RUSSIAN RIVER BIOLOGICAL ASSESSMENT INTERIM REPORT 1 - FLOOD CONTROL OPERATIONS AT COYOTE VALLEY AND WARM SPRINGS DAMS

Prepared for:

U.S. ARMY CORPS OF ENGINEERS
San Francisco District
San Francisco, California

and

SONOMA COUNTY WATER AGENCY
Santa Rosa, California

Prepared by:

ENTRIX, INC.
Walnut Creek, California

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The Sonoma County Water Agency (SCWA), the U.S. Army Corps of Engineers (USACE), and the Mendocino County Russian River Flood Control and Water Conservation Improvement District (MCRRFC&WCID) are undertaking a Section 7 Consultation under the federal Endangered Species Act (ESA) with the National Marine Fisheries Service (NMFS) to evaluate effects of operations and maintenance activities on listed species and their critical habitat. The Russian River watershed is designated as critical habitat for threatened stocks of coho salmon, chinook salmon and steelhead. SCWA, USACE and MCRRFC&WCID operate and maintain facilities and conduct activities related to flood control, channel maintenance, water diversion and storage, hydroelectric power generation, and fish production and passage. The California Department of Fish and Game (CDFG) operates the hatchery facilities under an agreement with USACE.

Federal agencies such as USACE are required under the ESA to consult with the Secretary of Commerce to insure that their actions are not likely to jeopardize the continued existence of listed species or adversely modify or destroy critical habitat. As part of the Section 7 Consultation, USACE and SCWA will submit to NMFS a biological assessment (BA) that will provide the basis for NMFS to prepare a biological opinion (BO) that will evaluate project operations. The BA will integrate the Interim Reports on various project operations.

This interim report evaluates the effects of current flood control operations on listed species and critical habitat in the Russian River. The facilities evaluated include Warm Springs Dam on Dry Creek and Coyote Valley Dam located on the East Fork Russian River near the city of Ukiah. There are three major areas of flood control operations addressed in this report: (1) channel geomorphology including scour of spawning gravels, bank erosion and channel maintenance, (2) ramping rates, and (3) inspection and maintenance of the dams. In general, there is a risk of adverse effects to protected populations related to maintenance and pre-flood inspection activities at Coyote Valley Dam. There is also a risk of potential adverse effects associated with maintaining channel geomorphic conditions on Dry Creek related to flood control operations at Warm Springs Dam. Based on analysis of these issues, flood control operations are likely to adversely affect the listed fish species, and are likely to adversely affect the designated critical habitat of the listed fish species.

For an explanation regarding the terminology of the conclusions presented above, please refer to Section 1.2 of the Introduction.

Channel Geomorphology

There are three issues related to potential flood control operational effects on channel geomorphic conditions: scour of spawning gravels, streambank erosion, and channel maintenance/geomorphology.

Scour of Spawning Gravels

Flood control releases from Warm Springs and Coyote Valley Dams have reduced the magnitude of flood peaks in the Russian River drainage. This reduction in flood peaks is generally accomplished by storing and later releasing the stored floodwaters over a longer period of duration than would have naturally occurred. However, flood releases may still be of sufficient magnitude and duration to adversely affect spawning habitat by scouring gravels to a depth that destroys the egg pocket. It is recognized that flows of sufficient magnitude are periodically needed to mobilize the streambed and transport sediments. Such flows are necessary to provide suitable spawning conditions by flushing fine sediments from the streambed. Ideally, there is a balance, or dynamic equilibrium between periodic mobilization of the streambed, transport of sediment, and sediment deposition and stability of spawning gravels.

Results indicate that stability of steelhead spawning gravels is very good in the upper mainstem reach. The potential for scour of chinook gravels is moderate, but represents an acceptable balance between periodic streambed mobilization and spawning gravel stability. In the Middle Reach of the Russian River at Alexander Valley, spawning gravels are subject to slightly more frequent scour than the Upper Reach. Results indicate moderately stable conditions for chinook gravels, and moderately, but slightly less stable conditions for steelhead gravels. Higher discharges due to tributary flow accretion and not to flood control operations account for a greater incidence of scour in the Middle Reach compared with the Upper Reach. In summary, flood control operations do not have a significant effect on spawning gravel scour in the Upper or Middle Reaches of the Russian River.

On Dry Creek, flood control operational effects were evaluated for steelhead, chinook, and coho salmon. Results indicate that there is a reasonably good balance between expected periodic streambed mobilization and spawning gravel stability for successful reproduction of chinook salmon, coho salmon, and steelhead. Coho salmon, utilizing smaller gravels for spawning, would be subject to a greater frequency of scour than either chinook or steelhead redds. Some mobilization and scour of spawning gravels to transport fine sediments is necessary over the long-term in order to maintain the quality of spawning gravels.

Streambank Erosion

Sustained releases of flood flows have been cited as a potential cause of streambank instability on both Dry Creek and the mainstem Russian River. Prolonged release of moderate to high streamflows may influence bank erosion and thereby affect habitat conditions by contributing sediment to the channel or altering cover, shading, and other factors relevant to the riparian corridor.

On the mainstem Russian River, 6,000 cubic feet per second (cfs) at Hopland in the Upper Reach, and 8,000 cfs at Cloverdale in the Middle Reach were identified as the flow threshold when bank erosion is likely to be initiated. The analysis indicates that prolonged flows above these thresholds are relatively infrequent. It is noteworthy that on many of the days when flows exceed the erosion threshold established in the criteria at either location, discharge from Coyote Valley Dam is low. Flood control operations are often timed so that reservoir outflows during prolonged peak streamflow conditions downstream are a relatively insignificant contributor to total flow and to bank erosion at Hopland or Cloverdale. Thus, flood operations at Coyote Valley Dam do not cause prolonged flows above the threshold that initiates streambank instability and erosion.

On Dry Creek, sustained flows above 2,500 cfs initiate bank erosion. The bank erosion analysis was performed at two locations, immediately below Warm Springs Dam and downstream of the most significant tributary confluence at Pena Creek, which is upstream of Yoakim Bridge (the Near Geyserville location). Overall, the analysis indicates that the potential for bank erosion is relatively low in most years. Inspection of the streamflow gaging records indicates that on many days when flows exceeded the erosion threshold at the Near Geyserville location, discharge from Warm Springs Dam was low. Similar to Coyote Valley Dam operations, the flood control operations at Warm Springs Dam are often timed so that reservoir outflows during prolonged peak streamflow conditions downstream are a relatively insignificant contributor to total flow and to bank erosion. The analysis indicates that flood operations at Warm Springs Dam are not a significant factor contributing to prolonged flows above the threshold that initiates streambank instability and erosion in most years.

Channel Maintenance/Geomorphology

Channel geomorphology refers to the form of a river, which includes channel dimensions (i.e., width, depth, confinement, entrenchment), gradient, planform, and bed material sizes. Channel geomorphology is intimately linked to the type and quality of fish habitat present. The change in hydrologic regime associated with flow regulation by dams will influence channel geomorphic response. The type and magnitude of adjustments depends on initial channel conditions and the extent of changes in discharge and sediment supply. The impact of dams on the morphology of a river tends to diminish downstream due to flow and sediment contributions from tributaries. Although the rate of channel change in response to flow regulation by dams is highly variable, most channel adjustments likely take place within a few decades following dam construction.

An equilibrium channel morphology (stream channel is neither aggrading or degrading over the long term) is maintained by flows that mobilize the streambed surface, transporting bedload at a rate which is about equal to sediment supply. Maintaining the frequency of incipient motion of the channel bed is often used as a minimum criteria for maintenance of channel morphological conditions. This assessment considered the potential for aggradation/degradation of the channel as a result of flow regulation by reservoir operations.

On the mainstem Russian River, flood control operations have not significantly altered the potential to mobilize the streambed. Peak flood frequencies remain sufficient to maintain channel geomorphic conditions. Therefore, flood control operations have a minimal effect on channel maintenance/morphologic conditions on the mainstem.

Flood control operations at Warm Springs Dam have had a greater influence on peak flood frequencies and expected bed mobilization on Dry Creek than on the Russian River mainstem below Coyote Valley Dam. Flood magnitudes and frequencies are likely insufficient to maintain geomorphic conditions, and may result in periodic sedimentation of the streambed that could impair spawning or rearing habitat.

Fish Stranding: Ramping Rates

To protect spawning gravel and juvenile salmonids within the Russian River and Dry Creek during flood control operations, USACE, in consultation with NMFS and CDFG, has developed interim guidelines for flow release changes, summarized as follows:

Reservoir OutFlow	Ramping Rate
0-250 cfs	125 cfs/hour
250-1,000 cfs	250 cfs/hour
>1,000 cfs	1,000 cfs/hour

The maximum ramping rates at release levels below 1,000 cfs differ from authorized rates; however, every effort is made to comply with the interim rates (USACE, 1998a,b). These ramping rates are intended for flood control activities, when flow releases are under the control of USACE. Flow changes above 1,000 cfs release are generally limited to a rate of 1,000 cfs/hr to protect against bank sloughing and are not related to fish stranding issues. Lower ramping rates at lower reservoir flow releases are to protect against fish stranding. Ramping rates are also separately evaluated under issues associated with dam inspections and maintenance activities, since ramping rates associated with these activities have been considerably different than those associated with flood control operations and streamflows are much higher on Dry Creek and mainstem Russian River when flood operations take place.

Interim ramping rates have been typically attained at both Warm Springs and Coyote Valley Dam. There have been no reports of strandings or mortalities due to ramping under operational conditions associated with flood control activities, which usually occur when streamflows are relatively high. Current operational conditions associated with interim ramping rates provide adequate protection to listed species.

Annual and Periodic Dam Inspections and Maintenance

Annual and periodic pre-flood inspections take place at both Coyote Valley and Warm Springs Dams. During 1998 and 1999, inspections took place during the months of September and June, respectively. In 2000, pre-flood inspection activities took place during May. Flows must be reduced or completely shut down, usually for periods of several hours, in order to accomplish the inspections. Additionally, flows may be reduced or shut down in order to perform periodic maintenance activities on the dams. Depending upon the maintenance activities to be performed, flows may be reduced or shutdown for periods lasting from an hour to several days depending if corrective actions are taking place or not. Ramping rates and reduced streamflow conditions are the two primary issues of concern associated with annual and periodic dam inspections and maintenance. Ramping during pre-flood inspection and maintenance activities that uses a 25 cfs/hr ramping rate provide adequate protection against stranding of listed species on Dry Creek. Ramping at 50 cfs/hr during May did not provide adequate protection, resulting in stranding of fry on the mainstem Russian River.

Ramping

During dam inspections and maintenance, ramping at Warm Springs Dam typically occurs at the rate of 25 cfs/hr. The current operational practices of 25 cfs/hr ramping was evaluated for approximately 1.5 miles downstream of Warm Springs Dam, which is the expected downstream extent of ramping effects before attenuation by tributary accretion. Only minor stranding of fry has been observed when ramping at 25 cfs/hr during May. During other months, no stranding or mortalities have been recorded. The stage change calculated with a 25 cfs/hr ramping rate is usually less than 0.16 ft/hr, which is a fairly rigorous standard considered in this BA.

Ramping at Coyote Valley Dam during maintenance and inspection activities are typically about 50 cfs/hr. On the mainstem Russian River, we considered the ramping performance at four cross-section locations from approximately 3 miles below Coyote Dam to 5 miles below the dam near the Perkins Street bridge crossing in Ukiah. Opportunities for stranding of fry and juveniles are likely given the recent ramping results at Coyote Valley Dam.

Reduced Streamflow Conditions

The effects of annual and periodic maintenance activities on low streamflow and habitat conditions are based on rearing criteria developed from Winzler and Kelly Consulting Engineers (1978) and existing monitoring observations.

Since there is a bypass flow capability at Warm Springs Dam, dewatering is unlikely and has not occurred under recent operational practices. The bypass streamflow is generally between 25-28 cfs. Annual pre-flood inspections that require the conduit to be evacuated generally last for less than two hours, although periodic maintenance work could require flow reductions over longer periods. Steelhead, coho salmon, and chinook salmon may be rearing in May when dam inspection and maintenance activities are scheduled. Based on the rearing evaluation criteria, reduced streamflows will not significantly affect listed species when there is a 25 cfs streamflow release into Dry Creek.

At Coyote Valley Dam, rescue of juvenile steelhead has, in the past, been necessary due to dewatering on the East Fork and further downstream on the mainstem Russian River during inspection and maintenance activities that took place in the fall. However, during recent inspection and maintenance in June 1999, no stranding and no rescue were necessary, as pools were maintained on the East Fork providing refuge habitat.

Winzler and Kelly rearing habitat criteria were not developed for the East Fork, but rearing habitat conditions recently appeared to be fair, given the monitoring observations in June 1999 and the relatively short period of time that flows were reduced. Nevertheless, there is a potential that pool habitat could be dewatered on the East Fork and stranding could occur.

1.1 SECTION 7 CONSULTATION

The Sonoma County Water Agency (SCWA), the U.S. Army Corps of Engineers (USACE), and the Mendocino County Russian River Flood Control and Water Conservation Improvement District (MCRRFC&WCID) are undertaking a Section 7 Consultation under the Federal Endangered Species Act (ESA) with the National Marine Fisheries Service (NMFS) to evaluate effects of operations and maintenance activities. The activities of the USACE, SCWA, and MCRRFC&WCID span the Russian River watershed from Coyote Valley Dam and Warm Springs Dam to the estuary, as well as some tributaries. The Russian River watershed is designated as critical habitat for threatened stocks of coho salmon, chinook salmon and steelhead. The SCWA, USACE and MCRRFC&WCID operate and maintain facilities and conduct activities related to flood control, water diversion and storage, hydroelectric power generation, and fish production and passage. The SCWA, USACE, and MCRRFC&WCID also are participants in a number of institutional agreements related to the fulfillment of their respective responsibilities.

Federal agencies such as USACE are required under the ESA to consult with the Secretary of Commerce to insure that their actions are not likely to jeopardize the continued existence of listed species or adversely modify or destroy critical habitat. USACE, SCWA and NMFS have entered into a Memorandum of Understanding (MOU) which establishes a framework for the consultation and conference required by the ESA with respect to the activities of USACE, SCWA and MCRRFC&WCID that may directly or indirectly affect coho salmon, chinook salmon and steelhead in the Russian River. The MOU acknowledges the involvement of other agencies including: the California Department of Fish and Game (CDFG), the U.S. Fish and Wildlife Service (USFWS), the State Water Resources Control Board (SWRCB), the North Coast Regional Water Quality Control Board (RWQCB), the State Coastal Conservancy, and the Mendocino County Inland Water and Power Commission (MCIWPC).

1.2 SCOPE OF THE BIOLOGICAL ASSESSMENT

As part of the Section 7 Consultation, USACE and SCWA will submit to NMFS a BA that provides a description of the actions subject to consultation, including the facilities, operations, maintenance and existing conservation actions. The BA will describe existing conditions including information on hydrology, water quality, habitat conditions, and fish populations. The BA will provide the basis for NMFS to prepare a biological opinion (BO) that will evaluate the project, including conservation actions.

This document presents an analysis of the potential for adverse impacts to the Russian River populations of coho salmon, chinook salmon, and steelhead as a result of certain activities. Because the ESA prohibits take of any individuals, the document will come to a conclusion of "likely to adversely affect" if any individual fish could be harmed by the proposed action, even if the overall risk of adverse impact to the overall population is low. Such a conclusion would mean that one or more listed fish might be harmed by the proposed action. Once a BA containing this determination is submitted to NMFS, formal consultation under the ESA will be initiated. During the formal consultation process, NMFS will make an assessment of whether the proposed action is likely to jeopardize the continued existence of the species. NMFS will present this conclusion in the form of a BO.

The BA will integrate a number of Interim Reports:

Report 1	Flood Control Operations
Report 2	Fish Facility Operations
Report 3	Instream Flow Requirements
Report 4	Water Supply and Diversion Facilities
Report 5	Channel Maintenance
Report 6	Restoration and Conservation Actions
Report 7	Hydroelectric Projects Operations
Report 8	Estuary Management Plan

This report evaluates the effects of current flood control operations on listed species and critical habitat in the Russian River. The facilities evaluated include Warm Springs Dam on Dry Creek and Coyote Valley Dam located on the East Fork Russian River near the city of Ukiah.

1.3 STATUS OF COHO SALMON, STEELHEAD AND CHINOOK SALMON IN THE RUSSIAN RIVER

The primary biological resources of concern within the project area are coho salmon, steelhead and chinook salmon. These species are each listed as threatened under the ESA. The pertinent Federal Register notices for these species are provided in Table 1-1. Coho salmon and steelhead are native Russian River species, although there have been many plantings from other river systems (CDFG 1991). It is uncertain whether chinook salmon used the Russian River historically (NMFS 1999). They have been stocked in the past, were not stocked in the last two years, but continue to reporduce in the watershed. The Central California Coast coho salmon Evolutionarily Significant Unit (ESU), which contains the Russian River, extends from Punta Gorda in northern California south to and including the San Lorenzo River in central California, and includes tributaries to San Francisco Bay, excluding the Sacramento-San Joaquin River system. The Russian River is the largest drainage included in the Central California Coast steelhead ESU, which extends from the Russian River down the coast to Soquel Creek near Santa Cruz, California. The chinook salmon listing defined the population unit that contains the Russian River as the California Coastal ESU. This ESU encompasses the region from Cape Blanco in Oregon south to San Francisco Bay.

Critical habitat for each of these species within the Russian River is designated as the current estuarine and freshwater range of the species including "all waterways, substrate, and adjacent riparian zones.…" For each species, NMFS has specifically excluded areas above Warm Springs and Coyote Valley Dams and within tribal lands.

Table 1-1 Federal Register Notices for the Salmonids of the Russian River.

Species	Listing	Take Prohibitions	Critical Habitat
Coho Salmon	Vol. 61, No. 212, Pgs. 56138-56147 Oct. 31, 1996	Vol. 61, No. 212, Pgs. 56138-56147 Oct. 31, 1996	Vol. 64, No. 86, Pgs. 24049-24062 May 5, 1999
Steelhead	Vol. 62, No. 159, Pgs. 43937-43954 Aug. 18, 1997	Vol. 65, No. 132, Pgs. 42422-42481 July 10, 2000	Vol. 65, No. 32, Pgs. 7764-7787 February 16, 2000
Chinook Salmon	Vol. 64, No. 179, Pgs. 50394-50415 Sept. 16, 1999	Not yet issued	Vol. 65, No. 32, Pgs. 7764-7787 February 16, 2000

Life history descriptions for these species are provided in sections 1.3.1 through 1.3.3 so that effects from project operations can be evaluated. All three species are anadromous, but steelhead may also exhibit a life history type that spends its entire life cycle in freshwater. These species migrate upstream from the ocean as adults and spawn in gravel substrate. Their eggs incubate for a short period, depending on water temperature, and generally hatch in the winter and spring. Juveniles spend varying amounts of time rearing in the streams and then migrate out to the ocean, completing the cycle. Details on life history, timing and habitat requirements are provided for each species.

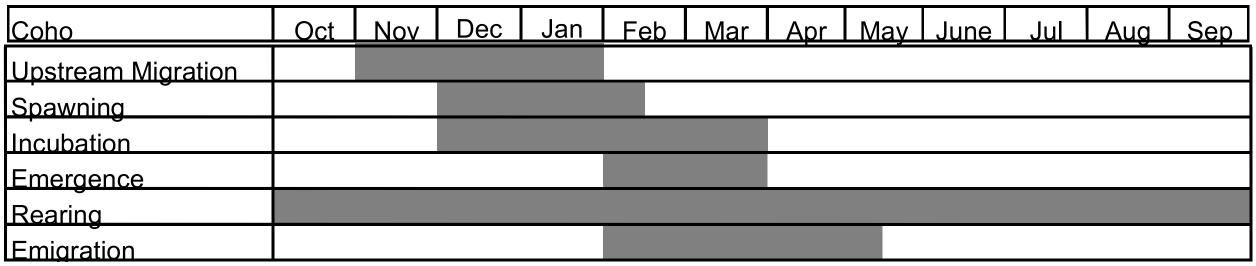
1.3.1 Coho Salmon

Coho salmon are much less abundant than steelhead in the Russian River basin. Spawning occurs in approximately 20 tributaries of the lower Russian River, including Dry Creek. In wet years, coho salmon have been seen as far upstream as Ukiah. The Don Clausen Fish Hatchery produces and releases an average of about 70,000 age 1+ coho salmon each year (1980-1998). However, no coho have been produced in the last two years.

1.3.1.1 Life History

The coho salmon life history is quite rigid, with a relatively fixed three-year life cycle. The best available information suggests that life history stages occur during times outlined in Figure 1-1 (EIP Associates [EIP] 1993, SCWA 1996, SWRCB 1997, RMI 1997, S. White, SCWA, pers. comm. 1999). Most coho enter the Russian River in November and December and spawn in December and January. Spawning and rearing occur in tributaries to the lower Russian River, for the most part downstream of Healdsburg Dam. The most upstream tributaries with coho salmon populations include Forsythe, Mariposa, Rocky, Fisher and Corral creeks. The mainstem below Cloverdale serves primarily as a passage corridor between the ocean and the tributary habitat.

After hatching, young coho will spend about one year in freshwater before becoming smolt and migrating to the ocean. Freshwater habitat requirements for coho rearing include adequate cover, food supply, and water temperatures. Primary habitat for coho includes pools with extensive cover. Outmigration takes place in late winter and spring. Coho salmon live in the ocean for about a year and a half, return as three-year-olds to spawn, and then die. The factors most limiting to juvenile coho production are high summer water temperatures, poor summer and winter habitat quality, and predation.



(EIP Assoc. 1993, SCWA 1996, SWRCB 1997, RMI 1997, S. White, SCWA, pers. comm. 1999).

Figure 1-1 Phenology of Coho Salmon in the Russian River Basin

1.3.2 STEELHEAD

There have been no recent efforts to quantify steelhead populations in the Russian River, but there is general agreement that the population has declined in the last 30 years (CDFG 1984, 1991). SCWA, CDFG and NMFS are currently developing programs to monitor trends in salmonid populations within the designated critical habitat boundaries for the basin. There has been substantial planting of hatchery reared steelhead within the basin, which may have affected the genetic constitution of the remaining natural population. Almost all steelhead planted prior to 1980 were from out-of-basin stocks (Steiner Environmental Consulting [Steiner] 1996). Since 1982, stocking of hatchery reared steelhead has been limited to progeny of fish returning to the Don Clausen Fish Hatchery and the Coyote Valley Fish Facility.

Steelhead occupy all of the major tributaries and most of the smaller ones in the Russian River Watershed. Many of the minor tributaries may provide spawning or rearing habitat under specific hydrologic conditions. Steelhead use the lower and middle mainstem Russian River primarily for migration to and from spawning and nursery areas in the tributaries and the mainstem above Cloverdale. However, it is possible that juvenile rearing may occur in the mainstem before smolt outmigration. The majority of spawning and rearing habitat for steelhead occurs in the tributaries.

1.3.2.1 Life History

Adult steelhead generally begin returning to the Russian River in November or December, with the first heavy rains of the season, and continue to migrate upstream into March or April. They have been observed in the Russian River during all months (S. White, SCWA pers. comm. 1999). The peak migration period tends to be January through March (Figure 1-2). Flow conditions are suitable for upstream migration in most of the Russian River and larger tributaries during the majority of the spawning period in most years. Sandbars blocking the river mouth in some years may delay entry into the river. However, during the times the sand barrier is closed, the flow is probably too low and water temperature is too high to provide suitable conditions for migrating adults further up the river (CDFG 1991).

Most spawning takes place from January through April, depending on the time of freshwater entry (Figure 1-2). Steelhead spawn and rear in tributaries from Jenner Creek near the mouth, to upper basin streams including Forsythe Creek, Maroposa, Rocky, Fisher and Corral creeks. Steelhead usually spawn in the tributaries, where fish ascend as high as flows allow (USACE 1982).

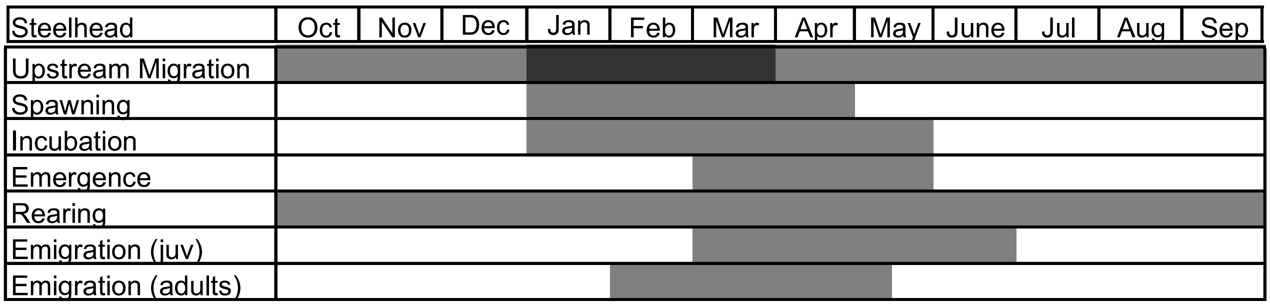


Figure 1-2 Phenology of Steelhead in the Russian River Basin

Gravel and streamflow conditions suitable for spawning are prevalent in the Russian River mainstem and tributaries (Winzler and Kelly Consulting Engineers [Winzler and Kelly] 1978), although gravel mining and sedimentation have diminished gravel quality and quantity in many areas of the mainstem. In the lower and middle mainstem (below Cloverdale) and the lower reaches of tributaries, water temperatures exceed 55^{o}F by April in some years (Winzler and Kelly 1978), which may limit the survival of eggs and fry in these areas.

