfs and subsequently dropped to 600 cfs. This flow fluctuation created a shallow pond around Gateway Riffle (RM 59.8). A visual survey showed there were no fish in the pond. The pond was dry within 24 hours.

In all years, the estimated abundance of stranded salmonids was significantly less than 1% of the estimated annual emigration (Table 3.1-1). The results of multiple t-tests comparing the mean size of stranded and non-stranded salmonids for each event failed to show statistically significant difference. Simple linear regressions using the relative abundance of stranded salmonids as the dependent variable and month (r^2=0.02, p=0.6) and river mile (r^2=0.22, p=0.07) as independent variables showed no statistical significance. A similar analysis using salmonid density instead of abundance was also insignificant. A Kruskall-Wallis analysis comparing the rank abundance of stranded salmonids for each pond type (SC, OCP, PH) showed no statistical difference between pond types (H=1.17, p=0.56).

Figure 3.1-1 illustrates the relationship between flow change and cumulative isolated area. The data is based on field observations and historical aerial photos. There appears to be several critical thresholds in flow reduction below which surface area of stranding ponds increase rapidly. The rapid increase in stranding pond surface area is most evident for flow reductions below 2,500 cfs and 1,700 cfs.

Table 3.1-1. A comparison of the estimated number of stranded and emigrated fall run Chinook salmon between January and May.

Year	Est. Stranded	Est. Emigrated	% Stranded
2001	46, 998	29,005,361	0.16
2002	--	--	--
2003	84, 082	11,843,353	0.71

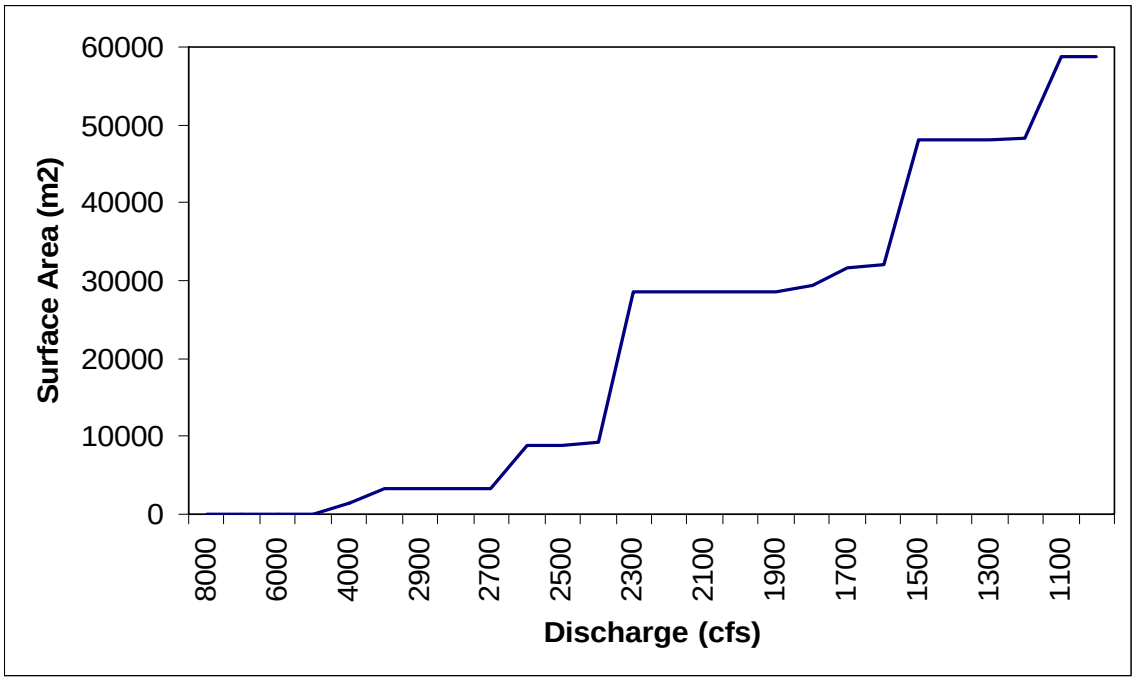


Figure 3.1-1. Cumulative surface area of isolation basin in relation to incremental decreases in river discharge.