After hatching, steelhead spend from one to four years in freshwater. Fry and juvenile steelhead are extremely adaptable in their habitat selection. Requirements for steelhead rearing include adequate cover, food supply, and water temperatures. The mainstem above Cloverdale and upper reaches of the tributaries provide the most suitable habitat, as these areas generally have excellent cover, adequate food supply, and suitable water temperatures for fry and juvenile rearing. The lower sections of the tributaries provide less cover, as the streams are often wide and shallow and have little riparian vegetation, and water temperatures are often too warm to support steelhead. In the summer, these areas can dry up completely. Available cover has been reduced in much of the mainstem and many tributaries because of loss of riparian vegetation and changes in stream morphology.

Emigration usually occurs between February and June, depending on flow and water temperatures (Figure 1-2). Sufficient flow is required to cue smolt downstream migration. Excessively high water temperatures in late spring may inhibit smoltification in late migrants.

1.3.3 Chinook Salmon

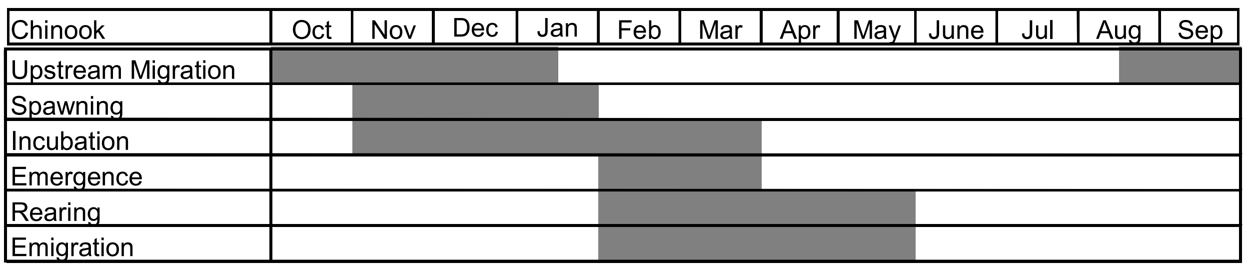
The historic extent of naturally occurring chinook salmon in the Russian River is debated (NMFS 1999). Whether or not chinook were present historically, the total run of chinook salmon today, hatchery and natural combined, is small. Historic spawning distribution is unknown, but suitable habitat formerly existed in the upper mainstem and in low gradient tributaries. Chinook currently spawn in the mainstem and larger tributaries, including Dry

Creek. Chinook tissue samples were collected this year by the SCWA and CDFG from Forsythe and Feliz Creeks, and Dry Creek and there were anecdotal reports of chinook in the Big Sulphur system.

1.3.3.1 Life History

Adult chinook salmon begin returning to the Russian River as early as August, with most spawning occurring after Thanksgiving. Chinook may continue to enter the river and spawn into January (Figure 1-3) (S. White, SCWA, pers. comm., 1999).

Unlike steelhead and coho, the young chinook begin their outmigration soon after emerging from the gravel. Freshwater residence, including outmigration, usually ranges from two to four months, but occasionally chinook juveniles will spend one year in fresh water. Chinook move downstream from February through May (Figure 1-3). Ocean residence can be from one to seven years, but most chinook return to the Russian River as two to four-year-old adults. Like coho salmon, chinook die soon after spawning.



(EIP Assoc. 1993, SCWA 1996, SWRCB 1997, RMI 1997, S. White, SCWA, pers. comm. 1999).

Figure 1-3 Phenology of Chinook Salmon in the Russian River Basin

1.4 BACKGROUND

1.4.1 COYOTE VALLEY DAM PROJECT

Lake Mendocino, located 3 miles east of the City of Ukiah, is the major feature of the USACE Coyote Valley Dam Project (CVDP). Lake Mendocino is impounded by Coyote Valley Dam (CVD), located on the East Fork of the Russian River, 0.8 miles upstream of the East Fork of the Russian River's confluence with the Russian River (see Figure 1-4). Coyote Valley Dam is a rolled earth embankment dam with a crest elevation of 784 feet above mean sea level (MSL), which is 160 feet above the original streambed. The CVDP was authorized by Section 204 of the Flood Control Act of 1950.

Lake Mendocino, which began storing water in 1959, has a capacity of 122,400 acre-feet at the spillway crest elevation of 764.8 feet above MSL, and captures a drainage area of about 105 square miles. The water supply pool capacity of Lake Mendocino was originally 72,300 acre-feet. Based on a bathymetric (water depth) survey in 1985 (SCWA and USGS 1985),

Figure 1-4 Map of Russian River Flood Control Facilities

sedimentation had reduced the lake's gross storage capacity to about 69,000[1] acre-feet at that time. Sedimentation continues at an estimated rate of about 120 acre-feet per year. The remaining capacity is used for flood control (see Figure 1-5). SCWA determines releases to be made from the water supply pool; however, when the water level rises above the top of the water supply pool (seasonally between elevations 737.5 feet and 748 feet above MSL) and into the flood control pool, USACE determines releases. USACE also determines releases during inspections and for maintenance and repair of the project.

During the rainy season (November through May), natural streamflow (rather than reservoir releases) accounts for most of the flow of the Russian River. From June through October, however, most of the flow in the Russian River downstream of Coyote Valley Dam and above Dry Creek is water imported from the Eel River via the Potter Valley Project (PVP), augmented by releases of stored water from Lake Mendocino.

1.4.2 Warm Springs Dam Project

Lake Sonoma is impounded by Warm Springs Dam at the confluence of Warm Springs Creek and Dry Creek, about 10 miles northwest of the City of Healdsburg (see Figure 1-4).

Warm Springs Dam is a rolled earth embankment dam with a crest elevation of 519 feet above MSL, which is 319 feet above the original streambed. Lake Sonoma began storing water in 1984. The Warm Springs Dam and Lake Sonoma Project, including downstream channel improvements, was authorized by the Flood Control Act of 1962.

Lake Sonoma has a gross capacity of 381,000 acre-feet at the spillway crest elevation of 495 feet above MSL and captures a drainage area of about 130 square miles. Under a contract with the federal government, SCWA has certain rights to the 212,000 acre-feet of water supply storage space in Lake Sonoma. As with Lake Mendocino, the contract gives SCWA the exclusive right to determine the rate of release of water from the water supply pool in Lake Sonoma (see Figure 1-5). USACE determines releases when the water level rises above the top of the water supply pool (elevation 451 feet above MSL) and into the flood control pool. USACE in consultation with SCWA, SWRCB and other regulatory agencies, determines releases during inspections, maintenance and repairs of the project scheduled outside of the flood control season.

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[1] For the purposes of reporting, SCWA uses the storage/capacity table developed in the 1985 bathymetric survey. However, the USACE continues to use the original storage/capacity table. Consequently, discrepancies will appear in reservoir storages reported by SCWA and USACE. All storage volumes discussed in this report are the 1985 bathymetric survey values reported by SCWA.

Figure 1-5 Lake Mendocino Flood Control Diagram

1.5 FLOOD CONTROL OPERATIONS OF COYOTE VALLEY DAM

USACE's primary objective for flood control releases from Lake Mendocino is, to the extent possible, to prevent flood flows on the East Fork Russian River from contributing to overbank flood stages on the Russian River below Coyote Valley Dam. The specific criteria for flood control operation are described in the Water Control Manual for Coyote Valley Dam (CVD Water Control Manual) (USACE, Exhibit A 1998). The general criteria for releases from the flood control pool, which includes all reservoir storage over the top of the water conservation pool, are summarized in the flood control diagram (Figure 1-5). The flood control diagram calls for successively increasing releases in three stages as reservoir levels rise towards the emergency spillway. The Hopland streamflow gauge, 14 miles downstream of Coyote Valley Dam, is the most downstream monitoring point for decisions affecting flood control releases from Lake Mendocino.

To the extent possible, USACE limits releases from Lake Mendocino to prevent local flooding at Hopland, which generally occurs when flows exceed 8,000 cfs. Because bank sloughing is likely to occur when flows decrease too rapidly, USACE limits changes in releases from Lake Mendocino to 1,000 cfs per hour.

More specific directions are included in Exhibit A to the CVD water control manual, titled "Standing Instructions to Damtenders" (CVD standing instructions). Operation for flood control is according to the Flood Control Diagram summarized by Exhibit A of the CVD Standing Instructions:

> *Schedules 1, 2 and 3 are used to empty the flood control space following a storm. Under these schedules, releases will be limited to: (1) the discharge that does not cause the flow at Russian River near Hopland to exceed 8,000 cfs and (2) the discharge that results in flow at Hopland being less than that reached during the previous storm. In addition, releases will be limited to (1) between 2,000 and 4,000 cfs if the reservoir pool did not reach elevation 746 feet MSL, (2) 4,000 cfs if the highest reservoir pool level reached was between elevation 746 and 755 feet MSL, and (3) 6,400 cfs if the pool level exceeded elevation 755 feet MSL. Schedules 1, 2 and 3 are used only if no significant rainfall is predicted.*
>
> *If significant rainfall is forecasted (1 inch in 24 hours or 0.5 inch in any six-hour period) maximum releases are limited to 2,000 cfs so that the reservoir releases can be reduced to 25 cfs within 1½ hours if necessary. Also when flow in the West Fork of the Russian River at Ukiah exceeds 2,500 cfs and is rising, releases from the reservoir will be reduced to 25 cfs.*
>
> *Outlet works gates may be used when the pool level is above the spillway crest (elevation 764.8 MSL) for Flood Control Schedule 3 releases, however the sum of the spill and the releases must not exceed 6,400 cfs.*
>
> *The Emergency Release Schedule is used between elevation 764.7 and 773 feet MSL, at which stage the flood control gates are fully open. The flood control gates remain fully open until the reservoir pool has receded to elevation 773 feet*

MSL, at which time the Emergency Release Schedule is implemented. When the reservoir pool has receded to elevation 764.7 feet MSL, Release Schedule 3 is maintained.

As shown in Figure 1-5, the available water conservation storage gradually encroaches into the flood control space after April 1 of any given year, when the need for flood control storage decreases. USACE may allow earlier encroachment if it determines that it will not impair the flood control function. During dry years, USACE has allowed this encroachment to occur as early as mid-February.

Inflows to Lake Mendocino were historically measured directly at the USGS gauging station on the East Fork Russian River, just upstream of Lake Mendocino. This station (USGS station no. 11461500) captures approximately 92 of the 105 square miles of drainage area contributing runoff to Lake Mendocino. Flow records for the station are no longer maintained by the USGS. However, stage records are being maintained by the USGS. Inflow to Lake Mendocino is computed from change in storage and releases.

Figures 1-6 and 1-7 show plots of reservoir inflow, storage and releases from Lake Mendocino during the 1996-97 and 1997-98 flood control seasons.

Water is released from Lake Mendocino for flood control purposes either through the use of outlet works or the spillway of the dam. Plan, profile, and section views of the outlet works are shown in Figure 1-8. The outlet works include three pairs of 5-foot by 9-foot hydraulically operated slide gates. Each pair of gates contains a service gate and an emergency gate. The service gates have separate control mechanisms, and may be operated singly or in combination. The emergency gates have one control mechanism, but can be operated singly by valve manipulation. An auxiliary generator is in place to provide hydraulic pressure in the event of a power failure. The outlet works are located in a concrete control tower in the reservoir (see Figure 1-9). The spillway is located about 0.6 miles upstream from the left abutment of the dam. The spillway structure consists of a concrete rectangular weir, about 200 feet wide with an ogee-shaped drop of about 8 feet. The crest elevation of the spillway is 764.8 feet.

Discharge capacity from the reservoir, with all gates open, is 6,500 cfs at the bottom of the flood control pool (i.e., when the water surface elevation reaches the stage when the reservoir is converted from water supply operation to flood control operation), and 7,300 cfs at gross pool. Releases above this level would require use of the spillway. The discharge capacity of the spillway is 35,800 cfs.

1.6 FLOOD CONTROL OPERATIONS OF WARM SPRINGS DAM

USACE's primary objective for flood control operation at Warm Springs Dam is to maximize the reduction in peak flood discharges on Dry Creek and the Russian River below Healdsburg. Because of the long travel time for water flow between Coyote Valley Dam and the Russian River/Dry Creek confluence, the operation of Warm Springs Dam for flood control purposes is independent of the Coyote Valley Dam operation.

Figure 1-6 Lake Mendocino Flood Control Operation 1996-97

Figure 1-7 Lake Mendocino Flood Control Operation 1997-98

Figure 1-8 Coyote Valley Dam Outlet Works

Figure 1-9 Coyote Valley Dam Plan, Profile and Section Views

The criteria for flood control operation of Lake Sonoma are similar to those for Lake Mendocino and are described in the Warm Springs Dam Water Control Manual (WSD Water Control Manual) (USACE, Exhibit A, 1998). The general criteria for releases from the flood control pool, which includes all reservoir storage over elevation 451.1 feet MSL, are summarized in the flood control diagram (Figure 1-10). As with Lake Mendocino, the flood control diagram includes three successive flood control pools, or schedules. For Lake Sonoma, the Hacienda Bridge gauge, approximately 16 miles downstream of Warm Springs Dam, is the most downstream monitoring point for decisions affecting flood control releases from Lake Sonoma.

To the extent possible, USACE limits releases from Lake Sonoma to restrict flows on the Russian River at Guerneville to 35,000 cfs, which is the approximate channel capacity in Guerneville. USACE also limits releases to prevent flooding downstream along Dry Creek, which generally occurs when flows just below the dam exceed 6,000 cfs. As with releases from Lake Mendocino, USACE limits changes in releases to 1,000 cfs per hour to prevent downstream bank sloughing.

More specific directions are included in Exhibit A to the WSD Water Control Manual, titled "Standing Instructions to Damtenders" (WSD standing instructions). Operation for flood control is in accordance to the Flood Control Diagram summarized by Section 9b of the WSD Standing Instructions:

> *Schedules 1 and 2 are used to empty the flood control space following a storm. Under these schedules releases will be limited to: (1) the discharge that does not cause the flow at Russian River near Guerneville to exceed 35,000 cfs and (2) the discharge that results in flow at Guerneville being less than that reached during the previous storm. In addition, releases will be limited to: (1) 2,000 cfs if the reservoir pool did not reach elevation 455 feet MSL, (2) 4,000 cfs if the highest reservoir pool level reached was between elevation 455 and 468 MSL, and (3) 6,000 cfs if the pool level exceeded elevation 468 MSL. Schedules 1, 2 and 3 are used only if no significant rainfall is predicted. If significant rainfall is forecasted (1 inch in 24 hours or 0.5 inch in any six-hour period) maximum releases are limited to 2,000 cfs so that the reservoir releases can be reduced to 25 cfs minimum within 1½ hours if necessary.*
>
> *Release schedule 3 will be maintained until elevation 502 MSL is reached by regulation of the outlet so that the combined flow from spills (pool above elevation 495 MSL) and releases through the outlet works will not exceed 6,000 cfs.*
>
> *The Emergency Release Schedule is used between elevation 502 MSL and elevation 505 MSL at which stage the flood control gates are fully open. The flood control gates remain fully open until the reservoir pool has receded to elevation 505 MSL, at which time the Emergency Release Schedule is implemented. When the reservoir pool has receded to elevation 502 MSL release schedule 3 is maintained.*

Figure 1-10 Warm Springs Dam and Lake Sonoma Flood Control Diagram

The allowable water conservation storage in Lake Sonoma remains constant throughout the year. Because of the configuration of the watershed above Lake Sonoma, direct measurement of reservoir inflow by stream gauging is impractical. Consequently, inflow is calculated as the algebraic sum of releases, changes in storage and the estimated evaporation.

Figures 1-11 and 1-12 show plots of reservoir inflow, storage and releases from Lake Sonoma during two recent flood control seasons: 1996-97 and 1997-98.

Water is released from Warm Springs Dam for flood control purposes through the use of outlet works in the left abutment of the dam, or through the use of the spillway, located in a natural saddle shape on the left abutment of the dam. The outlet works include two gate passages, which each contain two hydraulically operated 5-foot by 8-foot flood control gates. The control structure located above the regulating gates accommodates multiple intakes designed for municipal and industrial uses, as well as for meeting water quality requirements. The control structure contains a 6-foot diameter wet well, an elevator, two 42-inch diameter air vents, butterfly control valves for the multi-level inlets, and auxiliary equipment (see Figure 1-13 for profiles and sections of the Warm Springs Dam control structure). Maximum discharge capacity of the outlet works is 8,100 cfs when the reservoir pool is at 513.1 feet MSL. The spillway was designed for a discharge of 29,600 cfs with the maximum reservoir pool elevation level 18 feet above the spillway crest.

1.7 PREVIOUS ENDANGERED SPECIES ACT ACTIONS ON COYOTE VALLEY DAM AND WARM SPRINGS DAM FLOOD CONTROL OPERATIONS

To assure the safety, structural integrity, and operational adequacy of these projects, the dams are inspected periodically. Routine inspections include annual pre-flood inspections and more comprehensive five-year inspections; however, inspections and evaluations may be more frequent if necessary. Non-routine inspections include post-earthquake inspections. For safety reasons, releases must be reduced or terminated during some portions of these inspections. Normal releases may also be reduced or modified for special testing, such as the outlet works vibration testing carried out in 1998. Following formal notification by USACE, SCWA notifies affected regulatory agencies, including FERC, the State Water Resources Control Board (SWRCB), and NMFS, and requests temporary relief from its minimum streamflow requirements if necessary.

USACE has entered into separate formal consultations with NMFS since 1997 to address the impacts on coho salmon and steelhead resulting from temporary flow reductions or increases from Warm Springs Dam and Coyote Valley Dam. The temporary flow reductions and related actions under the ESA are summarized as follows:

1. In July 1997, USACE provided NMFS with a biological assessment and requested a formal consultation under ESA Section 7 to address the effects of flow reductions resulting from proposed repair work on the Emergency Water Supply Pipeline (EWSP) at Warm Springs Dam, and the annual pre-flood inspection at Warm Springs Dam. The EWSP, which

Figure 1-11 Lake Sonoma Flood Control Operation 1996-97

Figure 1-12 Lake Sonoma Flood Control Operation 1997-98

Figure 1-13 Warm Springs Dam Control Structure–Profiles and Sections

supplies water from the Warm Springs Dam outlet works to the Don Clausen Fish Hatchery located at the base of Warm Springs Dam,[1] was damaged during high flood releases during a flood event in January 1997. On September 30, 1997, NMFS issued a biological opinion and incidental take statement for these activities.

In November 1997, USACE submitted a supplement to its July 1997 biological assessment to NMFS to address a vibration analysis test on the Warm Springs Dam outlet works (USACE 1997b). The test, which was intended to determine the cause of damage to the EWSP and outlet works during the January 1997 event, required varying releases from below 50 cfs to over 3,000 cfs over a two-day period. The consultation was requested under 50 CFR (Code of Federal Regulations) Sec. 402.05 (Emergencies), which provides that:

> *(a) Where emergency circumstances mandate the need to consult in an expedited manner, consultation may be conducted informally through alternative procedures that the Director of the National Marine Fisheries Service determines to be consistent with the requirements of sections 7(a)-(d) of the Endangered Species Act. This provision applies to situations involving acts of God, disasters, casualties, national defense or security emergencies, etc.*

Due to dam safety concerns relating to the reliability of the outlet works, USACE proceeded with the testing in January and February of 1998. Additional tests were carried out in March 1998. A biological opinion was not issued to USACE for the testing. NMFS protested additional tests that USACE performed in March 1998 that were needed to complete the analysis of the vibration phenomena on the EWSL.

2) In July 1998, USACE submitted a biological assessment to NMFS to address the impacts of flow reductions during periodic inspections at Warm Springs Dam and Coyote Valley Dam (USACE 1998). On September 4, 1998, NMFS issued a biological opinion and incidental take statement for these activities (NMFS 1998b).

3) In May 1999, USACE submitted a biological assessment to NMFS to address the impacts of flow reductions during pre-flood inspections at Warm Springs Dam and Coyote Valley Dam (USACE, 1999a). In June 1999, NMFS issued a biological opinion and incidental take statement for these activities (NMFS, 1999).

4) USACE consulted with NMFS in February 2000, for emergency repairs to the EWSL at Warm Springs Dam.

   On Thursday, February 17, 2000, the emergency water supply line at Warm Springs Dam sustained damages during high flood releases of up to 4,000 cfs. Damages to the EWSL consisted of a broken support bracket, which is used to attach the water line to the side of the stilling basin. Due to a significant pressure drop in the fill line observed by project staff during the high releases, there was concern that the EWSL within the outlet tunnel may have sustained damage. On February 23, 2000, NMFS issued a letter of concurrence with the proposed action, concluding that the flow reduction was not likely to adversely affect

[1] Operation of the hatchery is described in detail in Report 2 (Fish Facility Operations).

federally listed species or habitat. The terms of concurrence required, ramping down/up were done in 50-75 cfs/hr increments and monitoring of Dry Creek.

An inspection of the EWSL within the main tunnel and repairs to the broken support bracket were scheduled for Friday, February 25, 20000. The inspection required that the releases through the outlet tunnel be halted for two hours and the EWSL was used to supply approximately 28 cfs to the fish hatchery and Dry Creek below the dam. During the reduced flow period, the bracket was repaired and the EWSL within the tunnel appeared not to have sustained any damages during the high releases.

In addition to these actions, USACE has developed modified guidelines for the rates at which releases from Warm Springs and Coyote Valley Dams may be changed during flood control operations. The existing Water Control Manuals allow releases to be changed at up to 1,000 cfs per hour. To protect spawning gravel and juvenile salmonids within the Russian River and Dry Creek, USACE, in consultation with NMFS and CDFG, has developed interim guidelines for release changes (USACE, Exhibit A 1998), summarized as follows:

Reservoir OutFlow	Ramping Rate
0-250 cfs	125 cfs/hour
250-1,000 cfs	250 cfs/hour
>1,000 cfs	1,000 cfs/hour

The USACE follows these guidelines approximately 90% of the time, based on flood control criteria (Pugner, USACE, pers. comm.). These guidelines will be used until final analyses and recommendations from the biological assessment and biological opinion are developed pursuant to the MOU (Eng, pers. comm. 1999).

Flood control operations at Warm Springs and Coyote Valley Dams may potentially affect salmonid populations and their habitat in several ways. The magnitude and frequency of flow releases from the dams affect channel geomorphology, scour of spawning gravels and the extent of bank erosion. Ramping rates (reductions in flow) during flood control operations or for dam maintenance activities have the potential to strand fish. The potential for these flood control activities to affect coho salmon, chinook salmon, and steelhead habitat are discussed, and evaluation criteria are defined in this section. Potential effects of flood operations on habitat conditions associated with changes in the flow regime are to be addressed in Report 3, Instream Flow Requirements.

2.1 GEOMORPHIC AND LAND-USE SETTING

The Russian River watershed is characterized geologically by northwest trending mountain ranges and intervening alluvial valleys. The river flows southward from its headwaters about 16 miles north of Ukiah through Redwood, Ukiah, Hopland, Alexander, and Healdsburg Valleys, and through the northwestern part of the Santa Rosa Plain, covering a distance of 90 miles. The river bends westward at Mirabel Park and flows for about 22 miles though a narrow canyon in the coastal range before entering the Pacific Ocean at Jenner. It drains an area of approximately 1,485 square miles including much of Sonoma and Mendocino Counties (SCWA 1999a). Major tributaries of the Russian River include the East Fork, Big Sulphur Creek, Maacama Creek, Dry Creek, and Mark West Creek. The Russian River has received substantial inflow from an inter-basin transfer of water from the Eel River through the PVP. This area of the Eel River drains a portion of northern Lake County.

The main stem Russian River joins the East Fork Russian River at a location commonly known as the Forks, in Mendocino County about 2 miles north of the city of Ukiah. Above the confluence with the East Fork, the Russian River is uncontrolled and drains an area of 100 square miles to the north and northwest of the Forks. The East Fork Russian River, controlled by Coyote Valley Dam and Lake Mendocino 0.8 miles above the Forks, drains an area of 105 square miles. A sequence of northwest/southeast trending fault-block ridges and alluvial valleys characterize the basin topography. Hills and mountains comprise 85 percent of the basin and alluvial valleys make up the remaining 15 percent. Unstable Franciscan lithology underlies most mountainous regions, and landslides are common.

In the Ukiah Valley, the Russian River flows in a relatively straight channel, lined with dense riparian vegetation. Gravel extraction occurs within the river channel and on the floodplain of the Ukiah Valley. Instream gravel mining and Lake Mendocino on the East Branch have caused up to 16 feet of channel bed degradation from the mid-1960's to the mid-1980's at the City of Ukiah (EIP 1993). Lake Mendocino annually traps an average of 21,000 tons (approximately 10 acre-feet) of gravel-sized sediment (EIP 1993). On Dry Creek, approximately 4,500 acre-feet of storage is reserved at Lake Sonoma for sedimentation which is based on an estimated rate of 90 acre-feet/year (USACE, 1986).

Downstream of the Ukiah Valley, the Russian River enters entrenched reaches through Hopland to Cloverdale and the Sonoma-Mendocino County line, before entering the 20-mile long alluvial Alexander Valley. In Alexander Valley, the river flows in a low gradient, wide, shallow, sinuous channel that is laterally migrating, causing bank erosion (EIP 1993). Gravel extraction occurs in-channel, and vineyard development has been taking place on the floodplain. Both degradation and aggradation have been measured at river cross-sections in the valley during the past two decades (EIP 1993).

The Russian River flows out of the Alexander Valley near the Jimtown Bridge and enters a sinuous canyon where the channel is confined and bounded by alluvial terraces. About 1 mile east of Healdsburg the river enters a 10-mile long alluvial valley (RM 33 to RM 23), known as the "Middle Reach." Dry Creek enters the Russian River about 1 mile downstream of Healdsburg, and the Wohler Bridge defines the lower boundary of the valley. In the Middle Reach, the Russian River is a generally straight channel flowing through a 2-mile wide floodplain. Land-use is dominated by vineyards and active or abandoned gravel extraction pits. In the portion of the Middle Reach between the Healdsburg Dam and the Wohler Bridge, the channel has the capacity to carry up to about the ten-year flood event. This capacity is due to a lowering of the channel bed by an average of 10 feet (EIP 1993), a result of intensive gravel mining since the 1940's and other land-use practices including grazing and agriculture since the early 1800's.

Below the Wohler Bridge, the Russian River flows westerly through a narrow valley bounded by mountains. The channel is straight and deep, with a low floodplain where the town of Guerneville is situated on the north side of the river. Guerneville is subject to frequent flooding, on average once every five years (EIP 1993). Gravel and sand bars are common along the channel. Below Guerneville, the Russian River flows into its coastal estuary near the confluence with Big Austin and Willow Creeks.

The upper reaches of Dry Creek are controlled by Warm Springs Dam and Lake Sonoma which drain about 130 square miles. Dry Creek, like the Middle Reach of the Russian River, has undergone considerable geomorphic changes, particularly after 1940 when intensive instream gravel extraction was occurring (EIP 1993). Gravel extraction continued in Dry Creek until about 1979. Severe erosion, degradation and channel widening occurred on Dry Creek during this period in response to channel incision of the Russian River mainstem up to 18 feet and from instream gravel extraction on Dry Creek.

The Russian River watershed is primarily an agricultural area with the greatest emphasis on vineyard and orchard crops. The major crops are prunes, pears and apples. Cherries and walnuts are also grown. There is considerable cattle and sheep grazing in the hilly areas surrounding the valleys. The watershed contains both dry and irrigated pasture, and both hay and grains are grown. Light industry and commercial development is a growing trend within and around the major urban centers of Ukiah and Santa Rosa. The primary industrial activities in the watershed include production and processing of timber products, wine products, and agricultural and animal products; gravel mining and processing; energy production; and miscellaneous light manufacturing operations (SCWA 1997).

2.2 HYDROLOGIC CONDITIONS

Lying within a region of Mediterranean climate, the watershed is divided into a fog-influenced coastal region and an interior region of hot, dry summers. The basin-wide mean annual precipitation is 41 inches, ranging from 22 to 80 inches (USACE 1982). The greatest precipitation occurs at high elevations near Mount St. Helena and in the coastal mountains near Cazadero, while the least amount falls in the southern Santa Rosa Plain (USACE 1982). Approximately 93 percent of the annual runoff occurs during the months of November to April (USACE 1986) in response to Pacific frontal storms. Runoff during the months of June to October is negligible. The pre-diversion runoff regime had episodic flows; high winter flows reflected the intensity and duration of storms, and low summer flows were sustained by groundwater. Importation of water from the Eel River and two large reservoirs changed that regime, reducing winter flow peaks, protracting high winter flows, and greatly increasing summer flows (Steiner 1996). The Russian River provides the water supply for approximately 500,000 people in Mendocino, Sonoma, and Marin Counties.

The USGS currently collects stage and discharge data at 17 gauges along the Russian River and various tributaries and stage data only at an additional five gauges. Historically, the USGS collected streamflow data at 16 gauges other than the 22 currently in operation. USGS has also collected sediment data at eight sites and water quality data at five sites. Table 2-1 shows the average annual discharge at selected locations. Streamflow on the East Fork Russian River near Ukiah represents approximately 50 percent of the average annual flow expected at Hopland, 25 percent of the average annual flow seen at Healdsburg, and 15 percent of the average annual flow seen at Guerneville. Average annual discharge on Dry Creek since construction of Warm Springs Dam (1983-1990) is about one-half of the unregulated (period 1939 to1983) average annual flow condition, due to the drought period following 1983.

Table 2-1 Average Annual Discharge

Site	Drainage Area (mi^2)	Period of Record	Avg. Ann. Discharge (cfs)
East Fk RR near Ukiah	105	1952-1982	355 [a]
RR near Hopland	362	1940-1982	722 [a]
RR near Healdsburg		1939-1990	1,418 [b]
RR near Guerneville	1,338	1939-1990	2,282 [b]
Dry Creek Near Geyserville		1939-1983	342 [b]
Dry Creek Near Geyserville		1983-1990	176 [b], [c]

(a) U.S. Army Corps of Engineers 1986
(b) EIP Associates 1993
(c) 1983-1990 is the period with operation of Warm Springs Dam on Dry Creek.

Most of the streamflow in the upper reaches of the Russian River during the summer months is provided by water that is available because of the PVP, which diverts water from the Eel River. Streamflows are also augmented by releases from Lake Mendocino and Lake Sonoma. The Russian River has highly variable flows. Flows during winter (December to March) are typically an order of magnitude greater than summer (June to September). About 80 percent of the annual discharge occurs during winter (Jones & Stokes Associates 1972), and the basin has been subject to many damaging floods.

Generally, the Russian River watershed responds rapidly to variations in rainfall, often resulting in flashy floods. The flood of record was 93,400 cfs at Guerneville, 71,300 cfs at Healdsburg, and 41,500 cfs at Hopland on December 23, 1964. Peak flood flow on Dry Creek prior to regulation by Warm Springs Dam was 32,400 cfs on January 31, 1963, and after regulation the peak flow was 5,280 cfs on February 17, 1986 (EIP 1993).

Coyote Valley Dam has only a slight effect on winter flood flows at Healdsburg due to the limited drainage area it controls, approximately 13 percent of the watershed (EIP 1993). A study by USACE in 1986 evaluated the effect that Coyote Valley Dam had on the flood of 1964. The results indicated that Coyote Valley Dam reduced by 29 percent the flood peak at Hopland, 14 miles downstream; reduced by 21 percent at Cloverdale, 30 miles downstream; reduced by 11 percent at Healdsburg, 58 miles downstream, and reduced by 7 percent at Guerneville, 74 miles downstream.

The 1.5-year flood at Hopland is approximately 14,500 cfs in the unregulated condition and 12,000 cfs in the regulated condition. At Healdsburg the 1.5-year recurrence interval flood is nearly identical in the regulated and unregulated conditions, about 25,000 cfs. At Guerneville, the 1.5-year recurrence interval under regulated conditions (as influenced by both Coyote Valley Dam and Warm Springs Dam) is approximately 30,000 cfs, and 37,000 cfs in the unregulated condition.

The 1.5-year recurrence interval flood is significant because the associated flows are considered to do the most work, over the long-term, in forming and maintaining channel morphologic characteristics (Leopold 1994). Typically, the bankfull discharge has an approximately constant recurrence interval of 1.5 years in the annual flood series. Flows greater than the 1.5-year flood event exceed the channel capacity and overflow the floodplain. Where the Russian River flows through broad alluvial valleys, overbank flow occurs in most years, whereas channel capacities are greater in the more confined canyon reaches and flooding occurs less frequently. According to USACE (1986), the channel capacities in Ukiah Valley, Hopland Valley, and Guerneville are 7,000 cfs, 8,000 cfs, and 35,000 cfs, respectively. Table 2-2 shows the channel capacity and 1.5-year (bankfull discharge) on the mainstem at various locations.

Table 2-2 Channel Capacity and 1.5 Year (Bankfull Discharge)

	Channel Capacity	1.5 Year Flow
Hopland	8,000 cfs	15,000 cfs
Healdsburg		25,000 cfs
Guerneville	35,000 cfs	30,000 cfs

In both the regulated and unregulated conditions, the 1.5-year flow at Hopland is greater than the 8,000 cfs channel capacity and would result in overbank flows. The 1.5-year regulated flow condition at Guerneville is approximately equivalent to the bankfull channel capacity. Thus, on average, every two out of three years, one flood can be expected that equals or exceeds the channel capacity in these reaches.

Warm Springs Dam has significantly reduced flood flows in Dry Creek to less than 25 percent of the pre-dam rates (EIP 1993). The floods of 1963 and 1986 on Dry Creek were of a comparable size, but flow regulation by Warm Springs Dam reduced the peak flood by approximately 83 percent (EIP 1993). The 1.5-year flood was about 11,000 cfs prior to construction of the dam, but has been reduced to about 2,500 cfs under regulated conditions. A 5-year recurrence interval flood on Dry Creek was over 24,000 cfs prior to regulation by Warm Springs Dam and is approximately 7,500 cfs today.

2.3 WATER QUALITY

Various water quality parameters are monitored by the USACE at Lake Mendocino and Lake Sonoma. These parameters include temperature, dissolved oxygen, and pH which are monitored in April and August at various reservoir depths, as well as at the reservoir inflow and outflow. Since flood control operations usually take place during the late fall, winter, and spring, water temperatures are relatively cool, and dissolved oxygen concentrations are high. Warm Springs Dam has a multiple level release that allows water to be withdrawn from different pool elevations. Coyote Valley Dam does not have a multi-level outlet capability, with releases made only through the low-level flood control outlet.

Table 2-3 shows water temperatures and oxygen concentrations for Lake Sonoma and Lake Mendocino in April of 1998 and 1999. Both reservoirs may develop moderate thermal stratification in the spring, with a more pronounced thermocline present in the summer. Temperature data from the mid-to-late 1960's indicate that there is no stratification present in Lake Mendocino during the winter months (Ritter and Brown, 1971) and is also unlikely to occur in Lake Sonoma. The data demonstrate that water temperatures and dissolved oxygen concentrations during flood control operations are unlikely to adversely affect listed species.

2.3.1 WATER TEMPERATURE AND DISSOLVED OXYGEN CONCENTRATIONS

Table 2-3 April Water Temperature and Dissolved Oxygen Concentrations [a]

	Temperature (F)	DO (mg/L)
Lake Mendocino		
1998 inflow	58.8	Not available
1998 outflow	52.9	10.0
1999 inflow	56.2	Not available
1999 outflow	50.3	8.7[b]
Lake Sonoma		
1998 inflow	64.5	Not available
1998 outflow	54	10.2
1999 inflow	57.3	Not available
1999 outflow	50.7	9.6[b]

[a] Data from US Army Corps of Engineers Sacramento District Annual Water Quality Reports for 1998 and 1999.

[b] DO values from in-reservoir sampling at approximately 105 ft. depth in Lake Mendocino and 177 ft. depth in Lake Sonoma.

During storm runoff events, suspended sediments naturally enter Lake Mendocino and Lake Sonoma. A portion of these sediments, particularly larger size fractions such as sands and gravels will deposit in the reservoir, although finer particle sizes will remain in suspension and are transported downstream. There is limited recent turbidity data available related to either reservoir. Turbidity is monitored twice a month from December through April since 1993 at the Coyote Valley Fish Facility and twice per month all year round at the Warm Springs Fish Hatchery since 1988.

The highest turbidity levels at the Coyote Valley Fish Facility was 74.5 NTU (February 15, 1993) with most values 5 NTU's or less. The highest turbidity levels at the Warm Springs Fish Hatchery was 200 NTU's (February 1, 1993), with most turbidity values 5 NTU's or less. Turbidity was measured by Ritter and Brown (1971) between 1964 to 1968 at several locations in the Russian River basin, including the East Fork Russian River above and below Lake Mendocino, the mainstem from Russian River near Ukiah to and on Dry Creek.

The Water Quality Control Plan for the North Coast Region sets a standard for turbidity as:

> *Turbidity shall not be increased more than 20 percent above natural occurring background levels. Allowable zones of dilution within which higher percentages can be tolerated may be defined for specific discharges upon the issuance of discharge permits or waiver thereof.*

2.3.2 Issues of Concern

In most streams, there are times when the water is naturally turbid, usually when storms produce runoff. Moderate levels of turbidity may give juveniles protection from predators. Turbidity levels of about 23 NTU apparently reduced the perceived risk of predation on juvenile chinook (Gregory 1993). Chinook salmon are known to occupy turbid rivers for a significant portion of their early life. High suspended solid concentrations cause physiological and behavioral stress responses (Newcombe and MacDonald 1991), but lower concentrations may reduce predation on juveniles. Low or moderate exposures of short duration can be tolerated by the fish. In general, however, salmonids survive better in clear water at all life stages, and high, long-term levels of turbidity can negatively affect them (Newcombe and Jensen 1996). Turbidity can also reduce primary productivity in aquatic systems (Lloyd *et al*. 1987).

Both reservoirs function by storing high flows and releasing them later at a more moderate rate. Turbid water may be released from the dams for several days as high flows are beginning to recede from the flood peak in the downstream channel.

Inflow to Lake Mendocino contains a much higher level of turbidity due to a higher percentage of fines imported from the Eel River through the PVP than inflow to Lake Sonoma (USACE, 1986). Since Lake Mendocino has a relatively short residence time compared with Lake Sonoma, much of the suspended sediments do not settle out. Therefore, flow releases from Coyote Valley Dam are more likely to influence downstream water quality. In the Russian River basin Dry Creek has the least persistently turbid water (Ritter and Brown, 1971). As tributaries downstream of the dams contribute suspended sediment and streamflow to the mainstem Russian

River and Dry Creek, the relative proportion of turbidity originating from flood control activities at each reservoir likely diminishes.

Since persistent turbidity is primarily associated with fine sediment particles (silts and clays) held in suspension, much of the sediment contained in high-flow releases will not settle out in the channel downstream, but will be transported as wash-load. Thus, it is unlikely that turbidity associated with flood control releases will adversely affect habitat conditions such as spawning gravels, riffles or pools. Persistent turbidity is most likely to effect behavioral activities such as abandonment of cover or short-term reduction in feeding rates. Feeding and territorial behavior of juvenile coho are disrupted by short-term exposures (2.5-4.5 days) to turbid water (up to 60 NTU) (Berg and Northcote 1985).

From the recent limited data available at the fish hatcheries, turbidities are often lower than 5 NTU's, Higher turbidities will occur, as expected during high flow events on both regulated and unregulated segments of the Russian River watershed. At a sampling station on the East Fork Russian River near Calpella above Lake Mendocino and on the East Fork Russian River near Ukiah below Lake Mendocino periods of persistent water turbidity (greater than 20 mg/L) were identified by Ritter and Brown (1971) (Table 2-4). The turbidity of the East Fork above Lake Mendocino was influenced by the turbidity of the water imported from the Eel River. Periods of persistent turbid water appear to be generally the same above and below Lake Mendocino (Table 2-4), although there are times when turbidity may last for a shorter or longer period at the end of the flood control season downstream of the reservoir.

Table 2-4 Periods of Persistent Turbidity (> 20mg/l), East Fork Russian River, 1965-1968[a]

	1965	1966	1967	1968
East Fork Russian River near Calpella	Dec. 20-July 16	Nov. 15-May 20	Nov. 15-May 19	Nov. 30-Apr. 15
East Fork Russian River near Ukiah	Dec. 21-May 19	Nov. 17-July 19	Nov. 18-June 7	Dec. 2-Apr. 19

[a] Source: Ritter and Brown (1971)

Ritter and Brown concluded that water in Lake Mendocino remains turbid about as long as the water entering the reservoir remains turbid. Water released from Lake Mendocino will remain turbid until the water flowing into the lake becomes clear. The persistence of the turbid water during the winter and spring runoff was attributed to the diversion of turbid water from the Eel River which does not permit the East Fork to become clear between rainstorms. Ritter and Brown further state that if Lake Mendocino did not exist, the turbid water that enters the lake would have flowed down the East Fork unobstructed and then down the Russian River. The turbidity of the water of the Russian River would be increased between storm events and the water probably would have been turbid as long as the East Fork water remained turbid. Lake Mendocino interrupts the turbid flows on the East Fork, and when releases from the lake are low for several days during periods between flood flow releases, the water of the Russian River becomes clear (Ritter and Brown, 1971). This is a condition that probably would not have occurred if the dam were not constructed. Therefore, flood control operations do not increase the amount or persistence of turbidity, and does not adversely affect listed species.

2.4 CHANNEL GEOMORPHOLOGY

Flood control operations may affect channel geomorphology, including streambed and streambank stability and maintenance of channel equilibrium conditions (i.e., channel is neither aggrading or degrading over the long-term). Alterations in channel morphology can have an adverse influence on fish habitat conditions. Bank erosion can increase sediment input that impairs spawning gravels by reducing the flow of oxygenated water and removal of metabolic wastes from redds. Alevins may also become entombed by fine sediment intrusion into spawning gravels. Pool habitat can also be diminished by sedimentation. Streambank instability can also reduce riparian vegetation, which results in a loss of cover habitat, increases in thermal loading by removing shade, and a reduction in the food supply by reducing the amount of terrestrial input. High magnitude flood releases can scour spawning gravels, resulting in direct mortality of incubating embryos. Insufficient flows of moderate magnitude can alter the long-term balance of sediment supply and sediment transport, resulting in conditions of dis-equilibrium and channel aggradation.

2.4.1 ISSUES OF CONCERN

2.4.1.1 Scour of Spawning Gravels

Flood control releases from Warm Springs and Coyote Valley Dams have reduced the magnitude of flood peaks in the Russian River drainage. This reduction in flood peaks is generally accomplished by storing and later releasing the stored flood waters over a longer period of duration than would have naturally occurred. However, flood releases may still be of sufficient magnitude and duration to adversely affect spawning habitat by scouring gravels to a depth which destroys the egg pocket.

2.4.1.2 Streambank Erosion

Sustained releases of flood flows have been cited as a potential cause of streambank instability on both Dry Creek and the mainstem Russian River. Prolonged discharges in excess of 2,500 cfs are believed to be responsible for accelerated bank erosion on Dry Creek (USACE draft Biological Assessment 1999). Sustained release of flood flows from Coyote Valley Dam are also cited as a contributor to streambank erosion on the mainstem Russian River (USACE draft Biological Assessment 1999). However, on the mainstem Russian River there is no information which identifies a flow threshold at which bank erosion begins to occur. A flow threshold at which bank erosion was assumed to occur was developed for this BA, and is described in the evaluation criteria (Section 2.4.2.2). There are also no reports that specify which mainstem stream reaches are subject to erosion, except that “high sustained releases erode the river bank for miles downstream” (USACE 1998).

2.4.1.3 Channel Maintenance/Geomorphology

The change in hydrologic regime associated with flow regulation by dams will influence channel geomorphic response. The type and magnitude of adjustments depends on initial channel conditions and the extent of changes in discharge and sediment supply. The impact of dams on the morphology of a river tends to diminish downstream due to discharge and sediment contributions from tributaries. Although the rate of channel change in response to flow regulation by dams is highly variable, most channel adjustments likely take place within a few decades following dam construction (Mount 1995).

Flow regulation by dam closure has reduced the magnitude of peak flood discharges at both Lake Sonoma and Lake Mendocino. In response, river channels typically modify their cross-sections by channel narrowing due to sediment deposition and encroachment by riparian vegetation. When the bed material is a sand and gravel mixture as on Dry Creek and the mainstem Russian River, channel incision will often accompany channel narrowing if the flood peaks are of sufficient magnitude to mobilize most of the bed materials. Excessive channel incision often results in over-steepened streambanks and subsequent erosion. If flood peaks are sufficiently reduced under flow regulation, then the coarser bed material will not be entrained, and only finer material will be transported, leading to an overall coarsening of the channel bed. At this point the river channel is armored, preventing further channel bed adjustments, although the streambank may remain susceptible to erosion. However, if flood peaks are substantially reduced so that there is little or no transport of coarse sediments, the channel response is likely to be aggradation. Coarse sediment supplied by local tributary input will exceed competence and lead to channel aggradation.

If flow regulation sufficiently reduces peak flood events so that the sediment transport regime is altered and coarsening of the channel bed or aggradation results, then fish habitat conditions may be adversely affected. Spawning gravels may be subject to accelerated rates of fine sediment intrusion, decreasing reproductive success. Increased sediment deposition in riffles may reduce benthic macroinvertebrate production, decreasing the available food base. Rearing habitat may also be affected due to sediment deposition in pools.

Channel geomorphic changes may also occur due to interruption of the sediment transport regime by dams and reservoirs. If coarse sediments are deposited within a reservoir removing a significant portion of the total sediment load, replenishment of sediments downstream will be reduced until there are sufficient sources of sediment input from downstream tributaries. This can lead to excess stream power immediately downstream of a dam since relatively clear water with little sediment in transport can perform more work scouring sediments from the streambed, banks, and floodplain. Thus, entrainment of fine sediments below the reservoir may continue. Without sediment replenishment and with excess stream power, only the coarsest material may be left behind, leading to armoring of the channel bed.

It is recognized that adequate flows are periodically needed to maintain channel geomorphic conditions by mobilizing the streambed and transporting sediments. Such flows are necessary to provide suitable spawning and rearing conditions for salmonids, flushing fine sediments from the streambed. This has been the case on the Trinity River where since dam closure export of water and increase in sediment yields from the watershed have buried spawning habitat (Mount, 1995). However, if flood releases are of sufficient magnitude and frequency to regularly scour redds, spawning may be adversely affected. This has occurred, for example, on the Sacramento River where release of high peak discharges from Shasta Dam has led to widespread channel scouring and incision leaving little spawning habitat and armored channels (Mount, 1995). Ideally, there is a balance, or dynamic equilibrium, between periodic mobilization of the streambed, transport of sediment, and sediment deposition and stability of spawning gravels. Lack of peak flows can reduce spawning success, as can an increase in the frequency and magnitude of peak flows also reduce spawning success.

The alteration of the flow regime associated with dams is not the only cause of changes in channel morphology. Land-uses and development in the Russian River watershed, including gravel extraction, agricultural practices, and urbanization, also influence channel geomorphic conditions. Clearing riparian vegetation, building roads, grazing, and other development activities can alter the flood hydrograph, increase bank erosion, increase sediment input from upland areas, and otherwise adversely influence channel geomorphic and aquatic habitat conditions. Land-uses that significantly increase or decrease (as in the case of gravel mining) sediment supply will cause as pronounced alterations in channel geomorphology as flood regulation by dams. Distinguishing the effects of flood-control operations separate from these land-use effects on channel conditions can be problematic.

Significant channel geomorphic changes were apparently already underway on Dry Creek prior to the construction of Warm Springs Dam. A study conducted by USACE concluded that gravel mining on Dry Creek and on the mainstem Russian River had caused about 10 feet of incision along the 14-mile channel length by the mid-1970's (USACE 1987). The channel incision on Dry Creek initiated lateral instability and subsequent bank erosion so that channel width had increased from about 90 feet to over 450 feet in some locations in the 1970's (USACE 1987). The 1987 study concluded that it was unlikely that further channel degradation would occur, but that continued lateral instability and erosion of the incised channel banks was likely.

On the mainstem Russian River between Healdsburg and Ukiah, gravel mining has also recently altered channel geomorphic conditions. The East Fork Russian River had experienced up to 16 feet of channel bed degradation by the mid-1980's and in the Alexander Valley (near Cloverdale), approximately 2 feet of bed degradation had occurred by 1990 (EIP 1993).

2.4.2 Evaluation Criteria

Evaluation criteria and analytical methods are described in detail for each of the channel geomorphic issues. All of the analyses consider how flood control operations affect those geomorphic issues identified in section 2.3.1. An important component of these analyses is related to expected streamflow conditions under present-day flood control operations at Warms Springs and Coyote Dams. Streamflow has an important influence on channel geomorphic conditions and therefore on fish habitat.

Representative streamflow conditions were determined by using models rather than using actual, historic streamflow data. The models provide a tool for simulating operational characteristics of the reservoirs and resulting streamflow conditions. As such, the hydrologic model emulates but does not necessarily match historic streamflow conditions exactly. The hydrologic model also has the advantage of being flexible. Operational conditions at each dam can be modified in the models so that streamflow conditions may be adjusted and the resulting potential change on geomorphic conditions and fish habitat tested. This is extremely useful when considering potential alternatives to flood control operations.

For this report, two streamflow models were combined and used in the analyses. The SCWA model provides average daily flow at various locations along the mainstem Russian River between Coyote Dam and Guerneville, and on Dry Creek downstream of Warm Springs Dam. The SCWA model was developed in the late 1980's to quantify relationships between streamflow, water demand, instream flow requirements, and water supply needs. The USACE HEC-5 model was developed specifically for this BA. This model also provides average daily flow at various locations along the mainstem Russian River between Coyote Dam and Guerneville, and on Dry Creek downstream of Warm Springs Dam.