4.0 DISCUSSION

4.1 JUVENILE STRANDING

Nearly all stranding areas upstream of Honcut Creek were inundated at some time during the period of study. The 8,000 cfs discharge below the Thermalito-Afterbay Outlet is the highest flow observed in the Feather River, since the beginning of the survey in Fall 2001. Of the 17 potential stranding areas identified downstream of Honcut Creek only 2 were isolated when flows receded to 1,050 cfs. However, flows in the downstream reaches of the Feather River are strongly influenced by other tributaries (like the Yuba River), and thus the direct influences of Oroville Project operations are more difficult to discern.

Upstream of Honcut Creek, the impact of stranding on Chinook salmon and steelhead populations appears to be very small when compared to the number of emigrants from the Feather River. Over three survey years, the only major water operation occurred in late February 2003. The peak of emigration for Chinook salmon occurred weeks prior to this event, which may have reduced the potential for impact. Also substantial increases in discharge have been shown to stimulate emigration of juvenile salmonids. The already relatively small number of rearing salmonids in the river at this time may have emigrated while discharge was increasing, thus reducing the overall risk of stranding to the population. Additionally, the fact that over 75% of steelhead spawning and early rearing is thought to be in the LFC suggests that at this time of year there is a very limited potential impact on juvenile steelhead (DWR 2003). Although only 2 isolated ponds were identified after a reduction of nearly 7,000 cfs, areas below Honcut Creek were not sampled for stranded fish. Our estimate of stranded fish is not representative of the entire Feather River; and likely underestimates the total impact of salmonid stranding. In subsequent surveys, sampling in reaches below Honcut Creek, may improve our ability to assess broader stranding Impacts in the lower Feather River.

There was no significant difference between the mean size of stranded and non-stranded fish. Additionally, within an isolation event, there were no differences in the mean size of fish stranded between ponds. This is likely a reflection of the small range in juvenile salmonid size at this time of year in the Feather River. The majority of salmon emigrate as fry shortly following emergence.

There was no apparent pattern in the distribution and size of ponded areas, which is likely why no relationship was found between the relative abundance or density of stranded fish and river mile. Researchers have shown that stranding is more significant in large off-channel ponds (OCP) because of favorable rearing conditions in these habitats, the distance of these habitats from the main river, and an apparent reluctance of juveniles to move away from protective cover (Bradford et al.1995, Higgins and Bradford 1996, Bradford 1997, Jones & Stokes 1999). Furthermore, in the Feather River a substantial proportion off all ponded areas are OCP. However, we failed to find

a difference in the amount of stranding between these and different pond types. Without experimentally manipulating flow it is difficult to collect data over the repeated range of flows necessary for such analyses, thus our sample size may be too small to detect differences. This is also true for drawing conclusions about the timing of flow fluctuations. We did not observe any relationship between the timing of flow fluctuations and the level of stranding. Evaluating factors that effect stranding rates is further complicated by the fact they often act synergistically. The magnitude of the event can be equally as important as the timing of the event.