The results of the two models were combined so that flow conditions between June through October are derived from the SCWA model, and flow conditions between November through May are derived from the USACE model. The combined model results most accurately emulate historic flow conditions, since it was determined that the SCWA model did a better job of estimating low flow conditions, and the USACE model did a better job of estimating relatively high flow conditions. The 36-year period of record covered by the combined model and used in all of the analyses are water years 1960 through 1995. For the remainder of this report, the combined flow model results are simply referred to as the hydrologic model.

2.4.2.1 Scour of Spawning Gravels Evaluation Criteria

Evaluation criteria for flood control effects on scour of spawning gravels was determined by estimating the hydraulic conditions necessary for the initiation of bed-particle motion. Incipient motion was derived from a modification of Shields' relationship for critical shear stress in non-uniform bed materials. Andrews (1983) determined that the average critical dimensionless shear stress for the median particle in the riverbed surface, $\tau *_{ci50}$, was 0.033. Andrews further found that in all rivers, the critical value of $\tau *_{ci50}$ was equaled or exceeded at the bankfull discharge. The mean bankfull dimensionless shear stress relative to the median particle diameter in the bed surface is 0.047. Thus, for an unarmored streambed, particles at least as large as the median diameter of the bed surface will be entrained by a bankfull discharge. Many hydraulic engineers and geomorphologists use 0.047 for critical dimensionless shear stress (Shields' parameter) in gravel bed streams (Simons, Li & Assoc. 1982), and this is the Shields value used in this assessment.

Using a Shields parameter of 0.047 for the mobilization of spawning sized gravels on the bed surface, the Shields relationship for critical shear stress ($\tau *_{ci}$) is defined as:

$$\tau *_{ci} = 0.047 (\gamma_s - \gamma)d_{50}$$

Where:

γ, γ_s = specific weight of the fluid and sediment, respectively
d_{50} = median particle diameter

Thus, critical shear (the threshold at which incipient motion occurs) can be calculated for a particle size distribution with a known median diameter (d_{50}). There are no data available for the size of spawning gravels used by salmon and trout on either Dry Creek or the mainstem Russian

River. For this analysis, the d_{50} (median particle diameter) of spawning sized gravels was assumed to be as follows:

Steelhead	22 mm
Coho	16 mm
Chinook	36 mm

These d_{50} are based on a compilation of spawning gravel particle sizes reported from numerous studies on streams throughout the western states (Kondolf 1993). The range of d_{50} represented by the 25^{th}, 50^{th}, and 75^{th} percentile values from these studies are shown in Table 2-3. The percentile values refer to the frequency distribution of d_{50} spawning gravel particle sizes associated with each species in the compiled studies. Thus, a 75^{th} percentile value indicates that only 25% of the d_{50} particle size values exceed the value listed in Table 2-5. The 50^{th} percentile is synonymous with the median, indicating that one-half of the d_{50} particle sizes were greater than, and one-half less than the listed values.

Table 2-5 D_{50} Spawning Gravel Sizes Compiled by Kondolf (1993)

	25^{th} Percentile	50^{th} Percentile	75^{th} Percentile
Steelhead	18	22	32
Coho	12	16	30
Chinook	22	36	48

The critical shear stress calculated using a Shields parameter of 0.047 for the d_{50} of spawning gravels in steelhead, coho, and chinook salmon redds are shown in Table 2-6.

Table 2-6 Critical Shear Stress for Steelhead, Coho, and Chinook Spawning Gravels

	D_{50} (mm)	Shields Parameter	Critical Shear (lbs/ft^2)
Steelhead	22	.047	.349
Coho	16	.047	.254
Chinook	36	.047	.572

The critical shear stress was compared with values of actual shear stress for a range of flood-flow discharges on Dry Creek and the mainstem Russian River between Healdsburg and Ukiah in two distinct stream reaches: Alexander Valley and upstream of Alexander Valley to Ukiah. Average shear stress values were determined for individual cross-sections using HEC-RAS hydraulic modeling. On Dry Creek, average bed shear stress values were calculated for 112 cross-sections. These cross-sections were surveyed by SCWA. On the mainstem Russian River, 56 cross-sections located downstream of Coyote Valley Dam were used to determine shear stress values. Of the 56 cross-sections, 30 were surveyed in the Alexander Valley for the SCWA Aggregate Resources Mining Plan in 1998 (Doris Anderson, SCWA, pers. comm.), and 26 were surveyed upstream of Alexander Valley to Ukiah in 1978 by Winzler and Kelly for USACE (1978). Since the impact of flood control operations from Coyote Valley Dam is insignificant below Healdsburg, and spawning is not considered to be significant on the lower mainstem reach (Winzler and Kelly 1978; Steiner 1996), no analysis was performed below Alexander Valley.

Actual shear stress values (calculated using HEC-RAS) that exceed the critical shear threshold identified in Table 2-6 can be expected to initiate motion in redd gravels. Initiation of motion occurs when critical shear stress is exceeded by actual channel-bottom shear stress, although the transport rate and distance of transport of the streambed material may be quite small when the critical shear stress is only slightly exceeded.

In order to confirm that initiation of motion associated with a given discharge is likely to be sufficient to scour redd gravels to the depth of a typical egg pocket, a second, supporting analysis was performed to estimate depth of scour. The amount of scour in a riverbed depends on the ability of the bed to reform the surface layer after it has been ruptured. To make such a determination, the size of the streambed sediments must be known from field studies. The streambed particle size that will not move with a given discharge is determined. This is accomplished by comparing the critical shear stress needed to move a given particle size, (determined by the Shield's relationship), with the actual particle shear stress for that discharge. The actual particle shear stress can be derived from the velocity associated with the given flow. By observing the percentage of bed material less than the size of the maximum sediment which will not move, the depth of scour necessary to leave an armor layer can be calculated by the equation (Simons, Li & Associates 1987):

$$\Delta Z = 2\ d_a/1\text{-}P_c$$

where:

ΔZ is the depth of scour
d_a is the size of the armoring material
P_c is the percent of material finer than the maximum moveable size

The greater the percent of streambed material finer than the maximum moveable size, the greater the depth of scour. Conversely, the smaller the percent of streambed material finer than the maximum moveable particle size, the smaller the depth of scour.

The maximum moveable size of streambed material (d_a) was determined from a defined relationship between flow velocity and sediment size (EIP 1993, based Simons & Associates 1987). The average flow velocity at the discharge which initiates motion was determined from HEC-RAS model output for each cross-section. The average flow velocity is entered on the curve to determine the maximum moveable size of streambed material.

There are no available particle size distribution curves from actually spawned gravels on either Dry Creek or the mainstem Russian River. For Dry Creek the size distributions used to determine the percentage of bed material finer than the maximum moveable sediment size (P_c) is based on particle size distribution data obtained from bed material grab samples (USACE 1987). Thirteen particle size distribution curves, each representing a different location along the Dry Creek channel profile were developed from USACE 1987 data and from twelve particle size distribution curves developed from USACE 1999 data. For the mainstem Russian River, Alexander Valley to Ukiah, five particle size distribution curves developed from recent 1999 bulk sampling in riffles performed by SCWA were used.

The streambed degradation analysis provides an estimate of depth to which scour will occur, confirming if redds are likely to be disturbed to the depth of the egg pocket. The average egg pocket depth for steelhead, coho, and chinook salmon is 20 to 30 cm (7.9 to 11.8 inches) (Bjornn and Reiser 1991). For this analysis, depth to the egg pocket was assumed to be 8 inches (0.7 feet) (B. Cox, CDFG, pers. comm.).

The analysis for influence of flood operations on scour of spawning gravels is based on the following procedure:

(1) Shear stress values determined in the HEC-RAS model are compared with the critical shear thresholds defined in Table 2-6 and used to determine the discharge at which initiation of motion will occur. The number of cross-sections expected to have initiation of motion for specified flow ranges are identified in Tables 2-7 to 2-13. The number of cross-sections at which spawning sized gravels will likely not experience initiation of motion given the existing hydrologic regime is also identified in each table. On Dry Creek there are three tables, one for each species. On the mainstem Russian River only steelhead and chinook gravels are evaluated, since coho do not spawn on the mainstem.

    Initiation of motion associated with the range of discharges is plotted as cumulative curves for each species using Tables 2-7 to 2-13. The initiation of motion curves show the cumulative number of cross-sections at which shear stress exceeds critical shear.

(2) The number of flood events that occur in the designated flow categories (Tables 2-7 to 2-13) are tallied for the period of record, water years 1960 to 1995, derived from flow modeling. The flow modeling represents the range of streamflow conditions expected under present-day flood control operations of Warm Spring Dam and Coyote Dam. The flow modeling is not an evaluation of actual historic conditions, but rather a tool which characterizes the magnitude and frequency of representative runoff conditions over time.

(3) An ordinal ranking score is applied to all flood events for each of the defined flow categories based on the different time periods when the flows occur and based on each of the three fish species of concern. The ordinal ranking score, 1-5, assigns a 1 to the highest potential effect and a 5 to the lowest potential effect. High potential for effects (i.e. low ordinal ranking) was assigned to higher flows and flows which occur during the latter part of the spawning and incubation season which have the greatest potential to scour the most redds and incubating alevins. The criteria for scoring are defined for each of the stream reaches and for each species as shown in Tables 2-14 to 2-20.

(4) Depth of scour is calculated to determine if the 0.7-foot criteria is exceeded for the discharge range associated with initiation of motion.

Dry Creek

Table 2-7 Steelhead Spawning Gravels: Number of Cross-Sections with Initiation of Motion

Flow Range	Number of cross-sections with initiation of motion in given flow range	Cumulative % moved
<1,300 cfs	25	22
>1,300-2,600 cfs	27	46
>2,600-5,500 cfs	32	75
>5,500 cfs	24	96

Never moved: 4 cross-sections = 4% of total 112

Table 2-8 Chinook Spawning Gravels: Number of Cross-Sections with Initiation of Motion

Flow Range	Number of cross-sections with initiation of motion in given flow range	Cumulative % moved
<3,000 cfs	21	19
>3,000-6,000 cfs	25	41
>6,000-9,000 cfs	20	61
>9,000 cfs	18	79

Never moved: 24 cross-sections = 21% of total 112
Note: discharge greater than 8,000 cfs has not occurred on Dry Creek

Table 2-9 Coho Spawning Gravels: Number of Cross-Sections with Initiation of Motion

Flow Range	Number of cross-sections with initiation of motion in given flow range	Cumulative % moved
<800 cfs	28	25
>800-1,400 cfs	27	49
>1,400-3,000 cfs	29	75
>3,000 cfs	26	98

Never moved: 2 = 2% of cross-sections

Mainstem Russian River in Alexander Valley

Table 2-10 Steelhead Spawning Gravels: Number of Cross-Sections with Initiation of Motion

Flow Range	Number of cross-sections with initiation of motion in given flow range	Cumulative % moved
<2,000 cfs	7	23
>2,000-5,000 cfs	8	50
>5,000-12,000 cfs	7	73
>12,000-24,000 cfs	7	97

Never moved: 1 cross-section = 2% of total 30

Table 2-11 Chinook Spawning Gravels: Number of Cross-Sections with Initiation of Motion

Flow Range	Number of cross-sections with initiation of motion in given flow range	Cumulative % moved
<5,000 cfs	6	20
>5,000-18,000 cfs	9	50
>18,000-27,000 cfs	7	75

Never moved: 8 cross-sections = 25% of total 30

Mainstem Russian River Upstream of Alexander Valley to Ukiah

Table 2-12 Steelhead Spawning Gravels: Number of Cross-Sections with Initiation of Motion

Flow Range	Number of cross-sections with initiation of motion in given flow range	Cumulative % moved
<500 cfs	10	38
>500 cfs	7	65

Never moved: 9 cross-sections = 35% of total 26

Table 2-13 Chinook Spawning Gravels: Number of Cross-Sections with Initiation of Motion

Flow Range	Number of cross-sections with initiation of motion in given flow range	Cumulative % moved
<1,000 cfs	5	19
>1,000 cfs	4	38

Never moved: 16 cross-sections = 62% of total 26

Scoring

The scoring system shown in Tables 2-14 to 2-18 is based on the number of cross-sections that will initiate bed movement within each of the stream reaches evaluated. As flows increase and more cross-sections experience bed movement, scores are lower. Whenever possible, at approximately every 20%-25% incremental change in the number of cross-sections moved, the corresponding ordinal ranking scores are lowered by 1. Thus, the first 20% of the cross-sections moved in the given flow range is given a 5, the next 20% (i.e., cumulative of 40% moved) receives a 4, and so on. Scores do not go to 0 at any of the locations because there were always some cross-sections at which shear values never attain the critical shear threshold, so there is no initiation of motion. This occurred at several of the most upstream cross-sections on the mainstem Russian River where large streamflows overbank and fill the floodplain before critical shear is attained.[1] This also occurs at some of the wider cross-sections that do not obtain sufficient depth of flow to generate the shear stress necessary to initiate motion of spawning

[1] This is one important function of floodplains. By allowing overbank flows, there is "hydraulic release," limiting the magnitude of bed shear stress.

sized gravels. Ordinal ranking scores do not reach the lower values when a relatively large percentage of the cross-section's shear values do not exceed critical shear threshold over the flow range (e.g., see Tables 2-19 and 2-20).

The first time period in each of the tables below is the estimated period before spawning is over, and the second estimated time period is during incubation after spawning is over. Scores are lower during the incubation time period to reflect the fact that flows which disrupt spawning gravels with incubating eggs will likely have a greater adverse effect on reproductive success for that year's class. Each of the daily flows from the hydrologic modeling record was scored for the relevant spawning and incubation time periods. The final score given for each water year is the highest impact event that occurs during the year.

Dry Creek

Table 2-14 Coho Scoring Criteria

Flow Range	**Coho** *Dec.1-Jan.31* (before spawning is over)	**Coho** *Feb.1-Feb.28* (incubation)
<800 cfs	5	5
>800-1,400 cfs	4	3
>1,400-3,000 cfs	3	2
>3,000-8,700 cfs	2	1

Table 2-15 Chinook Scoring Criteria

Flow Range	**Chinook** *Nov.1-Jan.31* (before spawning is over)	**Chinook** *Feb.1-Mar.31* (incubation)
<3,000 cfs	5	5
>3,000-6,000 cfs	4	3
>6,000-9,000 cfs	3	2
>9,000-15,000 cfs	2	1

Table 2-16 Steelhead Scoring Criteria

Flow Range	**Steelhead** *Dec.1-April30* (before spawning is over)	**Steelhead** *May1-May31* (incubation)
<1,300 cfs	5	5
>1,300-2,600 cfs	4	3
>2,600-5,500 cfs	3	2
>5,500-12,000 cfs	2	1

Mainstem Russian River in Alexander Valley

Since coho do not utilize the mainstem Russian River for spawning, only scour of chinook salmon and steelhead spawning gravels were evaluated.

Table 2-17 Chinook Scoring Criteria

Flow Range	**Chinook** *Nov.1-Jan.31* (before spawning is over)	**Chinook** *Feb.1-Mar.31* (incubation)
<5,000 cfs	5	5
>5,000-18,000 cfs	4	3
>18,000-27,000 cfs	3	2

Table 2-18 Steelhead Scoring Criteria

Flow Range	**Steelhead** *Dec.1-April30* (before spawning is over)	**Steelhead** *May1-May31* (incubation)
<2,000 cfs	5	5
>2,000-5,000 cfs	4	3
>5,000-12,000 cfs	3	2
>12,000-24,000 cfs	2	1

Mainstem Russian River Upstream of Alexander Valley to Ukiah

Table 2-19 Chinook Scoring Criteria

Flow Range	**Chinook** *Nov.1-Jan.30* (before spawning is over)	**Chinook** *Feb.1-Mar.30* (incubation)
<1,000 cfs	5	5
>1,000 cfs	4	3

Table 2-20 Steelhead Scoring Criteria

Flow Range	**Steelhead** *Dec.1-April30* (before spawning is over)	**Steelhead** *May1-May30* (incubation)
<500 cfs	5	5
>500 cfs	4	3

Since the impact of flood control operations from Coyote Valley Dam is insignificant below Healdsburg, and spawning is not considered to be significant on the lower mainstem reach (Winzler and Kelly 1978; Steiner 1996), no analysis was performed below Alexander Valley.

2.4.2.2 Bank Erosion Evaluation Criteria

On Dry Creek, criteria for evaluation of streambank stability impacts are based on an analysis of the frequency of flood flows greater than 2,500 cfs. Prolonged discharges in excess of 2,500 cfs are responsible for accelerating bank erosion on Dry Creek (USACE draft Biological Assessment 1999). Daily average flow from the hydrologic model was used for the assessment. For each year in the period of record (1960-1995), flows greater than 2,500 cfs were tallied. Scoring is based on the percentage of time in each water year that exceeds 2,500 cfs, as shown in Table 2-21. The greater the number of days in any given year with flows exceeding 2,500 cfs, the lower the score. For years with flows greater than 2,500 cfs occurring less than 1% of the time (i.e., three days or less per year), a score of 5 is applied. For years with 2,500 cfs or greater magnitude flows occurring more than 4% of the time in any given year (16 or more days), a score of 1 is applied.

Table 2-21 Scoring Criteria for Dry Creek Streambank Stability

Percent of time flows greater than 2,500 cfs	Number of days per year	Score
<1%	3 or less	5
1%-2%	4-7	4
>2%-3%	8-11	3
>3%-4%	12-15	2
>4%	16 or more	1

No flow threshold has been specified at which bank erosion occurs on the mainstem Russian River. Therefore, the same unregulated recurrence interval flood that initiates bank erosion on Dry Creek was selected as the flow at which bank erosion is initiated on the mainstem below Coyote Valley Dam. On Dry Creek, the flow which initiates bank erosion, 2,500 cfs, corresponds to an 88% exceedance flow (as a one-day annual maximum) or a 1.1-year, one-day recurrence interval flood under unregulated conditions. This is slightly greater than the annual flood, which over the long-term will be equaled or exceeded about once every year. The 1.1-year, one-day flood under unregulated conditions is 6,000 cfs at Hopland and 8,000 cfs at Cloverdale.

The analytical approach for flood operation effects on mainstem Russian River bank erosion is the same as for Dry Creek, using 6,000 cfs at Hopland and 8,000 cfs at Cloverdale. Scoring criteria for both locations are shown in Table 2-22. Streambank erosion was not considered further downstream since the ability to control flood flows becomes greatly diminished at Healdsburg.

Table 2-22 Scoring Criteria for Mainstem Russian River Streambank Stability

Percent of time flows >6,000 cfs at Hopland and >8,000 cfs at Cloverdale	Number of days per year	Score
<1%	3 or less	5
1%-2%	4-7	4
>2%-3%	8-11	3
>3%-4%	12-15	2
>4%	16 or more	1

Flow changes above 1,000 cfs/hr are generally limited to a rate of 1,000 cfs/hr (interim ramping guidelines) to protect against bank sloughing and are not related to fish stranding issues. There may be a relationship between the rate at which flows are ramped down and the potential for saturated stream banks with high pore pressures to slough. However, there are no data available on either Dry Creek or the mainstem Russian River to relate high flow recession rates to incidences of bank erosion.

2.4.2.3 Channel Maintenance/Geomorphology Evaluation Criteria

There is no single, well-established methodology for the determination of how regulated flood flows may change channel geomorphology or affect fish habitat. An equilibrium channel morphology (stream channel is neither aggrading or degrading over the long term) is maintained by flows that mobilize the streambed surface, transporting bedload at a rate which is about equal to sediment supply. Maintaining the frequency of incipient motion of the channel bed is often used as a minimum criteria for maintenance of channel morphological conditions. It is characteristic for alluvial channels to have incipient mobilization of the channel bed at discharges that are approximately 80 percent of the 1.5 to 2.0 year annual maximum flood stage height (bankfull stage) (Andrews 1983). Typically, the 1.5 to 2.0 year annual maximum flood is considered to be the flow which, over the long-term, will do the most work in transporting sediments and is therefore defined as the effective or “channel-forming” discharge (Leopold 1994).

Maintenance of geomorphic conditions is based on the channel-forming 1.5-year annual maximum flood flow, shown in Table 2-23. The 1.5-year flow can be expected to occur approximately twice out of every three years, or 66% of the time. Thus for the 36 year period of record available from the hydrologic model, there should be approximately 24 flood flows that occur as annual peaks which equal or exceed the 1.5 year flood.

Scoring criteria consider how often the flow regime equals or exceeds the natural channel forming discharge (1.5-year annual maximum flood flow). If the current flow regime achieves or exceeds the natural 1.5 year annual maximum flood magnitude in approximately two-thirds of the years over the simulated period of record (about 24 years out of 36 years), then channel maintenance is maximized, and the score is 5. If the current flow regime does not meet or exceed the natural channel forming flow as frequently, then channel maintenance is not maximized, and lower corresponding scores are given.

The hydrologic modeling provides a simulated representation of average daily flow for the period of record. The 1.5-year channel forming flow is calculated based on the annual instantaneous peak discharge, which will always be greater than the average daily flow. Therefore, in order to perform this assessment, it was necessary to estimate the average daily flow which corresponds to the 1.5-year instantaneous peak discharge. The corresponding average one-day discharge was previously calculated by USACE (1998), and is shown in Table 2-23. The one-day, 1.5 year annual flood flow is used as the criteria for this analysis. The assumption is that the one-day flood flow includes the instantaneous peak flow that corresponds to the channel forming discharge. It is recognized that this assumption may not be strictly true close to the dams, since flood flow releases are controlled and relatively evenly distributed throughout the day (Paul Pugner, USACE, pers. comm.). However, with distance downstream from the release point, the contributing drainage area will make up an increasingly larger proportion of the streamflow, resulting in higher instantaneous peaks contained within the average daily discharge.

Table 2-23 Channel Maintenance Flow Associated with the 1.5-Year Peak Discharge and 1.5-Year One-Day Discharge

	1.5-Year Peak Discharge	1.5-Year One-Day Discharge
Dry Creek below Warm Springs Dam	9,500	5,000
Dry Creek near Geyserville	11,000	7,000
Russian River at Hopland	14,500	9,500
Russian River at Cloverdale	18,000	14,000
Russian River at Healdsburg	25,000	21,000

Note: 1.5 Year unregulated flow for peak and one-day discharge from USACE flood frequency curves.

Scoring criteria are shown in Table 2-24. A single score is given for the entire period of record (water years 1960 to 1995), since any single year alone does not encompass a sufficiently long time period to assess if flood control operations are adequate to maintain channel geomorphic conditions. By definition, the channel-forming flow should occur about twice out of every three years, as a long-term average. When the channel forming flow occurs less frequently, lower scores are applied. If the maximum annual discharge never meets or exceeds the threshold for the natural channel forming flow, the score is 0. Channel forming flows that occur more frequently received correspondingly higher scores (see Table 2-24). The scoring applies equally to steelhead, coho, and chinook salmon.

Table 2-24 Scoring Criteria for Maintenance of Channel Geomorphic Conditions

Annual Flood Exceedance Frequency	Number of Years per 36-Year Period of Record[a]	Score
51%-66%	19-24	5
36%-50%	14-18	4
21%-35%	8-13	3
11%-20%	5-7	2
1%-10%	4 or less	1
0%	0	0

[a] Multiple channel forming flows that may occur in a single year are counted as one occurrence for that year.

2.5 FISH STRANDING: RAMPING RATES

2.5.1 ISSUES OF CONCERN

To protect spawning gravel and juvenile salmonids within the Russian River and Dry Creek during flood control operations, USACE, in consultation with NMFS and CDFG, has developed interim guidelines for flow release changes, summarized as follows:

Reservoir OutFlow	Ramping Rate
0-250 cfs	125 cfs/hour
250-1,000 cfs	250 cfs/hour
>1,000 cfs	1,000 cfs/hour

The maximum ramping rates at release levels below 1,000 cfs differ from authorized rates, however, every effort is made to comply with the interim rates (USACE, 1998a,b). These ramping rates are intended for flood control activities only. Flow changes above 1,000-cfs release are generally limited to a rate of 1,000 cfs/hr to protect against bank sloughing and are not related to fish stranding issues. Lower ramping rates at lower reservoir flow releases are to protect against fish stranding. The ramping rate guidelines are followed for flood operations that ramp flows down as well as releases that ramp flows up (Bond, USACE, pers. comm.).

In addition to ramping during flood control operations, change in flow releases from Warm Springs and Coyote Valley Dams are scheduled annually for dam maintenance and inspection activities. In order to perform the annual and periodic dam inspection and maintenance work, ramping down flow releases is necessary for conduit inspections. Ramping rates during dam inspection and maintenance have in recent years been determined by consultation between USACE and NMFS prior to each year's annual inspection. Ramping rates related to dam maintenance and pre-flood inspection activities are separately discussed and evaluated in Section 2.6.

In addition to regular pre-flood inspection and maintenance activities, both dams have historically required infrequent but important testing of the outlet works to verify safe operation of the projects. Testing may include investigations to determine damages, identify the cause of damages, verify the reliability of outlet works and changes in Standard Operating Procedures to insure the continued operational integrity of the project. The flow releases necessary for testing are not the same as those required for pre-flood inspection and maintenance activities. Testing flow releases are variable, and the need to conduct testing may arise at anytime throughout the year. An example of dam safety testing was the vibration analysis conducted in January, February and March 1998 at Warm Springs Dam, where outflow varied between 50 cfs and 3,000 cfs. This testing was performed to investigate the reliability of the outlet works and to insure the continued safe operation of the dam.

Recent research in Washington indicates that natural flow recessions associated with the annual snowmelt hydrograph occur at a very slow rate and tends to reduce the likelihood of stranding of small salmonids (Hunter 1992). If discharge is decreased too rapidly by flow regulation, then juvenile, or even adult salmon, can be stranded and killed.

Juveniles, and particularly fry, are more susceptible to stranding than adults. Once chinook salmon grow to 50-60 mm or steelhead grow to 40 mm, they are substantially less vulnerable, but adult stranding has also been documented (Hunter 1992). Fry that have just absorbed the yolk sac and have recently emerged from the gravel are the most vulnerable because they are poor swimmers and typically reside along shallow stream margins (Phinney 1974, Woodin 1984). Stranding of juvenile coho and rainbow trout on a gravel substrate in an artificial stream at low temperature was less frequent at slow rates of dewatering (6 cm/hr stage change rather than 30 cm/hr) and if flow reductions occurred at night (Bradford, *et al.* 1995). Stranding of juvenile coho was reduced when the slope of the bar exceeded 6%.

The behavioral response of fish to flow fluctuations and how it may cause downstream emigration is not well understood. Studies conducted during the early 1970's by McPhee and Brusven (1976, cited in Hunter 1992) demonstrate that streamflow fluctuations trigger benthic drift and cause juvenile salmon to migrate downstream. Streamflow fluctuations can also cause both juvenile and adult fish to become trapped in shallow areas which are then exposed to elevated temperature or predation.

Redds are also susceptible to lowering water levels. Salmonid eggs can survive for weeks in dewatered gravel if they remain moist and are not frozen or subjected to high temperatures. However, dewatering is lethal to alevins (yolk sac fry that hatch from the eggs and live for a brief period within the interstitial spaces of the streambed gravels). Since salmonids spawn over a period of months, eggs and alevins are often present at the same time.

Ramping rates typically constrain the rate (cfs/hr) at which a controlled release can be changed. Ramping rates are important to fisheries management agencies because they affect the rate at which instream hydraulic, and therefore habitat conditions, can be changed. The rate at which a controlled release is changed affects the rate at which total streamflow and downstream flow depths, flow velocities, channel top widths, and wetted surface areas change. The degree to which a particular ramping rate affects instream hydraulic and habitat conditions depends upon several site-specific factors:

- the percentage of total streamflow affected by the ramped release
- the amount of streamflow during ramping
- stream channel shape, cross-sectional area, and slope
- downstream distance from the ramping location

Perhaps the most difficult factor to understand quantitatively is the degree to which a flow change is “attenuated” as it progresses downstream. The influence of a sudden change in flow on stage is most pronounced at the location where the change occurs and decreases rapidly in the downstream direction. If a controlled release is ramped up, a portion of the released water goes into channel storage rather than directly into streamflow. Channel storage is represented by that portion of the channel cross-section over which the increased flow is spread, or temporarily “stored” along the channel length. This reduces the amount of flow and moderates the resulting change in water surface elevation (stage) observed downstream from the point of ramping. If the controlled release is ramped down, a portion of channel storage is “evacuated” to become streamflow. The rate and degree to which channel storage changes influence stage primarily depends upon the size of the flow change (ramping) relative to streamflow and channel size, cross-sectional area, channel shape, and slope. Tributary inflow is also important. As tributary inflow contributes to streamflow in the channel, the relative effect of ramping represents a proportionally smaller influence on total channel flow and associated change in stage. For this analysis of ramping rates on Dry Creek, attenuation is assumed to occur within 1 to 1.5 miles downstream of Warm Springs Dam which is the location of the first major tributary input at Pena Creek. On the mainstem Russian River, ramping effects are assumed to be attenuated by about 5 miles or less downstream of Coyote Dam near the Perkins Street bridge crossing in Ukiah. At the Forks, there is usually considerable flow from the mainstem Russian River during flood control operations that would attenuate ramping effects. Flows of about 2,500 cfs on the mainstem Russian River influence backwater effects on the East Fork (Pugner, USACE, pers. comm.). Flow in the mainstem Russian River is usually increasing as reservoir releases are being reduced during flood control operations, which moderates the ramping effects.

It is unlikely that ramping up rates associated with flood control operations would have an effect on listed species. Dam releases during flood control operations are made when downstream tributary flows are receding after a storm event, thereby reducing rather than augmenting natural flood peaks. Ramping up rates follow the interim guidelines, so that when release flows are above 1,000 cfs, ramping occurs at no more than 1,000 cfs/hr. This ramping rate is lower than natural flow increases associated with storm events. The USGS gage at Ukiah (11461000) located above the Forks was inspected and evaluated for natural flow changes for the period November 1995 to June 1999. Flows at the Ukiah gage are not regulated, and therefore represent natural flow fluctuations. On the rising limb of the storm hydrograph, hourly increases in flows above 1,500 cfs average 390 cfs/hr, and 10% of the time (90^{th} percentile) exceed 960 cfs/hr. A storm hydrograph for January 20-24, 1997 is shown in Figure 2-1. From USGS stage data for this station, the maximum stage change associated with the rising limb of this storm event is approximately 1.9 ft/hr. The stage change associated with the average 390 cfs/hr increase in flows is approximately 0.5 ft (when flows are greater than 1,000 cfs). These data indicate that natural stage changes are sometimes greater than the Hunter criteria.

2.5.2 Ramping Rate Evaluation Criteria

The Washington Department of Fisheries has proposed a rate of stage change that will generally protect fish (Hunter 1992). Hunter's ramping guidelines are modified with the phenology of salmonids in the Russian River for this assessment (Table 2-25).

Table 2-25 Rates of Stage Change Based upon Hunter (1992) and Life History Stages for Salmon and Steelhead in the Russian River

Season	Rates
March 1 to July 1	1 inch/hour
June 1 to November 1	2 inches/hour

Drawing from Hunter's proposed guidelines, during juvenile rearing periods, which occur year-round for steelhead and coho salmon in the Russian River, 2 inch/hour (0.16 ft/hr) stage change is appropriate. In the Mirabel Rubber Dam Fish Sampling Program (Chase 2000), chinook smolts have been caught in a rotary screw trap at the Mirabel Rubber Dam in April, May and June, of 1999 and 2000, suggesting that chinook do rear in the Russian River watershed. Insufficient data are available to say where rearing occurs.

The Hunter (1992) guidelines are considered to represent a rigorous and conservative ramping standard for the Russian River. Hunter developed his guidelines based on streams located in the northwest, a hydrologic regime that is dominated by snowmelt processes. Snowmelt streams usually have relatively gradual changes in runoff conditions. In the Russian River drainage, streamflow is driven by often intense Pacific frontal storms that naturally result in very "flashy" runoff conditions and therefore relatively larger changes in stage compared with snowmelt runoff conditions.

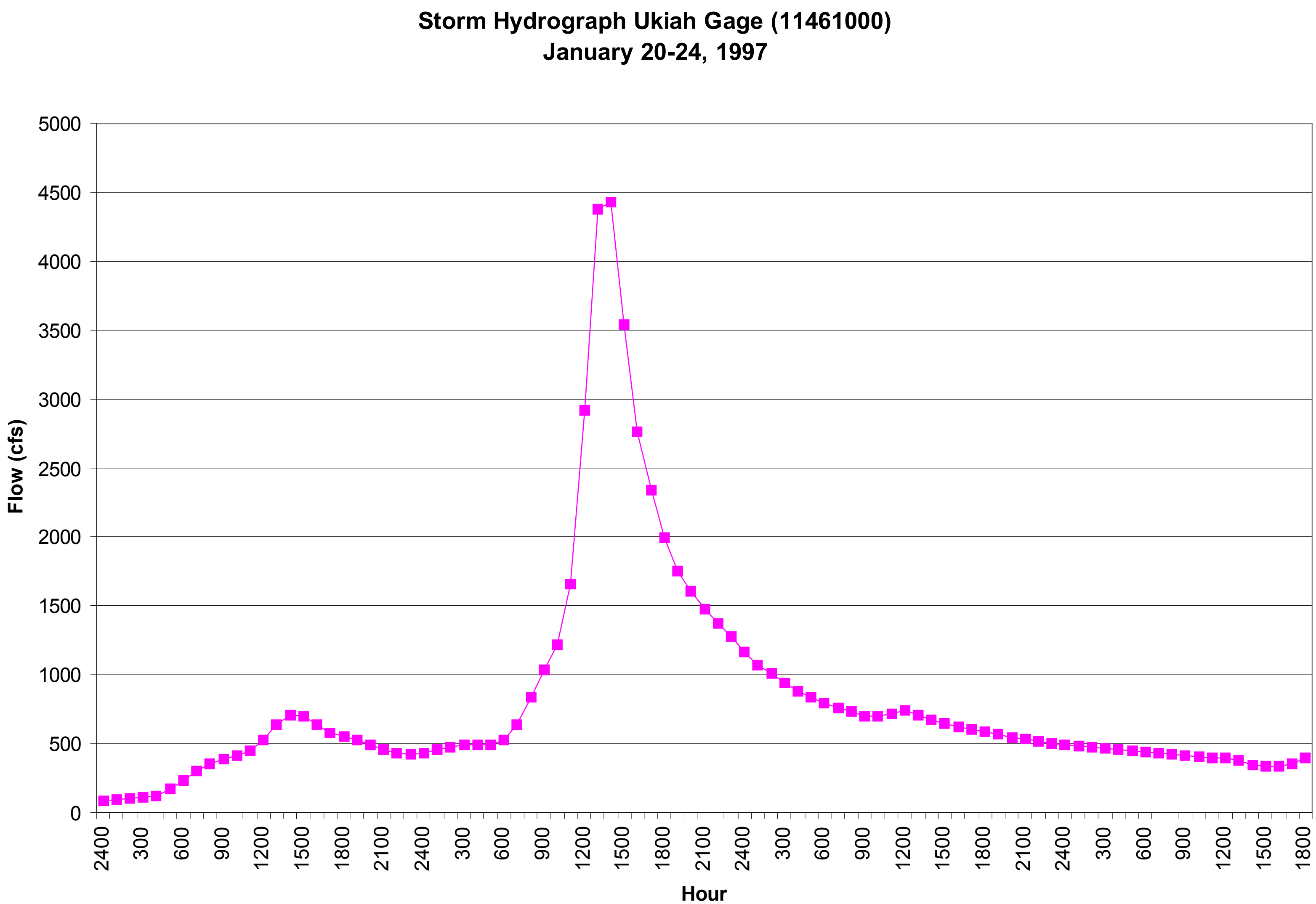

Figure 2-1 Storm Hydrograph Ukiah Gage

By comparison to the Hunter guidelines, stage changes associated with the receding limb of storm events were reviewed for the USGS Ukiah gage (11461000) located above the Forks. For the period November 1995-June 1999, the average stage change is approximately 0.3 to 0.4 ft/hr when flows are greater than 1,500 cfs. At the 90th percentile, stage changes range from 0.4 to 0.5 ft/hr or more when flows are greater than 1,500 cfs. Thus, the Hunter guidelines are considered to present a high standard for ramping.

2.5.2.1 Ramping Release Rate 1,000-250 cfs

Ramping may occur at higher or lower streamflow conditions during the winter and spring runoff periods as part of flood control operations. When the reservoir release is between 1,000-250 cfs, the interim guideline for the ramping rate is 250 cfs/hr.

Evaluation criteria and scoring for ramping in the 1,000-250 cfs flow range (Table 2-26) are based on Hunter's (1992) guidelines and the interim ramping rates established by USACE in consultation with NMFS and CDFG. The highest score is given if stage changes meet Hunter's (1992) guidelines, 0.16 ft/hr during periods when juveniles are present. Ramping that exceeds Hunter's (1992) guidelines by up to 100%, receive a score of 4. Ramping activities that exceed Hunter's guidelines by more than 100% but do meet the established interim ramping rate (250 cfs/hr), receive a score of 3. Ramping rates that exceed the interim flow criteria by up to 50% (i.e., up to 375 cfs/hr) receive a score of 2, and if ramping rates exceed the interim flow criteria by more than 50% (greater than 375 cfs/hr), the score is 1.

Table 2-26 Ramping Evaluation Criteria for Streamflows 1,000 cfs-250 cfs

Criteria	Score
Meet 0.16 ft Maximum Stage Change	5
Within 100% of 0.16 ft Criteria (0.32 ft) for Stage Change	4
Meets Interim Ramping Criteria (250 cfs/hr)	3
Exceeds Interim Ramping Criteria up to 50% (375 cfs/hr)	2
Exceeds Interim Ramping Criteria by Greater than 50% (>375 cfs/hr)	1

In order to determine if the ramping rates meet, or the extent to which they exceed the criteria in Table 2-26, stage-discharge relationships were obtained from HEC-RAS modeling for the appropriate cross-sections. The HEC-RAS model provides information on the change in stage (depth) associated with a change in discharge. The model itself does not account for the effects of attenuation of releases by flow contributions from downstream tributaries or accretion in baseflow. Therefore, the HEC-RAS model may overestimate changes in stage for progressively downstream cross-sections. Pools, side-channels and gravel bars attenuate the ramping rate by storing water from higher flows and releasing the water gradually. The largest actual changes in stage are expected closest to the dam.

On Dry Creek, the ramping evaluation includes a 1.5-mile long reach below Warm Springs Dam (see discussion under section 2.5.1). Ten cross-sections (103 to 112) were used in the assessment. On the mainstem Russian River, four cross-sections (48, 48.1, 49, 49.1) closest to Coyote Valley Dam, from about 3 miles to 5 miles downstream of the dam, were used. There are no cross-sections available for the East Fork Russian River (cross-section data was collected at two locations on the East Fork near CVD in May 2000 by the SCWA, but these cross-sections have not been used in the HEC-RAS modeling), so an evaluation of stage-discharge relationships relative to Hunter's guidelines could not be performed. However, flow release data at both dams was examined from recent years (1997 to 1999) to determine the extent to which flood control operations may be meeting the interim ramping criteria as designated in Table 2-26.

2.5.2.2 Ramping Release Rate 250-0 cfs

Ramping of release flows in the range of 250-0 cfs typically take place in winter or spring as flood control operations reduce flows from much higher rates following storm events. Flows at the Ukiah gage, above the Forks on the mainstem Russian River, are usually greater than 500 cfs when flood control operations are ramping at release rates less than 250 cfs. During most of the year, juvenile salmonids are expected to be present, and therefore the criteria for juveniles applies (0.16 ft/hr). The evaluation criteria (Table 2-27) are similar to that presented for the release rates 1,000-250 cfs, except that the interim flow guidelines call for a maximum ramping rate of 125 cfs/hr when reservoir releases are within the 250-0 cfs range (USACE, 1998a,b).

Table 2-27 Ramping Evaluation Criteria for Streamflows 250 cfs-0 cfs

Criteria	Score
Meet 0.16 ft Maximum Stage Change	5
Within 100% of 0.16 ft Criteria (0.32 ft) for Stage Change	4
Meets Interim Ramping Criteria (125 cfs/hr)	3
Exceeds Interim Ramping Criteria up to 50% (188 cfs/hr)	2
Exceeds Interim Ramping Criteria by greater than 50% (>188 cfs/hr)	1

The analysis procedure using the HEC-RAS model to determine change in stage at the designated cross-sections is exactly the same as that discussed for the 1,000-250 cfs ramping range.

2.6 ANNUAL AND PERIODIC DAM INSPECTIONS AND MAINTENANCE

2.6.1 ISSUES OF CONCERN

Annual and periodic pre-flood inspections take place at both Coyote Valley and Warm Springs Dams. During 1998 and 1999, inspections took place during the months of September and June, respectively. In 2000, dam inspection and maintenance activities took place during the month of May. It is unlikely that maintenance inspections for Coyote Dam will occur in the spring with the exception of actions classified as emergency situations. Flows must be reduced or completely shut down, usually for periods of several hours, in order to accomplish the inspections. Additionally, flows may be reduced or shut down in order to perform periodic maintenance activities on the dams. Depending upon the maintenance activities to be performed, flows may be reduced or shut down for periods lasting several hours to one day or longer. Ramping rates and reduced streamflow conditions are the two primary issues of concern associated with annual and periodic dam inspections and maintenance.

2.6.1.1 Ramping Rates

In order to perform the annual and periodic dam inspection and maintenance work, ramping down flow releases is often necessary. In recent years, ramping rates have been determined by consultation between USACE and NMFS prior to each year's annual inspection. In the past, stranding has been documented below Coyote Valley Dam, but not below Warm Springs Dam. These cases are discussed in the next section *Reduced Streamflows during Inspection and Maintenance.* At Warm Springs Dam, the ramping rate is typically 25 cfs/hr. At Coyote Valley Dam, the typical ramping rate during inspection activities is 50 cfs/hr. These are the smallest ramping rates possible with the current infrastructure at both dams.

Issues of concern relative to ramping rates during pre-flood inspection and maintenance activities are similar to those discussed in section 2.5.1 and are primarily related to stranding and de-watering. Depending upon when maintenance and inspection activities take place, ramping may affect both fry and juvenile life stages.

2.6.1.2 Reduced Streamflows During Inspection and Maintenance

During shut-down or reduction of flow from either dam, stranding and mortality particularly for fry, have the potential to occur. A bypass flow of about 25-28 cfs is usually maintained at Warm Springs Dam during pre-flood inspections. During inspections at Coyote Valley Dam, there is no bypass capability, so flow releases must be completely shut down. However, a small flow is maintained below the dam for up to several hours as the plunge pool and afterbay drain, or if the stilling basin is dewatered for inspection as occurred in June 1999. In 2000, maintenance activities were scheduled in May with the hope that higher stream flows in the mainstem would attenuate effects from flow reductions at Coyote Valley Dam. Flow contributions on the mainstem below the Forks is always greater in the spring compared with the summer or fall months. Inspection of flow records since 1995 at the Ukiah gage (USGS gage 11461000), located above the Forks, indicates that flow has never been less than 11 cfs. Flows are usually greater than 35 cfs, and may be up to several hundred cubic feet per second. In contrast, flows in September at the Ukiah gage are almost always 1-2 cfs. Streamflows on the East Fork during maintenance activities are expected to be very low since there is no bypass capability. However, during the June 1999 inspection and maintenance, pools were observed to be maintaining, and a small flow was apparent (although it was not measured) despite flow reductions to 0 cfs at Coyote Valley Dam (Terry Marks, USACE, pers. comm., 2000).

Stranding due to ramping rates or partial dewatering of the channel during scheduled activities at Coyote Valley Dam did occur on the mainstem Russian River below the Forks when maintenance and pre-flood inspections were scheduled in May 2000. With the first decrease in flows from about 168 to 118 cfs, over ten salmonids were stranded below the Forks, and the decision was made to abandon the scheduled maintenance at that time (T. Daugherty, NMFS pers. comm. 2000). During a scheduled maintenance activity on Dry Creek in May of 2000, only a few (eight) steelhead were found stranded by the time the ramp-down was completed (R. Sundermeyer, ENTRIX, Inc. and T. Daugherty, NMFS, pers. comm. 2000).

Table 2-28 outlines the periods when salmonid fry may be present. Rearing coho salmon and steelhead fry may be present in Dry Creek in late winter and spring. Additionally, steelhead and coho juveniles may be present in Dry Creek. In the mainstem Russian River below Coyote Valley Dam, chinook salmon and steelhead fry as well as chinook, coho and steelhead juveniles, may be present during various times in the year. The critical issues addressed in this assessment are reduced instream flow effects on habitat conditions and the potential for stranding below Coyote Valley Dam. Below Warm Springs Dam, the critical issue is reduced stream flow effects on habitat conditions.

Table 2-28 Times When Fry May Be Present in the Russian River Drainage

Species	Emergence	Fry may be present
Coho	Feb. 1 - Mar. 31	Feb - April
Steelhead	Mar. 1 - May 31	March - June
Chinook	Feb. 1 - Mar. 31	February - April

Stress is likely to occur when fish are displaced from established rearing areas and crowded into residual pools. Residual pools with high fish densities could be subject to food competition, or predation by avian species and vertebrates, including hatchery fish preying on wild fish. Stranding could occur on riffles, gravel bars, and in backwater pools if flow becomes intermittent, and mortality may result if fish become desiccated. Water temperatures could also be elevated.

In October 1997, the emergency water supply pipeline at Warm Springs Dam was repaired, and the annual pre-flood inspection performed. A minimum 28 cfs release was maintained from the dam for periods lasting for approximately eight hours over several days in order to perform the repairs and inspection. Dry Creek was monitored by USACE during this time. The monitoring concluded that there was adequate flow for juvenile salmonids, since no mortalities or stranding were discovered (USACE, 1997).

A periodic inspection was conducted at Coyote Valley Dam on September 9, 1998. There were no bypass flows during this inspection. Streamflow was monitored 4 miles downstream from the dam, but flow velocities were too low to measure with a current meter. Discharge was estimated to be less than 30 cfs. Further downstream at Hopland, the USGS gage indicated the discharge was below the rating table (indicating less than 200 cfs) for about seven hours. Some juvenile steelhead were stranded and rescued below the dam on the East Fork to about 12,000 feet downstream on the mainstem Russian River below the Forks.

A pre-flood inspection at Coyote Valley Dam was performed on June 10, 1999. Approximately ten hours were planned to conduct the inspection of the outlet works conduit and stilling basin, but this was cut short by a few hours. Releases from Coyote Valley Dam were below the minimum 25 cfs instream flow requirement for about four hours. SCWA petitioned the State Water Resources Control Board for a temporary urgency change in minimum flow requirements, which was approved for this inspection. During the inspection, streamflow at the Ukiah gage (above the Forks) was 12-14 cfs, and at Hopland it ranged between 93-221 cfs. Although water was pumped out of the stilling basin (contributing about 5 cfs downstream), the stilling basin was never dewatered and an inspection of it was cancelled. Direct mortality was a concern due to potential entrainment when pumping the stilling basin. NMFS issued an Incidental Take Statement in the biological opinion for the maintenance activity and required monitoring of the East Fork Russian River for strandings and temperature (NMFS, 1999). No strandings or fish mortalities were found, and there were no significant increases in temperature (Terry Marks, USACE, pers. comm.).

2.7 EVALUATION CRITERIA

2.7.1.1 Ramping Rates

Evaluation criteria for ramping during pre-flood inspections are based on the historical incidence of stranding that has been documented at Warm Springs and Coyote Valley Dams. At Coyote Valley Dam, flow reductions of 50 cfs/hr during the month of May have resulted in fish stranding on the mainstem Russian River. Stranding of juvenile steelhead was documented in September 1998 on the lower East Fork and mainstem Russian River. At Warm Springs Dam, flow reductions of 25 cfs/hr have resulted in very limited stranding of steelhead during May when fry are present. Stream widths in Dry Creek and the upper mainstem below the Forks are similar (100-150 ft widths), and HEC-RAS modeling indicates similar stage change relationships for 25 cfs/hr flow reductions. Therefore, one set of ramping criteria has been developed for application to both locations. Evaluation criteria for ramping rates are given in Table 2-29. Scoring criteria distinguish times when fry are present and when only juveniles are present.

Table 2-29 Evaluation Criteria for Low Reservoir Outflows (250-0 cfs) During Dam Maintenance and Pre-Flood Inspection Periods

Change in Flow (cfs/hr)	Score Juvenile	Score Fry
0-10	5	5
10-20	5	4
20-30	4	3
30-40	3	2
40-50	2	1
>50	1	0

The evaluation criteria in Table 2-29 are appropriate only for those streamflow conditions when there is relatively low flow contribution below the Forks on the mainstem. Ramping during flood control operations occur when streamflows are much higher on the mainstem, typically 500 cfs or more at the Ukiah gage. Under these streamflow conditions, there are no exposed channel bars on the mainstem or the East Fork, and stranding is much less likely. Therefore, ramping evaluation criteria appropriate for assessing potential stranding are those previously defined in Table 2-27 for flows between 250-0 cfs.

Evaluation criteria listed in Table 2-29 should be used when streamflows are less than 500 cfs at the Ukiah gage. Stage-discharge relationship information generated by the HEC-RAS model were used as an independent check to identify how the flow ranges in the evaluation criteria compare with Hunter's criteria. Stage changes associated with 25 cfs/hr reductions at Warm Springs Dam and both 50 cfs/hr and 25 cfs/hr at Coyote Valley Dam were modeled.

Warm Springs Dam

Stage changes associated with 25 cfs/hr incremental flow reductions beginning at 250 cfs, then 225 cfs, 200 cfs, 175 cfs, 150 cfs, 125 cfs, 100 cfs, and 75 cfs are shown for ten cross-sections on Dry Creek in Figure 2-2. The change in stage associated with a given streamflow is shown by the height of each bar. For example, the bar on the x-axis at 250 cfs for cross-section 103 represents a flow reduction from 250 cfs to 225 cfs, and the associated stage change is indicated on the y-axis as less than 0.08 ft. A bar for cross-section 103 representing a flow reduction from 225 to 200 cfs, and the associated stage change indicated on the y-axis is a little greater than the change at 250-225 cfs. Transect 112 is closest to Warm Springs Dam, and transect 103 the most distant. Overall, the stage change associated with 25 cfs/hr ramping meets the 0.16 ft/hr Hunter criteria within most of the flow ranges below 250 cfs.