The generally low level of stranding suggests that current ramping rates in the HFC may be suitable. Yet, beach stranding for which ramping rates would have the highest impact was not field verified. Beach stranding was not considered during our field sampling due to the following factors: (1) this type of stranding is generally believed to be only a minor component of overall stranding potential in the lower Feather River; (2) ramping rates are very low (roughly 1 inch stage change per hour) and should minimize beach stranding impacts; (3) problems with predation by birds before a survey could be conducted which would frustrate any effort at accurate beach stranding survey results; (4) this type of stranding would occur in intragravel spaces and therefore be very difficult to quantify in any reliable quantitative manner. However, much experimental research has been conducted regarding the effect of ramping rates on juvenile salmonid stranding. Bradford et al. (1995) and Bradford (1997) found that significantly more coho salmon and rainbow trout juveniles were stranded at ramping rates of 30 centimeters per hour (cm/h) (11.8 inches per hour) than at 6 cm/h (2.4 inches per hour). Similar results were reported for juvenile Chinook salmon in simulated side channels during the fall (Bradford et al. 1995). Based on a field investigation of stranding of chinook salmon and steelhead fry in the Sultan River, Washington, Olson and Metzgar (1987) recommended ramping rates ranging from 1 to 6 inches per hour (2.5 to 15 cm/h) depending on flow range, season, and time of day.

Oroville operations are currently working under flow fluctuation guidelines designed to minimize the potential for fish stranding. In the LFC flow reductions are restricted to 200 cfs/day for within bank flows. Under within-bank flow conditions, a flow reduction of 200 cfs/day is approximately equivalent to a 1/10 inch/hour stage elevation change in the LFC of the Feather River extending from the Fish Barrier Dam to the Thermalito Afterbay Outlet (personal communication, Ted Sommer). Ramping rates of 1 inch per hour are among the slowest ramping rates currently used in other regulated rivers. Revision of LFC ramping standards to at least 1 inch per hour would maintain desirable protective standards for fisheries but also be less burdensome to project operations.

5.0 REFERENCES

Bradford, M. J. 1997. An experimental study of stranding of juvenile salmonids on gravel bars and in sidechannels during rapid flow decreases. Regulated Rivers: Research & Management 13:395–401.

Bradford, M. J., G. C. Taylor, J. A. Allan, and P. S. Higgins. 1995. An experimental study of the stranding of juvenile coho salmon and rainbow trout during rapid flow decreases under winter conditions. North American Journal of Fisheries Management 15:473-–479.

DWR. 2002. Redd Dewatering and Juvenile Steelhead and Spring-Run Salmon Stranding in the Lower Feather River. Sacramento, CA. January 2002.

DWR. 2003. Redd Dewatering and Juvenile Steelhead and Spring-Run Salmon Stranding in the Lower Feather River. Sacramento, CA. June 2003.

DWR. 2004. Distribution and Habitat Use of Steelhead and Other Fishes in the Lower Feather River, 1999-2001. Sacramento, CA. April 2004.

Greene, S. 1992. Daily fork length table from data by Frank Fisher, California Department of Fish and Game. Sacramento (CA): California Department of Water Resources, Environmental Services Department.

Higgins, P.S., and M. J. Bradford. 1996. Evaluation of a large-scale fish salvage to reduce the impacts of controlled flow reduction in a regulated river. North American Journal of Fisheries Management 16:666–673.

Hunter, M. A. 1992. Hydropower flow fluctuations and salmonids: a review of the biological effects, mechanical causes, and options for mitigation. State of Washington, Department of Fisheries, Technical Report No. 119.

Jones & Stokes. 1998. Assessment of potential fish stranding impacts associated with April 1998 flow reductions on the Yuba River. Sacramento, CA. Prepared for Yuba County Water Agency, Marysville, CA.

————. 1999. An evaluation of fish stranding and entrapment on the lower Yuba River during a controlled, short-term flow reduction. Sacramento, CA. Prepared for Yuba County Water Agency, Marysville, CA

————. 2002. An evaluation of fish stranding and entrapment on the lower Yuba River during a controlled, short-term flow reduction. Sacramento, CA. Prepared for Yuba County Water Agency, Marysville, CA

Olson, F. W., and R. G. Metzgar. 1987. Downramping to minimize stranding of salmonid fry. Pages 691–701 in B. W. Clowes (ed.), Waterpower ’87, Proceedings of the International Conference on Hydropower. New York: American Society of Civil Engineers.