Russian River and East Fork below Coyote Valley Dam

Stage changes associated with 25 cfs/hr incremental flow reductions beginning at 250 cfs, then 225 cfs, 200 cfs, 175 cfs, 150 cfs, 125 cfs, 100 cfs, and 75 cfs, and 50 cfs are shown for four cross-sections on the mainstem Russian River below the Forks in Figure 2-3. Cross-section 49.1 is closest to the dam (about 2.5 miles downstream), and cross-section 48 is furthest from the dam (about 5 miles downstream). The change in stage associated with a given streamflow is shown by the height of each bar. Cross-section data for the East Fork Russian River have recently been obtained, but stage discharge relationships from HEC-RAS modeling were not developed for this analysis. Stage changes associated with 50 cfs/hr incremental flow reductions are shown in Figure 2-4.

At 25 cfs/hr reductions, the 0.16 ft/hr criteria is met at most flow intervals in all four of the cross-sections for flow ranges below 250 cfs. At 50 cfs/hr reductions, the 0.16 ft/hr criteria is exceeded, and stage changes are generally in the range of 0.24 to 0.32. This suggests that the potential for stranding is greater at Coyote Valley Dam.

2.7.1.2 Reduced Streamflow

Criteria for evaluating the effects of annual and periodic maintenance activities are based on flow conditions for rearing. The rearing criteria were developed from Winzler and Kelly (1978) and existing field monitoring observations recorded during inspection and maintenance activities.

Previous information developed for flow-related effects on rearing habitat and used for development of evaluation criteria were drawn from studies prepared by Winzler and Kelly (1978) and CDFG studies (Baracco 1977). Winzler and Kelly (1978) conducted a systematic survey of existing and potential fish habitat in the mainstem Russian River and Dry Creek. They divided the mainstem Russian River into three reaches based upon the hydrologic characteristics of the drainage basin. The Lower Reach extends from the river mouth to Healdsburg and includes the confluence with Dry Creek. The Middle Reach extends from Healdsburg to Cloverdale and includes the confluence with Big Sulphur Creek. The Upper Reach extends from Cloverdale to the Forks near Ukiah.

Optimum streamflow for rearing habitat in the three mainstem reaches were based upon conditions observed during winter and summer field surveys in 1978 (Figure 2-5). An important

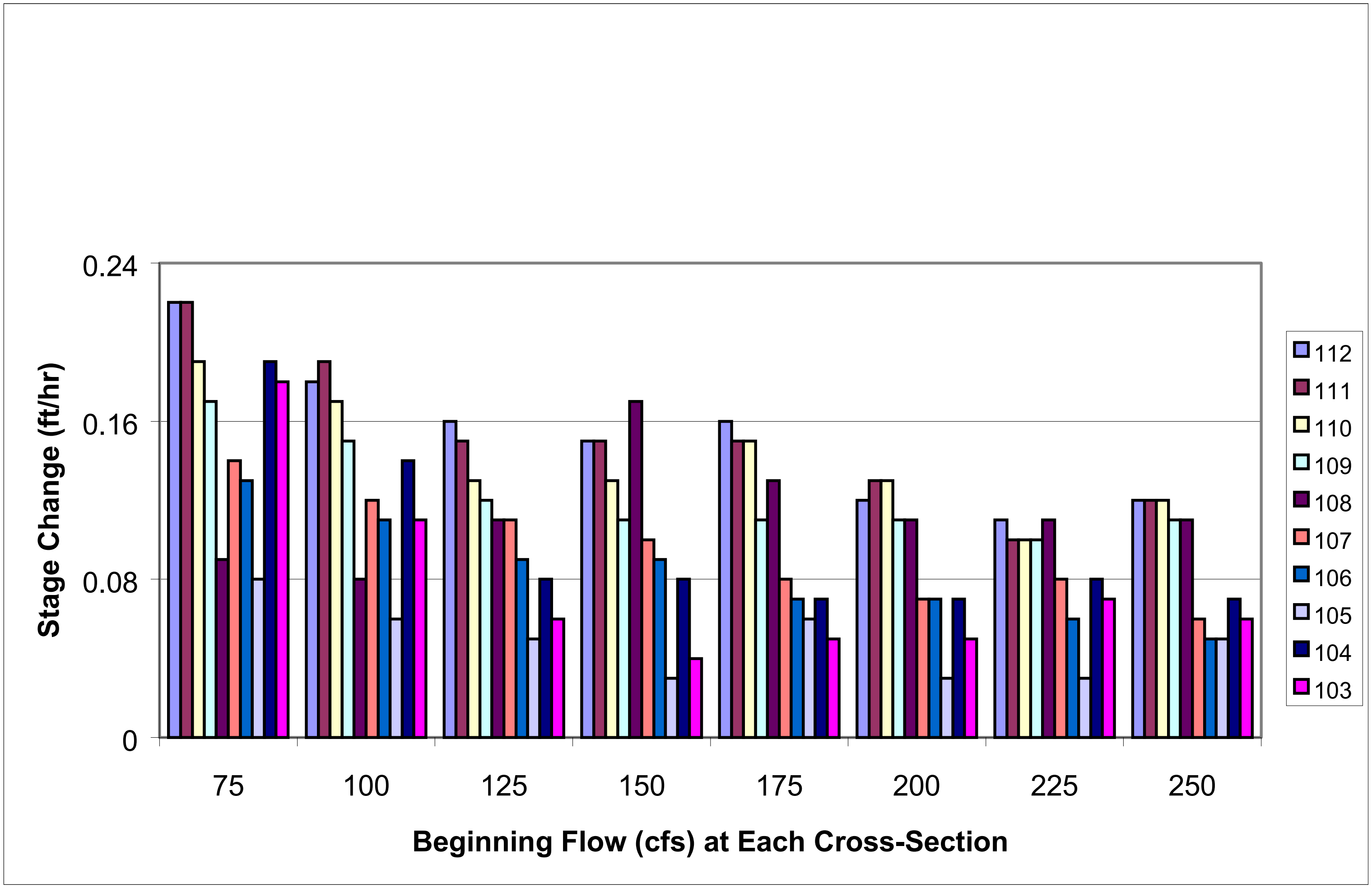

Figure 2-2 Stage Changes Associated with 25 cfs/hr Ramping Rate at Warm Springs Dam

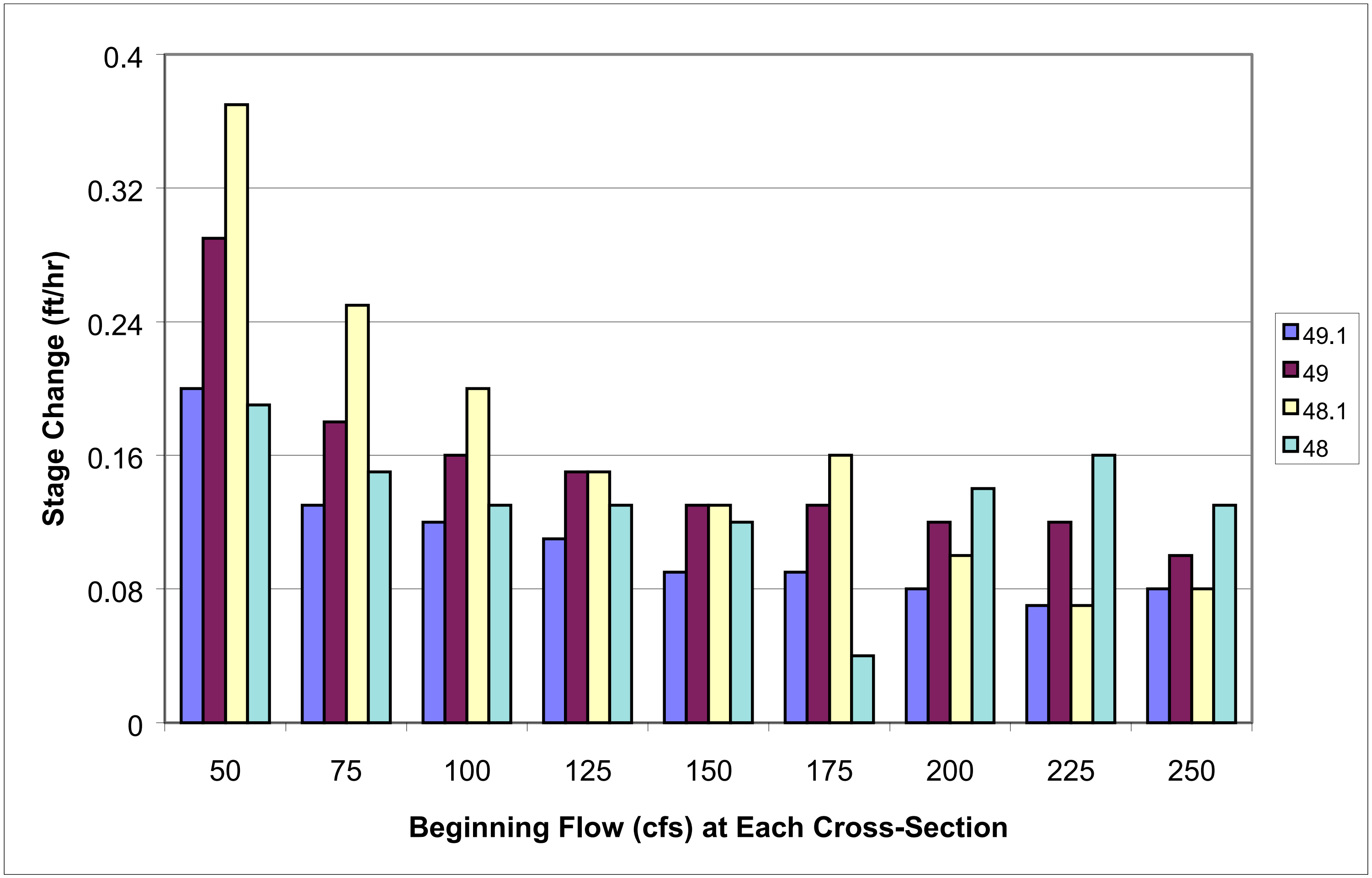

Figure 2-3 Stage Changes Associated with 25 cfs/hr Ramping Rate on Mainstem Russian River below Coyote Valley Dam

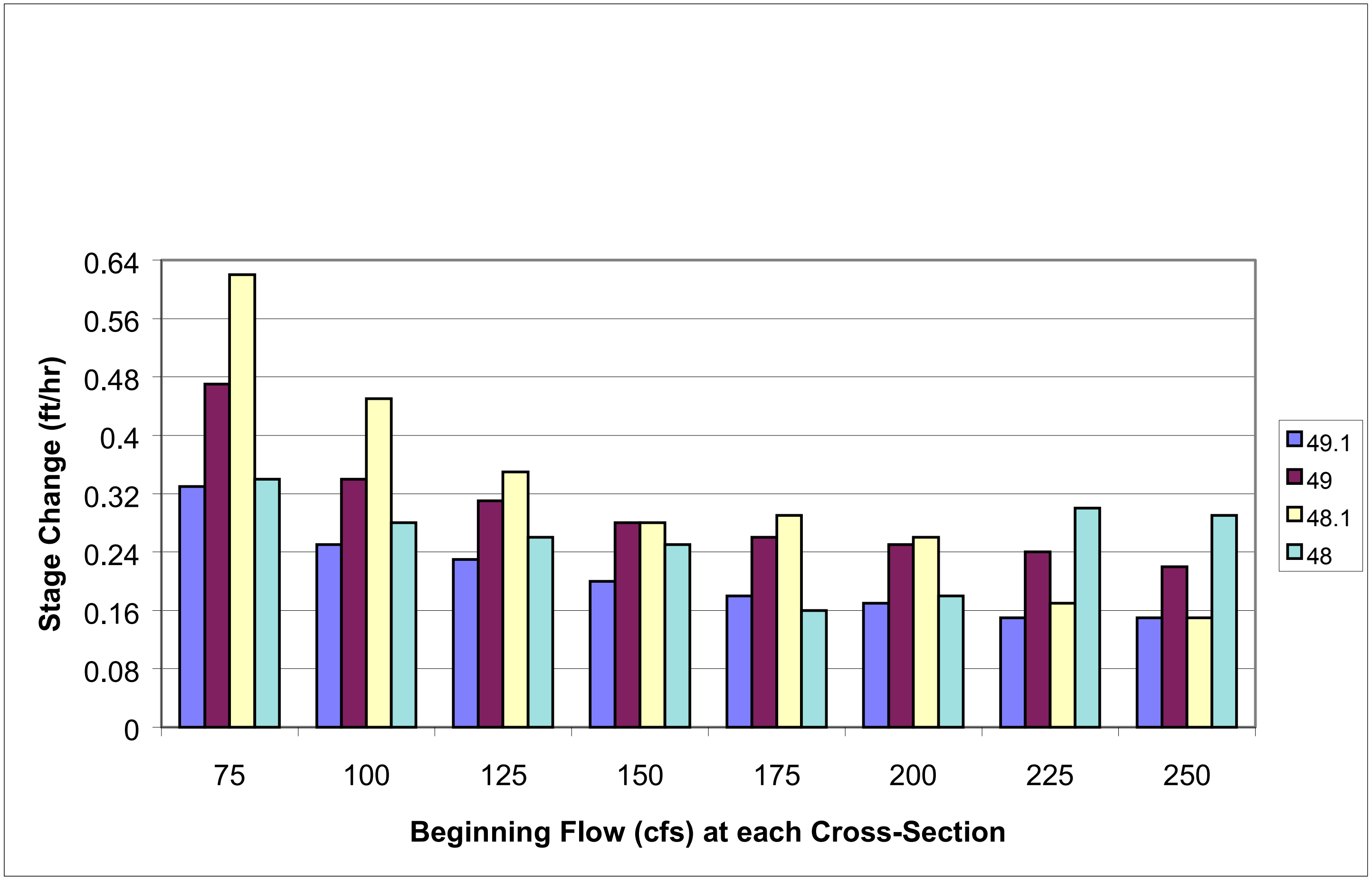

Figure 2-4 Stage Changes Associated with 50 cfs/hr Reductions in Flow at Cross-sections in Mainstem Russian River below Coyote Valley Dam

Main Stem Nursery Habitat (Winzler and Kelly, 1978)

Streamflow in CFS	Habitat		
	Upper	Middle	Lower
0			
20	668	609	406
25	650	520	400
50	594	190	350
75	510	92	322
100	266	98	252
125	260	0	247
150	200	0	170
175	200	0	85
200	200	0	0

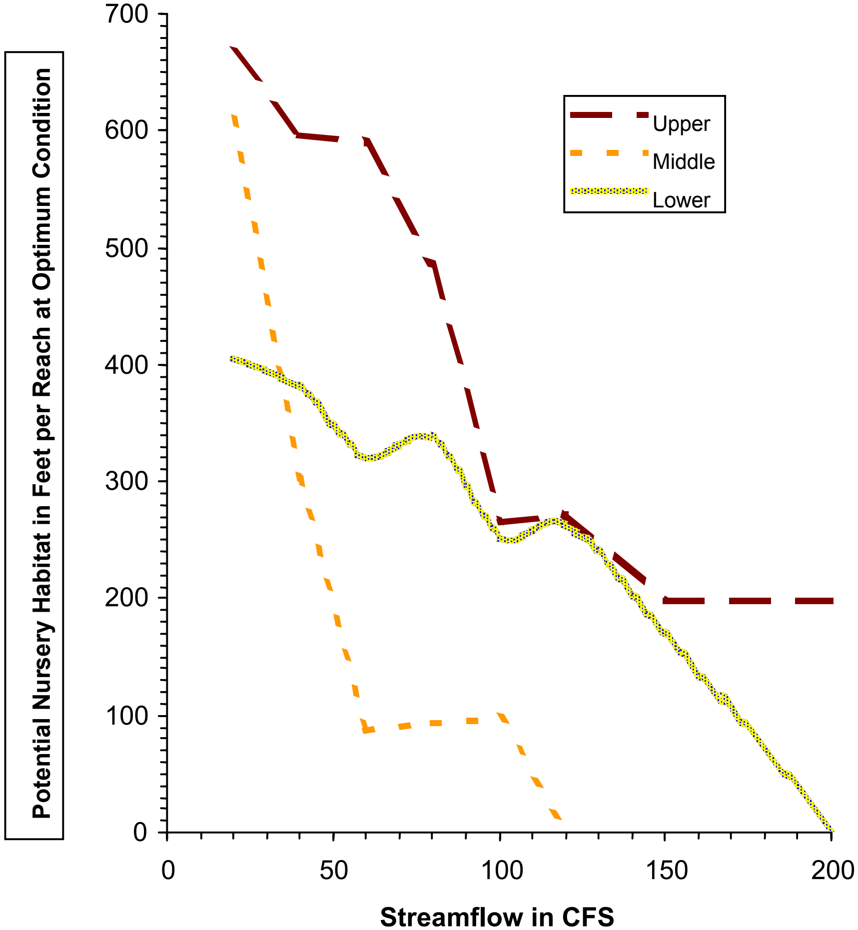

Figure 2-5 Potential Rearing Habitat in Feet per Reach at Optimum Conditions for the Mainstem Russian River

consideration for flow for optimum nursery habitat was that while flow should be available to permit juvenile migration over critical riffles and instream structures (such as semi-permanent water impoundment dams), it should not be so great as to severely limit resting habitat. Therefore, potential nursery habitat was defined in terms of average water velocity limits for the production of resting space. Flows with velocities of 0.7 feet per second (fps) or less produce resting space.

Upper Russian River

Rearing habitat scoring categories were developed for the Upper, Middle and Lower Reaches of the Russian River by dividing rearing habitat into five quintile streamflow ranges. Table 2-30 shows the evaluation criteria for the Upper Reach of the Russian River.

Table 2-30 Rearing Habitat Scores for the Upper Reach of the Russian River

Habitat Scores	Quintile Range	Streamflow in CFS	Streamflow in CFS	Streamflow in CFS
5	536-668	19-71		
4	402-536	15-18	71-88	
3	268-402	9-14	88-100	107-122
2	134-268	4-8	100-106	>122
1	>0-134	>0-3		
0		0		

Flows expected downstream of Coyote Valley Dam during maintenance and pre-flood inspection activities are compared with the rearing habitat criteria to derive a habitat score.

Dry Creek

Rearing habitat scoring categories were similarly developed for Dry Creek by dividing habitat from Figure 2-6 into five quintile ranges (Table 2-31). All three of the protected species utilize Dry Creek, and therefore criteria are applied during the time periods that each of the species is present.

Table 2-31 Rearing Habitat Scores for Dry Creek

Habitat Scores	Quintile Range	Streamflow in CFS	Streamflow in CFS
5	472-588	7-21	
4	354-472	5.5-7	21-23
3	236-354	0-5.5	23-27
2	118-236		27-43
1	0-118		43-48
0	0		>48

Flows expected downstream of Warm Springs Dam during maintenance and pre-flood inspection activities are compared with the rearing habitat criteria to derive a habitat score.

Dry Creek Nursery Habitat (Winzler and Kelly 1978)

Streamflow in CFS	Habitat
0	
5	43
10	522
15	568
20	500
25	295
30	222
35	228
40	170
45	70
50	0

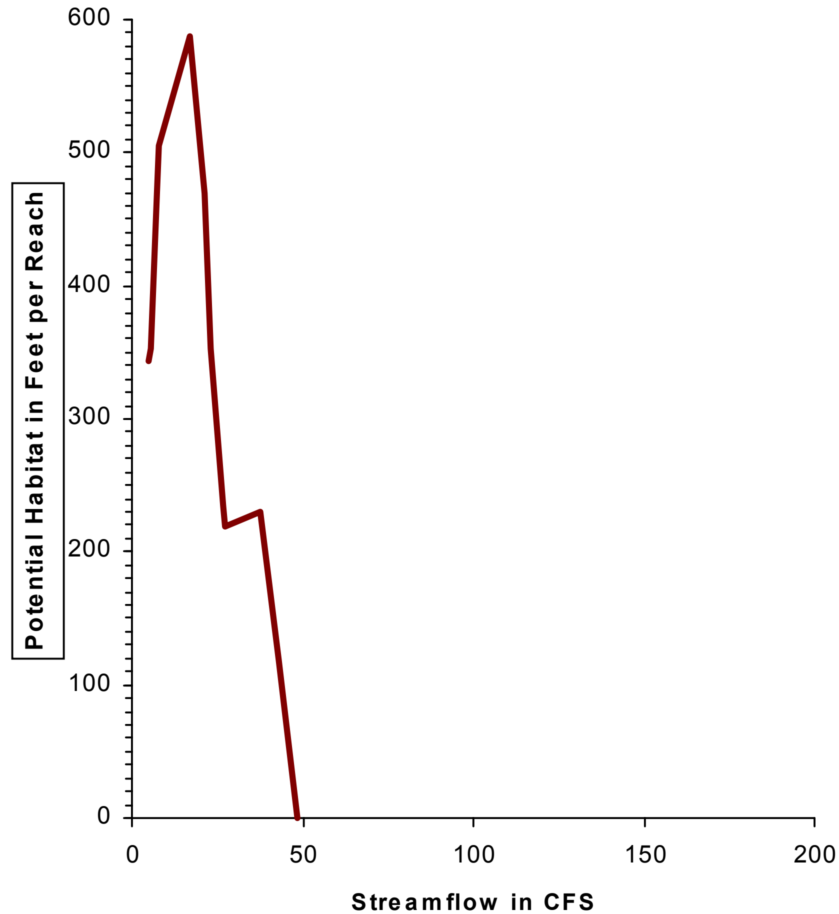

Figure 2-6 Potential Rearing Habitat in Feet per Reach at Optimum Conditions for Dry Creek

3.1 CHANNEL GEOMORPHOLOGY

3.1.1 EVALUATION OF FLOOD CONTROL OPERATION EFFECTS ON SCOUR OF SPAWNING GRAVELS

Scour of spawning gravels was evaluated at three locations: on Dry Creek; the mainstem Russian River in Alexander Valley (upstream of Healdsburg); and the mainstem upstream of Alexander Valley to Ukiah. Results for initiation of motion and estimated depth of scour are discussed by location.

Dry Creek

On Dry Creek, flood control operational effects were evaluated for scour of steelhead, chinook, and coho salmon spawning gravel. A summary of scoring frequency for the period of record modeled, 1960-1995, is presented in Table 3-1. Scores are highest for chinook salmon spawning gravels with 47% of the years receiving a 5. There were no years receiving a score of 1. For scour of steelhead gravels, a score of 3 was received in 33% of the years, with about 28% of the years receiving a 2 and 22% of the years receiving a 5. There were no years when steelhead received a 1. Coho spawning gravels faired more poorly than steelhead gravels, with 42% of the years achieving a 1. However, 36% of the years received a score of 3 or better. The larger sized spawning gravels associated with chinook redds (D_{50} 36mm) and steelhead redds (D_{50} 22mm), compared with coho salmon redds (D_{50} 16mm), accounts for the greater stability of gravels and better overall scores for chinook spawning gravels.

Table 3-1 Dry Creek Spawning Gravel Scour Scores

Score	5	4	3	2	1
Steelhead	22.2%	16.7%	33.3%	27.8%	0%
Chinook	47.2%	11.1%	27.8%	13.9%	0%
Coho	13.9%	5.6%	16.7%	22.2%	41.7%

Considering that the streambed should be periodically entrained in order to flush and transport fine sediments and thereby maintain good quality spawning gravels, the scores probably indicate a reasonably good balance between streambed-mobilization and spawning gravel stability for successful reproduction of chinook; an acceptable balance for steelhead, and only a fair balance for coho. The smaller sized gravels (D_{50}) that are typically used by coho salmon is the main reason for the greater frequency of scour.

Depth of scour calculations indicate that all chinook sized gravels, and all but one cross-section location for steelhead gravels will scour to a depth equal to or greater than 0.7 feet for the identified discharge range which initiates motion. There are a total of nine transects that do not scour to the 0.7 foot depth for coho sized gravels at the discharge range which would initiate motion. The nine transects represent about 8% of the total locations analyzed. Overall, the scores for coho salmon spawning habitat probably slightly over-represent the frequency with which scour may affect the egg pocket.

Mainstem Russian River

The Upper Reach of the mainstem Russian River between Ukiah and Alexander Valley (near Cloverdale) is scored in Table 3-2. Since coho do not use the mainstem, they are not scored. Scour of steelhead gravels receive a fairly good score with about 56% of the years receiving a 4, and 42% of the years receiving a 3. Chinook spawning gravels receive an overall moderately fair score, with almost all years (97%) receiving a 3. The lower incidence of scour of the steelhead gravels, compared with chinook gravels in the upper mainstem reach, at least partially reflects the late season incubation period for steelhead. A score of 3 is received when flows are greater than 500 cfs, which occurs about 42% of the time during the month of May. The incubation period for chinook, however, is February and March. Higher flows can be expected during these months in the upper mainstem reach, and therefore scour of chinook spawning gravels during the more sensitive incubation period is more frequent than for steelhead.

Table 3-2 Ukiah to Alexander Valley (Near Cloverdale) Spawning Gravel Scour Scores

Score	5	4	3	2	1
Steelhead	2.8%	55.6%	41.7%	0%	0%
Chinook	2.8%	0%	97.2%	0%	0%

The spawning gravel scour scores for the Middle Russian River reach in Alexander Valley are provided in Table 3-3. Scores are fair for steelhead, with 58% of the years receiving a 2 and 41% of the years receiving a 3 or better. Chinook scores indicate moderately stable conditions, with 64% of the years receiving a 3, and about 22% of the years receiving a score of 4 or 5. Higher discharges due to natural flow accretion from tributary input account for the lower scores in Alexander Valley compared with Ukiah Valley further upstream.

Table 3-3 Alexander Valley Spawning Gravel Scour Scores

Score	5	4	3	2	1
Steelhead	2.8%	5.6%	33.3%	58.3%	0%
Chinook	11.1%	11.1%	63.9%	13.9%	0%

Based on depth of scour calculations, all chinook gravels scour to the depth of the egg pocket. There is one location in the Upper Reach, and one location in the Middle Reach, that does not scour to the egg pocket depth in steelhead gravels. Thus, scores for scour of spawning gravels in Tables 3-2 and 3-3 represent the frequency with which scour is likely to affect the egg pocket.

3.1.2 Evaluation of Flood Control Operation Effects on Bank Erosion

Dry Creek

When sustained flows above 2,500 cfs occur on Dry Creek, streambank erosion is initiated. For the period of record (water years 1960 to 1995), streamflows above 2,500 cfs were tallied on an annual basis. The greater the number of days that exceed 2,500 cfs in a given year, the greater the likelihood of streambank erosion and the lower the score. Dry Creek bank erosion scores are presented for two locations (immediately below Warm Springs Dam and Near Geyserville) by water year in Table 3-4. The Near Geyserville location is below the Pena Creek confluence, which represents the most significant tributary input on the Dry Creek system.

Figure 3-1 is a frequency histogram of the Dry Creek bank erosion scores. Near Geyserville, about half of the years in the period of record analyzed receive a score of 5, indicating that no more than 3 days per year flows exceeded 2,500 cfs. More than one-half of the years received a score of 5 below Warm Springs Dam. A score of 1 was received near Geyserville for ten out of the 36 years in the record. Thus, approximately 28% of the time, flows exceeded 2,500 cfs more than 16 days in each of those ten years.

Bank erosion scores are relatively good immediately below Warm Springs Dam. About 28% of the time (ten years in the period of record) streamflow conditions are highly conducive to bank erosion near Geyserville. Inspection of the flow records indicates that in many years when the score is 1, there are at least five or more consecutive days with flows exceeding 2,500 cfs, indicating prolonged high flow conditions.

It is important to note that on many days when flows exceeded the erosion threshold at the Near Geyserville location, discharge from Warm Springs Dam was low. For example, inspection of the modeled flow records indicate that in water year 1983, there were 33 days when flows exceeded the 2,500 cfs erosion threshold Near Geyserville (Table 3-4); but on 13 of those 33 days, the release from Warm Springs Dam was no greater than 120 cfs. Flood control operations are often timed so that reservoir outflows during prolonged peak streamflow conditions downstream are a relatively insignificant contributor to total flow and bank erosion.

Of the 318 days during the modeled period of record when flows exceeded the 2,500 cfs erosion threshold, there were 114 days (36% of the time), when natural flow accretion alone below Warm Springs Dam was greater than the 2500 cfs erosion threshold. Flow releases were either very low or smaller than natural flow accretion below the dam on so that the erosion threshold would have been exceeded regardless of flow releases from the dam. Therefore, the evaluation criteria may overstate the influence of flood control operations at Warm Springs Dam on downstream bank erosion. Regardless, the scoring results indicate that flood operations at Warm Springs Dam do not cause prolonged flows above the threshold that initiate streambank instability and erosion in most years.

Mainstem Russian River

When sustained flows exceed 6,000 cfs at Hopland and 8,000 cfs at Cloverdale, the evaluation criteria indicate that streambank erosion is initiated on the Russian River. A tally of the number of flows exceeding the bank erosion threshold and the resulting bank erosion scores are presented for both locations by water year in Table 3-5. A frequency histogram of scores is presented in Figure 3-2.

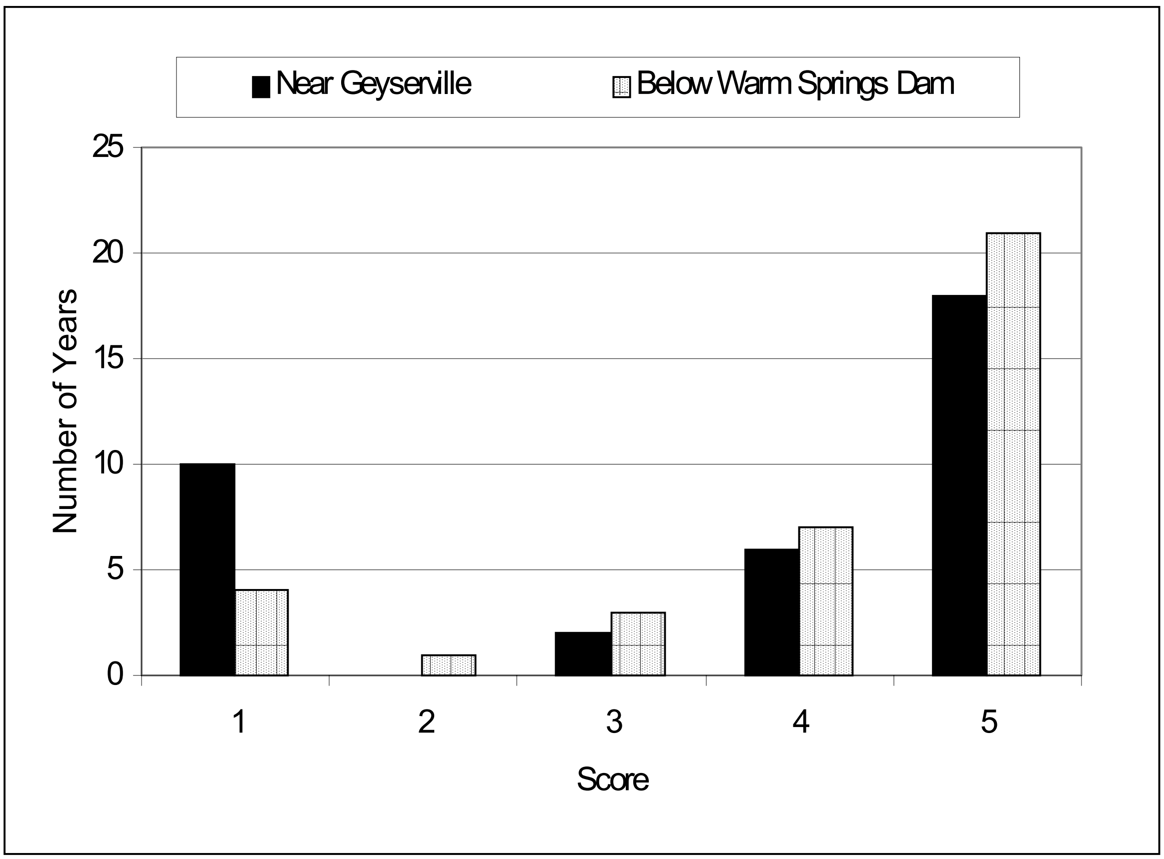

Figure 3-1 Frequency Histogram of the Dry Creek Bank Erosion Scores

Table 3-4 Number of Days with Flow Exceeding 2,500 cfs on Dry Creek and Score

Water Year	Days Exceeding 2,500 cfs		Score	
	Below Warm Springs Dam	Near Geyserville	Warm Springs Dam	Near Geyserville
1960	3	3	5	5
1961	0	0	5	5
1962	4	7	4	4
1963	5	6	4	4
1964	0	0	5	5
1965	10	16	3	1
1966	4	4	4	4
1967	9	8	3	3
1968	0	0	5	5
1969	19	18	1	1
1970	26	31	1	1
1971	1	5	5	4
1972	0	0	5	5
1973	7	18	4	1
1974	17	33	1	1
1975	3	7	5	4
1976	0	0	5	5
1977	0	0	5	5
1978	0	6	5	4
1979	0	2	5	5
1980	12	21	2	1
1981	0	0	5	5
1982	7	18	4	1
1983	10	36	3	1
1984	0	3	5	5
1985	0	0	5	5
1986	5	10	4	3
1987	0	0	5	5
1988	0	1	5	5
1989	0	0	5	5
1990	0	0	5	5
1991	0	0	5	5
1992	0	0	5	5
1993	7	25	4	1
1994	0	2	5	5
1995	33	39	1	1

Table 3-5 Number of Days with Flow Exceeding 6,000 cfs at Hopland, 8,000 cfs at Cloverdale and Corresponding Annual Score

Water Year	Days Exceeding 6,000 cfs at Hopland	Days Exceeding 8,000 cfs at Cloverdale	Score	
			Hopland	Cloverdale
1960	2	4	5	4
1961	2	3	5	5
1962	4	5	4	4
1963	2	2	5	5
1964	1	2	5	5
1965	16	16	1	1
1966	2	3	5	5
1967	5	4	4	4
1968	0	0	5	5
1969	12	10	2	3
1970	13	12	2	2
1971	7	6	4	4
1972	0	0	5	5
1973	5	6	4	4
1974	9	17	3	1
1975	8	7	3	4
1976	0	0	5	5
1977	0	0	5	5
1978	15	14	2	2
1979	1	1	5	5
1980	9	13	3	2
1981	1	2	5	5
1982	12	12	2	2
1983	13	18	2	1
1984	4	7	4	4
1985	1	1	5	5
1986	2	14	5	2
1987	0	0	5	5
1988	1	1	5	5
1989	1	1	5	5
1990	0	0	5	5
1991	0	3	5	5
1992	0	1	5	5
1993	6	9	4	3
1994	0	0	5	5
1995	12	21	2	1

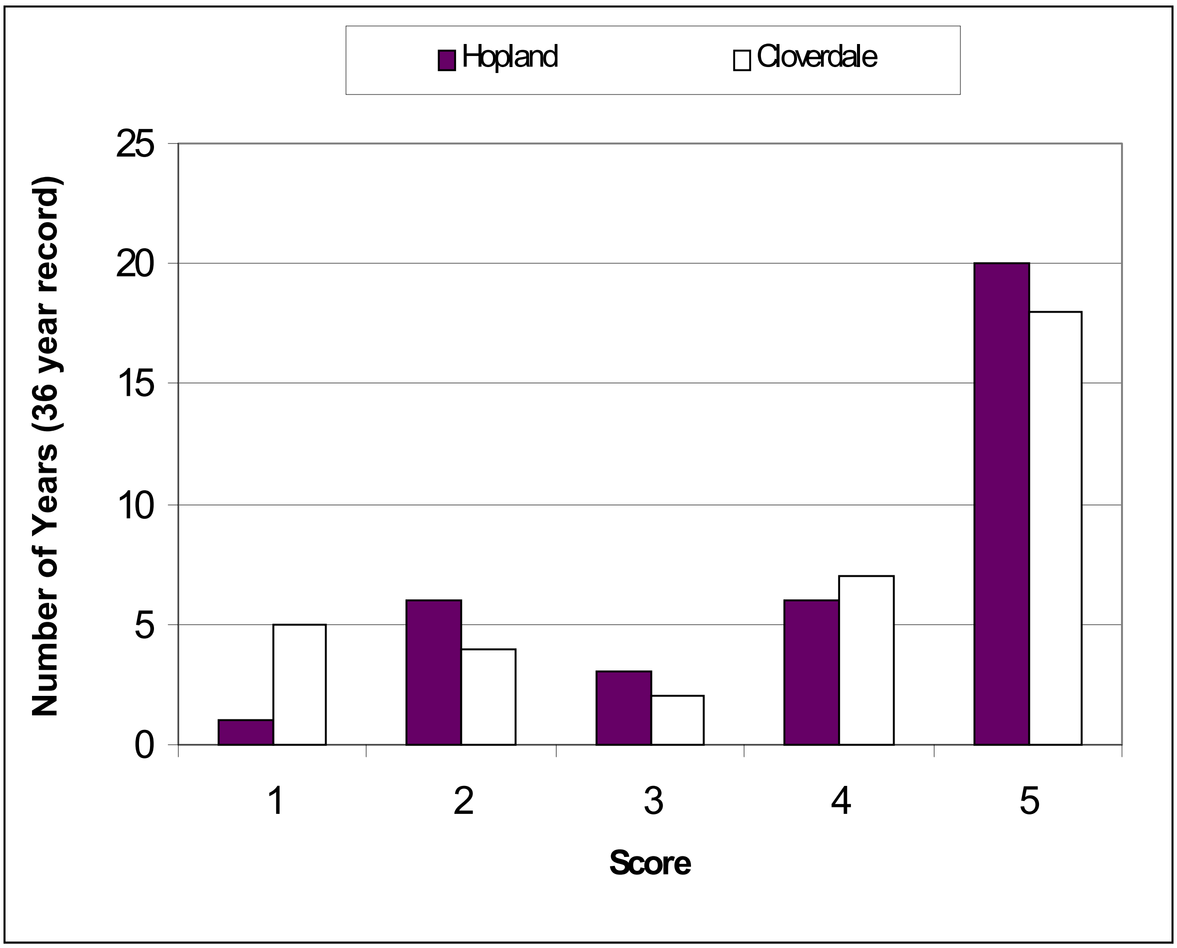

Figure 3-2 Frequency Histogram of Bank Erosion Scores on Mainstem Russian River

The majority of years receive a score of 5 at both locations evaluated. At Hopland, 80% of the 36 year period of record received a score of 3 or better. At Cloverdale, 75% of the 36 year period of record receive a score of 3 or better. It is noteworthy that on many of the days when flows exceed the erosion threshold established in the criteria, discharge from Coyote Valley Dam is low. For example, in 1995 there were 12 days when flows exceeded the 6,000 cfs erosion threshold, but the release from Coyote Valley Dam never exceeded 600 cfs, and was usually only 35 cfs. At Cloverdale, there were 21 days when flows exceeded the 8,000 cfs erosion threshold, but on only three of those days was the release from Coyote Valley Dam responsible for increasing the total discharge above the erosion threshold. Flood control operations are often timed so that reservoir outflows during prolonged peak streamflow conditions downstream are a relatively insignificant contributor to total flow and bank erosion at Hopland or Cloverdale. Thus, evaluation criteria may overstate the influence of Coyote Valley Dam operations on flow and bank erosion. Nevertheless, the scoring results indicate that flood operations at Coyote Valley Dam do not cause prolonged flows above the threshold that initiates streambank instability and erosion.

3.1.3 Evaluation of Flood Control Operation Effects on Channel Maintenance/Geomorphology

Scoring criteria are shown in Table 3-6. A single score is given for the entire period of record (1960 to 1995), since any single year alone does not encompass a sufficiently long time period to assess if flood control operations are adequate to maintain channel geomorphic conditions. By definition, the natural channel-forming flow should occur about twice out of every three years, as a long-term average. When the channel forming flow occurs less frequently, lower scores are applied. Channel-forming flows that occur less than 10% of the time (i.e., less frequently than one out of every ten years) receive a low score of 1, and if the natural channel forming flow is never equaled or exceeded, the score is 0 (see Table 3-6). The scoring applies equally to steelhead, coho, and chinook salmon.

Table 3-6 Scoring Criteria for Maintenance of Channel Geomorphic Conditions

Annual Flood Exceedance Frequency	Number of Years per 36 Year Period of Record[a]	Score
51%-66%	19-24	5
36%-50%	14-18	4
21%-35%	8-13	3
11%-20%	5-7	2
1%-10%	4 or less	1
0%	0	0

[a] Multiple channel forming flows that may occur in a single year are counted as one occurrence for that year.

Mainstem Russian River

The hydrologic record developed from flow modeling was evaluated to determine the frequency of occurrence of the channel-forming flow. As discussed in section 2.3.2.3, this flow (as an average one-day discharge) was estimated to be 9,500 cfs at Hopland, 14,000 cfs at Cloverdale, and 21,000 cfs at Healdsburg (see Table 2-21). Table 3-7 shows the number of flood events that equal or exceed the channel-forming flow at each location (years which do not achieve the channel-forming flow are not shown) and the resulting score based on the criteria in Table 3-6. The score is a function of the number of years that have at least one flood event as an annual maximum that equals or exceeds the channel forming discharge.

The results show that at Hopland and Cloverdale, the channel-forming discharge will occur with an annual exceedance frequency between 36%-50%, or about 18 times over the 36 years in the period of record analyzed. Therefore, a score of 4 is given for these two locations, indicating that the flood regime on the Upper Reach of the mainstem Russian River is adequate to maintain channel geomorphic conditions. At Healdsburg, the channel-forming discharge is equaled or exceeded in 21 out of the 36 years assessed, so the score is 5. This reflects the fact that peak flow events at Healdsburg are relatively unaffected by flood control operations at Coyote Valley Dam.

Table 3-7 Tally of Flow Events Exceeding Channel-Forming Discharge (as Average Daily Flow) and Score for Mainstem Russian River

Water Year	Hopland 9,500 cfs	Cloverdale 14,000 cfs	Healdsburg 21,000 cfs
1960	1	2	2
1962	0	1	3
1963	1	2	2
1965	6	6	5
1966	2	2	1
1967	1	1	1
1969	4	4	2
1970	7	5	7
1971	2	2	3
1973	1	0	3
1974	3	4	5
1975	1	0	1
1978	4	3	5
1980	3	4	5
1982	5	4	6
1983	6	5	9
1984	0	2	1
1986	1	6	7
1991	0	0	1
1993	2	3	3
1995	5	9	9
Number of Water Years with a Flow Event that Equals or Exceeds Channel Forming Discharge	18	18	21
Score	**4**	**4**	**5**

Dry Creek

The channel forming discharge (as an average daily flow) on Dry Creek was estimated to be 7,000 cfs near Geyserville (below the Pena Creek tributary confluence). Table 3-8 shows the number of flood events that equal or exceed the channel-forming flow (years that do not achieve the channel-forming flow are not shown). Results show that there are six years that equal or exceed the channel-forming discharge on Dry Creek. This represents a 17% frequency for the 36 year period of record, and therefore the score is 2. This is a low score, indicating that flood operations have reduced the frequency of achieving the channel-forming flow (which is the purpose of a flood control project) and may not be adequate to maintain overall channel geomorphic conditions.

Table 3-8 Tally of Flow Events Exceeding Channel-Forming Discharge on Dry Creek

Water Year	Near Geyserville 7,000 cfs
1970	4
1971	1
1973	1
1974	2
1978	1
1980	2
Number of Water Years with a Flow Event that Equals or Exceeds Channel Forming Discharge	6
Score	**2**

Immediately below Warm Springs Dam the channel forming discharge (as an average daily flow) is 5,000 cfs. There were no flows over the period of record which equaled or exceeded the channel forming discharge. Therefore, the score for the channel reach between the dam and Pena Creek is 0, indicating potentially inadequate channel maintenance flow.

3.2 Fish Stranding: Ramping Rate Effects on Protected Species

Ramping rates constrain the rate (cfs/hr) at which a controlled release can be changed to protect against fish stranding. The following analysis of ramping rates for Dry Creek and the Russian River assumes the influence of ramping on Dry Creek has been attenuated within 1-1.5 miles downstream of Warm Springs Dam and on the mainstem Russian River about 5 miles or less downstream of Coyote Dam near the Perkins Street bridge crossing in Ukiah. Scoring criteria assess whether the rates of stage change during project operations meet either the Hunter guidelines or the interim ramping rate guidelines (Table 2-26).

3.2.1 Warm Springs Dam

Stage-discharge relationship information generated by the HEC-RAS model was used to evaluate potential ramping effects. Hourly flow release data was also inspected to determine to what extent ramping was occurring within the established interim guidelines.

Hourly flow release data at Warm Springs Dam was inspected for 1997 to 1999. Typically, ramping rates were within the established interim guidelines of 250 cfs/hr for flows between 1,000 cfs to 250 cfs and only infrequently exceeded this ramping rate. For flows below 250 cfs, ramping rates were within the established interim guidelines of 125 cfs/hr and only infrequently exceeded this ramping rate. Often flow reductions were less than the 125 cfs/hr rate when releases were below 250 cfs. Therefore, based on the scoring criteria in Table 2-26 and 2-27, flood control operations receive a score of at least 3, or better if the more restrictive Hunter (1992) evaluation criteria can be achieved.

On Dry Creek the first ten cross-sections up to 1.5 miles below Warm Springs Dam were tested. Stage changes associated with 250 cfs/hr reductions in flow exceeded the criterion of 0.16 ft/hr for juveniles at all ten cross-sections tested on Dry Creek. HEC-RAS model results indicate that stage changes range from .20 feet to 0.8 feet. The greatest change in stage at each cross-section was always associated with ramping at the lowest release flows, from 500 cfs to 250 cfs.

Four of the ten most downstream cross-sections (numbers 103 to 106) generally met the 100% increase in 0.16 ft/hr evaluation criteria for juveniles (i.e., 0.32 ft/hr), which would merit a score of 4. However, the remaining six cross-sections closest to Warm Springs Dam did not meet the 0.32 ft/hr evaluation criteria. Therefore the final score is a 3 for ramping during reservoir releases in the range of 1,000-250 cfs (Table 3-9). This score is applicable to both fry and juvenile life stages for all three protected species.

Table 3-9 Dry Creek Ramping Scores for High Reservoir Outflows (1,000-250 cfs)

Criteria	Score	Scoring Category
Meet 0.16 ft Maximum Stage Change		5
Within 100% of 0.16 ft Criteria (0.32 ft) for Stage Change		4
Meets Interim Ramping Criteria (250 cfs/hr)	X	3
Exceeds Interim Ramping Criteria up to 50% (375 cfs/hr)		2
Exceeds Interim Ramping Criteria by Greater than 50% (375 cfs/hr)		1

Results were similar for stage changes associated with 125 cfs/hr flow reductions when reservoir release flows are between 250-0 cfs. Stage changes were usually greater than 0.5 feet/hour, and range between 0.2 to 0.8 feet. The 0.16-foot stage change could not be met at any of the cross-sections. The 0.32 ft/hr evaluation criteria could be met at only a few of the most downstream cross-sections. Therefore the final score is a 3 for ramping during reservoir releases in the range of 250-0 cfs (Table 3-10). This score is applicable to both fry and juvenile life stages for steelhead and chinook salmon.

Table 3-10 Dry Creek Ramping Scores for Low Reservoir Outflows (250-0 cfs)

Criteria	Score	Scoring Category
Meet 0.16 ft Maximum Stage Change		5
Within 100% of 0.16 ft Criteria (0.32 ft) for Stage Change		4
Meets Interim Ramping Criteria (125 cfs/hr)	X	3
Exceeds Interim Ramping Criteria up to 50% (188 cfs/hr)		2
Exceeds Interim Ramping Criteria by Greater than 50% (1>188 cfs/hr)		1

3.2.2 COYOTE VALLEY DAM

Hourly flow release data at Coyote Valley Dam was inspected for 1997 to 1999. Typically, ramping rates were within the established interim guidelines of 250 cfs/hr for flows between 1,000 cfs to 250 cfs and only infrequently exceeded this ramping rate. For flows below 250 cfs, ramping rates were within the established interim guidelines of 125 cfs/hr and only infrequently exceeded this ramping rate. Often flow reductions were less than the 125 cfs/hr rate when releases were below 250 cfs. Therefore, based on the scoring criteria in Table 2-26, flood control operations receive a score of at least 3, or better if the more restrictive Hunter (1992) evaluation criteria can be achieved.

On the mainstem Russian River, we considered the ramping performance at four cross-sections from about 3 miles below Coyote Dam to 5 miles below the dam near the Perkins Street bridge crossing in Ukiah. There are no existing cross-section surveys further upstream or on the East Fork Russian River. Similar to the results for Dry Creek, at 250 cfs/hr ramping rates, none of the six cross-sections could achieve 0.16 criteria, nor could they achieve the stage change within 100% of the criteria. Change in stage was generally 0.5 ft or more when ramping at 250 cfs increments. Therefore the final score is a 3 for ramping during reservoir releases in the range of 1,000-250 cfs (Table 3-11). This score is applicable to steelhead fry and juvenile life stages. Chinook and coho do not generally rear in the East Fork.

Table 3-11 Coyote Valley Dam Ramping Score for High Reservoir OutFlow (1,000-250 cfs)

Criteria	Score	Scoring Category
Meet 0.16 ft Maximum Stage Change		5
Within 100% of 0.16 ft Criteria (0.32 ft) for Stage Change		4
Meets Interim Ramping Criteria (250 cfs/hr)	X	3
Exceeds Interim Ramping Criteria up to 50% (375 cfs/hr)		2
Exceeds Interim Ramping Criteria by Greater than 50% (375 cfs/hr)		1

Results were similar for stage changes associated with 125 cfs/hr flow reductions when reservoir release flows are between 250-0 cfs. Stage changes were greater than 0.5 ft at this ramping rate. Thus, 0.16 foot stage change criteria could not be met at any of the cross-sections, nor could they achieve the stage change within 100% of the criteria. Therefore, the final score is a 3 for ramping during reservoir releases in the range of 250-0 cfs (Table 3-12). This score is applicable to steelhead and chinook fry and juveniles. Coho salmon generally rear in the tributaries rather than the mainstem.

Table 3-12 Coyote Valley Dam Ramping Scores for Low Reservoir Outflows (250-0 cfs) During Flood Control Operations

Criteria	Score	Scoring Category
Meet 0.16 ft Maximum Stage Change		5
Within 100% of 0.16 ft Criteria (0.32 ft) for Stage Change		4
Meets Interim Ramping Criteria (125 cfs/hr)	X	3
Exceeds Interim Ramping Criteria up to 50% (188 cfs/hr)		2
Exceeds Interim Ramping Criteria by Greater than 50% (>188 cfs/hr)		1

3.3 Annual and Periodic Dam Inspection and Maintenance Effects

3.3.1 Ramping Rates

Ramping rates during dam maintenance or inspection activities are 25 cfs/hr at Warm Springs Dam and 50 cfs/hr at Coyote Valley Dam. Evaluation criteria score ramping practices at Warm Springs and Coyote Valley dams for periods when fry are present and when juveniles only are present. Because fry are the most susceptible life history stage, protection for them will protect other life-history stages.

Table 3-13 Evaluation Criteria for Low Reservoir Outflows (250-0 cfs) During Dam Maintenance and Pre-Flood Inspection Periods

Change in Flow (cfs/hr)	Score Juvenile	Score Fry	Operations Score	Species Affected*
0-10	5	5		
10-20	5	4		
20-30	4	3	WSD	co, st,
30-40	3	2		
40-50	2	1	CVD	co, st, ch
>50	1	0		

*co = Coho, st = steelhead, ch = chinook

At Warm Springs Dam, flows are ramped at a rate of 25 cfs/hr, and a score of 3 is given for the period when fry are present. Table 3-14 outlines the periods when spawning and incubation take place, and estimates when fry may be present for each species. Growth is dependent on habitat conditions and food availability, and may vary from year to year. The score for juveniles is 4, and the risk for stranding is less when fry are not present.

Table 3-14 Times When Fry May Be Present in the Russian River Drainage

Species	Emergence	Fry May Be Present
Coho	Feb. 1 - Mar. 31	Feb. - April
Steelhead	Mar. 1 - May 31	Mar. - June
Chinook	Feb. 1 - Mar. 31	Feb. - April

At Coyote Valley Dam, flows can not be decreased at a rate less than 50 cfs/hr. Therefore a score of 1 is given for periods when fry are present, and 2 when only juveniles are present. Stranding has been documented on the mainstem Russian River during inspection and maintenance activities on Coyote Valley Dam. During May, when higher flows might have been expected to attenuate the effects of ramping down fish are smaller and may be more susceptible to stranding. During low flow months, less attenuation from mainstem flow would be expected to occur, and dewatering becomes a concern. These scores are applicable when ramping takes place during periods when flows are less than 500 cfs at the Ukiah gage. Dam maintenance and pre-flood inspection activities at Coyote Valley Dam have the potential to affect salmonids of all three species.

3.3.2 Annual and Periodic Dam Inspection Effects Related to Reduced Flows

Dry Creek

Since there is a bypass flow capability at Warm Springs Dam, dewatering is unlikely, and has not occurred under recent operational practices. The bypass streamflow is generally about 25 cfs. Steelhead, coho salmon, and chinook salmon fry may be rearing in May when dam inspection and maintenance activities are scheduled.

Based on the rearing evaluation criteria (Table 2-31), a 25 cfs streamflow in Dry Creek receives a score of 3. It is noteworthy that a slightly lower streamflow, 21-23 cfs receives a higher score of 4, and slightly higher streamflow, 27-43 cfs receives a lower score of 2. The higher flows (27-43 cfs) are associated with higher velocities, which based on the Winzler and Kelly criteria result in less favorable rearing conditions than lower flows with associated lower velocities. The final score for rearing habitat conditions is a 3 for steelhead, coho salmon, and chinook salmon.

East Fork and Mainstem Russian River Below Coyote Valley Dam

At Coyote Valley Dam, dewatering and rescue of juvenile steelhead was necessary on the East Fork and further downstream on the mainstem Russian River during inspection and maintenance activities that took place in September 1998. However, during inspection and maintenance in June 1999, streamflow releases were near 0 cfs. No stranding was documented, nor was rescue necessary, as pools were maintained on the East Fork to provide refuge, except for a very small area of the stream near the dam at the streamflow gaging weir (Terry Marks, USACE, pers. comm.). The presence of pools and lack of stranding may have in part been due to dewatering of the stilling basin, which provided about 5 cfs for several hours following cessation of releases from the dam. In addition, flow accretion from seepage or groundwater contributions may have also maintained pools and a small streamflow.

Winzler and Kelly rearing habitat scores do not include the East Fork, so it is not applicable to use their criteria to rate habitat conditions during maintenance and inspection activities. Habitat conditions were apparently adequate to support fry and juvenile rearing, given the monitoring observations in June 1999 and the relatively short period of time that flows were reduced. Nevertheless, there is a potential that pool habitat could be dewatered on the East Fork and stranding could occur if:

- inspection and maintenance activities lasted for more than several hours requiring a longer period of flow cessation from Coyote Dam;
- the stilling basin does not need to be dewatered for inspection in any given year, eliminating this source of flow contribution;
- inspection and maintenance take place in a drought year when there is little baseflow accretion from groundwater contributions.

Further downstream on the mainstem from the Forks to about 4 miles downstream, actual flow conditions are assumed to be approximately that recorded by the Ukiah gage, upstream from the Forks. In June 1999 this flow was about 14 cfs. Inspection of flow records since 1995 indicate that 35 cfs or more may be expected at the gage. Assuming that flows on the mainstem are at least 9-14 cfs, the score for rearing habitat conditions on the mainstem is a 3 (Table 3-15). Given that flows may often be greater than 14 cfs, rearing habitat scores will improve. Between 15-18 cfs the score is a 4, and from 19-71 cfs, the score is a 5. At flow ranges above 71 cfs, rearing scores begin to decrease. However, if flows are greater than 71 cfs on the mainstem at the Forks, cessation of flows at Coyote Dam would only tend to reduce mainstem Russian River flow and thereby improve rearing conditions. For purposes of this assessment, the rearing habitat score on the mainstem is a 3, which is based on the lowest one-day streamflow recorded at the Ukiah gage in the month of May during the past five years. It is likely that for most days in May, habitat scores will be better than a 3, reflecting the typically higher flow conditions on the mainstem.

Table 3-15 Rearing Habitat Score for the Upper Reach of the Russian River

Habitat Scoring	Score	Streamflow in CFS	Streamflow in CFS	Streamflow in CFS
5		19-71		
4		15-18	71-88	
3	X	9-14	88-100	106-122
2		4-8	100-106	>122
1		>0-3		
0		0		

In general, there is a risk of significant effects on protected species related to activities associated with maintenance and pre-flood inspection activities at Coyote Valley Dam. There is also a potential risk of significant effects associated with maintaining channel geomorphic conditions on Dry Creek related to flood control operations at Warm Springs Dam. Based on analysis of the issues, flood control operations are likely to adversely affect the listed fish species and are likely to adversely affect the desginated critical habitat of the listed fish species. There are no cumulative effects associated with flood control operations or dam maintenance and pre-flood inspection activities at either dam.

4.1 SUMMARY OF FLOOD CONTROL OPERATION EFFECTS ON CHANNEL GEOMORPHOLOGY

4.1.1 SCOUR OF SPAWNING GRAVELS

Potential for scour of spawning gravels was evaluated at three locations: Dry Creek, mainstem Russian River in Alexander Valley (upstream of Healdsburg), and the mainstem Russian River upstream of Alexander Valley to Ukiah. The potential for scour of spawning gravels was based on an analysis of channel hydraulic conditions that initiate motion of the streambed and the expected depth of scour. The analysis distinguishes between streambed particle sizes used by steelhead, chinook, and coho salmon for spawning. Some mobilization and scour of spawning gravels is necessary over the long-term in order to maintain the quality of spawning gravels by transporting fine sediments. However, frequent mobilization and scour of spawning gravels will reduce reproductive success.

On Dry Creek, flood control operational effects were evaluated for steelhead, chinook, and coho salmon. Results indicate that there is a reasonably good balance between expected periodic streambed mobilization and spawning gravel stability for successful reproduction of chinook, and an acceptable balance for successful steelhead and coho reproduction. Coho salmon, utilizing smaller gravels for spawning, would be subject to a greater frequency of scour than either chinook or steelhead redds. About 36% of the time, it can be expected that coho salmon will have fairly stable gravel substrate for spawning through the high flow season, and about 64% of the time, there will likely be mobilization of gravels at most locations on Dry Creek. Depth of scour calculations indicate that for 92% of the coho gravels that are mobilized, there will be scour to the depth of the egg pocket.

On the mainstem Russian River, potential effects were evaluated for steelhead and chinook only, since coho salmon do not utilize the mainstem for spawning. The Upper and Middle Reaches, between Ukiah and Alexander Valley were included in the assessment. Downstream of Alexander Valley, spawning habitat is limited (Winzler and Kelly 1978), and flood control operations have a diminishing effect on high flow conditions; so the lower mainstem reach was not considered for evaluation.

Results indicate that stability of steelhead spawning gravels is very good in the upper mainstem reach. The potential for scour of chinook gravels is moderate, but represents an acceptable balance between periodic streambed mobilization and spawning gravel stability. The lower incidence of scour of steelhead gravels compared with chinook gravels is at least partially due to the later season incubation period for steelhead. The incidence of flows that might scour spawning gravels later in the season when steelhead are incubating is fairly low on the Upper Reach.

In the Middle Reach of the Russian River at Alexander Valley, spawning gravels are less stable and subject to slightly more frequent scour than the Upper Reach. Results indicate moderately stable conditions for chinook, and moderately, but slightly less stable conditions for steelhead. Higher discharges due to tributary flow accretion probably account for the greater incidence of scour in the Middle Reach compared with the Upper Reach. Flood control operations do not have a significant affect on spawning gravel scour in the Middle Reach or Upper Reach of the Russian River.

4.1.2 Bank Erosion

The potential for bank erosion was evaluated on Dry Creek and the Upper and Middle Reach of the Russian River. The analysis is based on an evaluation of the magnitude and frequency of streamflows (using hydrologic modeling provided by USACE) above a threshold discharge identified as the flow at which bank erosion is initiated.

It should be noted that bank erosion is not solely a function of streamflow conditions. Removal of riparian vegetation under various land-use and land-management practices generally increases the risk of bank erosion. Additionally, bank erosion is to some degree a natural process of lateral channel migration that sustains important components of fish habitat by recruiting spawning gravel, woody debris and detritus from the riparian corridor.

On Dry Creek, sustained flows above 2,500 cfs are considered to initiate bank erosion. The bank erosion analysis was performed at two locations, immediately below Warm Springs Dam and downstream of the most significant tributary confluence at Pena Creek (the Near Geyserville location). Overall, the analysis indicates that the potential for bank erosion is relatively low in most, but not all years. For more than one-half of the years in the period of record (21 out of 36 years) there are only three or fewer days when streamflow exceeds 2,500 cfs immediately below Warm Springs Dam.

There are about ten years in the period of record when streamflow exceeds the 2,500 cfs threshold for at least 16 days or more below the Pena Creek confluence. Thus bank erosion is an infrequent, but periodically occurring problem. However, inspection of the streamflow gaging records indicates that on many days when flows exceeded the erosion threshold at the Near Geyserville location, discharge from Warm Springs Dam was low. Flood control operations are often timed so that reservoir outflows during prolonged peak streamflow conditions downstream are a relatively insignificant contributor to total flow and therefore to bank erosion. There were approximately 68 days out of the total 319 days in the period of record when flow releases were less than 500 cfs from Warm Springs Dam, but total flow exceeded 2,500 cfs near Geyserville. There are also many days when flow at the Near Geyserville location is well above the 2,500 cfs erosion threshold, much of which was from natural flow accretion below the reservoir, so that even without the additional flow releases from Warm Springs Dam the erosion threshold would have been exceeded. This occurred approximately 36% of the time over the period of record. Thus, the evaluation criteria may overstate the influence of flood control operations at Warm Springs Dam as a contributor to downstream bank erosion. Regardless, the scoring results indicate that flood operations at Warm Springs Dam are not a significant factor contributing to prolonged flows above the threshold that initiates streambank instability and erosion in most years.

On the mainstem Russian River, 6,000 cfs at Hopland in the Upper Reach, and 8,000 cfs at Cloverdale in the Middle Reach were identified as the flow threshold at which bank erosion is likely to be initiated. The analysis indicates that prolonged flows above these thresholds are relatively infrequent. At Hopland, 80% of the 36-year period of record modeled receive a score of 3 or better. At Cloverdale, 75% of the 36-year period of record receive a score of 3 or better. It is noteworthy that on many of the days when flows exceed the erosion threshold established in the criteria at either location, discharge from Coyote Valley Dam is low. Flood control operations are often timed so that reservoir outflows during prolonged peak streamflow conditions downstream are a relatively insignificant contributor to total flow and to bank erosion at Hopland or Cloverdale. Thus, evaluation criteria may overestimate the influence of Coyote Valley Dam operations on flow and bank erosion. Nevertheless, the scoring results indicate that flood operations at Coyote Valley Dam do not cause prolonged flows above the threshold that initiates streambank instability and erosion.

4.1.3 Channel Maintenance/Geomorphology

Maintaining channel geomorphic conditions, particularly balancing sediment supply with sediment transport so that the channel is neither aggrading or degrading, was evaluated for Dry Creek and the mainstem Russian River. The analysis is based on an evaluation of the magnitude and frequency of streamflows (using hydrologic modeling provided by USACE) above a threshold discharge identified as the natural channel-forming flow.

On Dry Creek, the natural channel forming discharge was estimated to be 7,000 cfs (as a one-day flow) downstream of the Pena Creek confluence and 5,000 cfs upstream of Pena Creek. Results indicate that the channel forming discharge is achieved below Pena Creek as an annual maximum flow about once every six years, over the long-term. This is lower than the commonly accepted channel maintenance flow which would be about once every two out of three years. This frequency of occurrence is given a score of 2 based on the established criteria (see Section 2.3.2) and reflects the ability of flood control operations at Warm Springs Dam to reduce the frequency of peak flow events. The channel forming discharge is never achieved in the 1.5-mile reach above Pena Creek. Therefore, the score for this reach of channel is 0. These scores indicate flows of potentially insufficient magnitude and frequency to maintain channel geomorphic conditions on Dry Creek. Insufficient channel maintenance flows may result in excess sedimentation of the streambed and could impair spawning or rearing habitat. This would be of most concern at locations downstream of the dam where tributaries deliver sediment to Dry Creek, and may therefore adversely affect critical habitat.

On the mainstem Russian River, the channel forming discharge was identified in the Upper Reach as 9,500 cfs at Hopland, and in the Middle Reach as 14,000 cfs at Cloverdale and 21,000 cfs at Healdsburg. The results indicate that the natural channel forming discharge occurs only slightly less often than the estimated "ideal" frequency of once every two out of three years. Therefore, flood control operations have a minimal effect on channel maintenance/morphologic conditions on the mainstem.

It should be recognized that there are many other factors and land-use conditions that may affect channel morphologic conditions. For example, gravel mining was recognized to have been a significant factor which in recent decades led to channel incision and widening on Dry Creek. Other conditions such as removal of riparian vegetation or land-uses that may increase watershed sediment supply can alter channel geomorphology and influence fish habitat conditions.

4.2 SUMMARY OF FLOOD OPERATION RAMPING EFFECTS ON FISH STRANDING

Fish stranding may occur due to ramping of streamflows during flood control operations at high reservoir releases (1,000-250 cfs) and at lower reservoir releases (less than 250 cfs). Fry and juveniles are most vulnerable during ramping due to their poorer swimming abilities, although adults can also be stranded. In consultation with NMFS and CDFG, USACE has developed interim guidelines for flow release changes, summarized as follows:

Reservoir OutFlow	Ramping Rate
0-250 cfs	125 cfs/hour
250-1,000 cfs	250 cfs/hour
>1,000 cfs	1,000 cfs/hour

Scoring criteria assess whether the rates of stage change during project operations meet either the Hunter guidelines or the interim ramping rate guidelines (see Tables 2-24 and 2-25). HEC-RAS modeling was used to determine the rate of stage change for selected cross-sections available from prior studies on Dry Creek, and on the mainstem Russian River. Hourly flow release data for recent years was also inspected to determine the extent to which flood control operations are meeting the interim ramping guidelines.

The potential for stranding is unlikely given the ramping rates generally used at Coyote Valley Dam and Warm Springs Dam during flood control operations. Current operational conditions associated with interim ramping rates provide adequate protection to listed species.

4.2.1 RAMPING AT WARM SPRINGS DAM

The analysis of ramping rate effects assumes the influence of ramping on Dry Creek has been attenuated within 1 to 1.5 miles downstream of Warm Springs Dam, above the Pena Creek confluence. Review of the hydrologic record indicates that Warm Springs Dam is usually operated within the 250 cfs/hr interim ramping rate (when reservoir flows are less than 1,000 cfs) and within the 125 cfs/hr interim ramping rate (when reservoir outflows are less than 250 cfs).

Stage-discharge modeling results using HEC-RAS indicate that the Hunter (1992) criteria for fry and for juveniles was not met with a 250 cfs/hr ramping rate for any of the ten cross-sections considered. Change in stage was generally between 0.2 to 0.8 ft/hr. Four of the ten most downstream cross-sections (numbers 103 to 106) generally met the criteria at 100% increase in 0.16 ft/hr evaluation criteria for juveniles (i.e., 0.32 ft/hr), however, the remaining six cross-sections closest to Warm Springs Dam did not meet the 0.32 ft/hr evaluation criteria. However, Warm Springs Dam is usually operated within the 250 cfs/hr interim ramping rate. Therefore the final score is a 3 for ramping during reservoir releases in the range of 1,000-250 cfs (Table 3-9). This score is applicable to both fry and juvenile life stages, for all three protected species.

Results were similar for stage changes associated with 125 cfs/hr flow reductions when reservoir release flows are between 250-0 cfs. Stage changes were usually greater than 0.5 ft/hr, and range between 0.2 to 0.8 ft. The 0.16 ft stage change criteria was not met at any of the cross-sections. The 0.32 ft/hr evaluation criteria could be met at only a few of the most downstream cross-sections. However, Warm Springs Dam is usually operated within the 125 cfs/hr interim ramping rate when reservoir outflows are less than 250 cfs. Therefore, the final score is a 3 for ramping during reservoir releases in the range of 250-0 cfs (Table 3-10). This score is applicable to both fry and juvenile life stages, for all three protected species.

4.2.2 Ramping at Coyote Valley Dam

On the mainstem Russian River, ramping effects were considered from about 3 miles below Coyote Valley Dam to 5 miles below the dam, using four cross-sections in this reach (no cross-sections are available closer than 3 miles from the dam). It is important to note that ramping effects will be most significant immediately below Coyote Valley Dam on the East Fork during flood control operations. At the Forks, there is usually considerable flow from the mainstem Russian River that would attenuate ramping effects. Often flows are greater than 2,500 cfs at the Forks during flood operations ramp-down, and there is a backwater effect on the East Fork which would attenuate stage changes (Pugner, USACE, pers. comm.).

Similar to the results for Dry Creek, at 250 cfs/hr ramping rates none of the four cross-sections could achieve the 0.16 criteria, nor could they achieve the stage change within 100% of the criteria. Change in stage was generally 0.5 ft or more when ramping at 250 cfs increments. However, Coyote Valley Dam is usually operated within the 250 cfs/hr interim ramping rate when reservoir outflows are 1,000 cfs - 250 cfs. Results were similar for stage changes associated with 125 cfs/hr flow reductions when reservoir release flows are between 250-0 cfs. Therefore the final score is a 3 for ramping during reservoir releases in the range of 1,000-250 cfs (Table 3-11). This score is applicable to steelhead fry and juveniles, and to chinook fry. Chinook juveniles are not present below Coyote Valley Dam, and coho salmon are also not present.

4.3 Annual and Periodic Dam Inspections and Maintenance

4.3.1 Ramping

Ramping during pre-flood inspection and maintenance activities that use a 25 cfs/hr ramping rate provides protection against stranding of listed species on Dry Creek. Ramping during pre-flood inspections and maintenance activities that use a 50 cfs/hr ramping rate at Coyote Valley Dam does not provide protection from stranding for either fry or juveniles. There is a potential for adverse effects to listed species on the East Fork and the mainstem Russian River for several miles below the Forks.

Warm Springs Dam

During dam inspections and maintenance, ramping at Warm Springs Dam typically occurs at the rate of 25 cfs/hr based on inspection of recent flow records and in accord with a recent biological opinion (NMFS, 1999). The current operational practice of 25 cfs/hr ramping was considered for about 1.5 miles downstream of Warm Springs Dam. Incidences of stranding were minor during May 2000, and have not been reported at other times when pre-flood inspections have been scheduled. Based on the evaluation criteria in Table 3-13, the final score for steelhead and coho salmon fry and juveniles is a 3. The stage change expected with a 25 cfs/hr ramping rate was determined using ten cross-sections below the dam and the stage-discharge relationship provided by HEC-RAS modeling. Results indicate that the change in stage is usually less than 0.16 ft/hr, which is a fairly rigorous criteria developed by Hunter (1992) and utilized by Washington State Department of Fisheries for snowmelt-regime streams.

Coyote Valley Dam

Ramping at Coyote Valley Dam during maintenance and inspection activities is typically about 50 cfs/hr. On the mainstem Russian River, we considered recent historical effects of ramping on the East Fork and mainstem Russian River related to incidences of stranding. Based on the evaluation criteria in Table 3-13, current ramping rates do not provide adequate protection from stranding for either fry or juveniles.

The final score for steelhead fry is 1, juveniles 2 and chinook salmon fry 1. Chinook salmon leave the Russian River drainage before the juvenile life stage, and so juveniles are not rated. Coho salmon are not found in the Upper Reach of the mainstem Russian River and are therefore not rated.

4.3.2 Reduced Flow Conditions

Criteria for evaluating the effects of annual and periodic maintenance activities are based on flow conditions for rearing and existing field monitoring observations. The rearing criteria were developed from Winzler and Kelly (1978). Based on the rearing evaluation criteria, reduced streamflows will not significantly affect listed species when there is a 25 cfs streamflow release into Dry Creek. Coyote Valley Dam operations will not significantly affect listed species on the mainstem Russian River below the Forks during maintenance and inspection activities if there is sufficient flow at the Ukiah gage. However, lack of bypass flow capability may cause dewatering and stranding on the East Fork.

Warm Springs Dam

Since there is a bypass flow capability at Warm Springs Dam, dewatering is unlikely, and has not occurred under recent operational practices. The bypass streamflow is generally about 25 cfs. Annual pre-flood inspections generally last for less than one-day, although periodic maintenance work could require flow reductions over a longer time frame. Steelhead, coho salmon, and chinook salmon may be rearing in May when dam inspection and maintenance activities are scheduled. Based on the rearing evaluation criteria (Table 2-26), a 25 cfs streamflow receives a score of 3, which indicates adequate rearing habitat conditions.

East Fork and Mainstem Russian River below Coyote Valley Dam

At Coyote Valley Dam, dewatering and rescue of juvenile steelhead has in the past been necessary on the East Fork and further downstream on the mainstem Russian River during inspection and maintenance activities that took place in the fall. However, during inspection and maintenance in June 1999 no stranding or rescue was necessary, as pools were maintained on the East Fork to provide refuge. The presence of pools and lack of stranding may have in part been due to dewatering of the stilling basin, which provided about 1-4 cfs for several hours following cessation of releases from the dam. In addition, flow accretion from seepage or groundwater contributions may have also maintained pools and a small streamflow. Flow downstream of the Forks near Ukiah on the mainstem Russian River was at least 14 cfs.

Inspection of flow records since 1995 indicate that 35 cfs or more may be expected at the Ukiah gage (USGS gage 11461000) in the month of May, contributing flow to the mainstem below the Forks. During the past five years streamflow have never been less than 11 cfs at the gage in May. Assuming that flows on the mainstem are at least 9-14 cfs, the score for rearing habitat conditions on the mainstem is a 3 (Table 3-13).

Winzler and Kelly rearing habitat criteria were not developed for the East Fork, but rearing habitat conditions appeared to be fair, given the monitoring observations in June 1999 and the relatively short period of time (several hours) that flows were reduced. Nevertheless, there is a potential that pool habitat could be dewatered on the East Fork and stranding could occur if:

- inspection and maintenance activities lasted for more than several hours requiring a longer period of flow cessation from Coyote Dam
- the stilling basin does not need to be dewatered for inspection in any given year, eliminating this source of flow contribution
- inspection and maintenance take place in a drought year when there is little baseflow accretion from groundwater contributions.

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