

## **Appendix 11N Other Flow-Related Upstream Analyses**

# Appendix 11N Other Flow-Related Upstream Analyses

## 11N.1 Introduction

This appendix provides the methods and results for analyses related to four potential direct effects of flows on anadromous salmonids and green sturgeon in the Sacramento, Feather, and American Rivers: redd dewatering, redd scour, juvenile stranding, and low-flow passage effects on upstream migration. Redd dewatering occurs when the water level drops below the depth of the redds or drops low enough to produce depth and flow velocity conditions that are inadequate to sustain incubating eggs or alevins in the redds. Redd scour occurs when flows are high enough to mobilize sediments, destroying redds and their incubating eggs and alevins or entombing the redds when sediments are redeposited. Juvenile stranding occurs when water level drops and the juveniles become isolated from suitable habitat. Juvenile salmon typically rest in shallow slow-moving water between feeding forays into swifter water, which makes them particularly susceptible to stranding during rapid reductions in flow (Jarrett and Killam 2015). Effects on upstream migrating adult salmon or sturgeon may occur if reduced flows result in inadequate water depth or flow over barriers for passage of adult fish.

Other potential effects of project flows on fish species are considered elsewhere in the RDEIR/SDEIS, including Appendix 11H, *Salmonid Population Modeling*; Appendix 11I, *Winter-run Chinook Salmon Life Cycle Model*; Appendix 11K, *Weighted Usable Area Analysis*; Appendix 11L, *Sturgeon Bay-Delta Analysis*, and Appendix 11M, *Inundated Floodplain and Side-Channel Habitat Analysis, including Yolo and Sutter Bypasses*. In addition, Chapter 11 includes a discussion of adult fish passage at the Yolo Bypass Fremont Weir. However, there were some potential effects that were not analyzed for this RDEIR/SDEIS because, due to the complexity of the effects and/or the scarcity of information needed to analyze them, no adequate analysis procedures are currently available.

The two major potential effects of flow on upstream migrating anadromous fish in the three rivers discussed in this appendix (Sacramento, Feather and American Rivers) are: 1) inadequate flow to allow passage over potential barriers such as diversion and bypass weirs and natural streambed obstructions and 2) bioenergetic costs to the fish of swimming in opposition to the flow. Effects of flows on fish passage at weirs and natural barriers are discussed, as noted above, in Chapter 11 and later in this appendix. The bioenergetic costs of adult salmon migrations were not analyzed because adequate analysis procedures to do so are unavailable. These costs are primarily related to flow velocities in the river channel and the bioenergetics of the fish (Enders et al. 2003; Liao 2007; Martin et al. 2015). While effects of uniform flow velocities on adult salmon bioenergetics are reasonably well understood (Enders et al. 2003), many natural settings, such as the river channel of the upstream reaches of the lower Sacramento, Feather, and American Rivers, have turbulent flow with complex flow velocity fields. These velocity fields vary greatly with discharge. Research has demonstrated that upstream migrating salmon

intersperse periods of rest in flow velocity refuges, including complex flow vortices, with spurts of high energy expenditure through channel sections with higher flow velocities (Liao 2007). The bioenergetics of the salmon, which are highly complex, depend on the path through the flow velocity fields selected by the salmon, which change with the amount of flow in the river (Liao 2007; Martin et al. 2015). Adding to the complexity, the effects of temperature on the salmon bioenergetics interact with those of the flow velocities (Martin et al. 2015). Ultimately, what is needed to assess the effects of different flows on upstream migrating salmon is a model that integrates river channel hydraulics, water temperatures, migration behaviors of the salmon, and their bioenergetics for different combinations of flow and temperature. No such model is currently available.

## 11N.2 Methods

### 11N.2.1 Redd Dewatering

The redd dewatering analyses for the Sacramento, Feather, and American Rivers are based on the maximum reduction in flow from the initial flow, or *spawning flow*, that occurs over the duration of an egg cohort. The duration of a cohort in a redd includes egg incubation and alevin development to emergence from the gravel. Based on technical assistance from the National Marine Fisheries Service (NMFS), cohort duration was estimated as 3 months for the four Chinook salmon races (fall-run, spring-run, winter-run, and late fall-run) and steelhead. The minimum flow of the egg cohort period is referred to herein as the *dewatering flow*. If flows during the 3 months subsequent to spawning are all greater than the spawning flow, no dewatering is assumed to occur. The analysis assumes that in Sacramento River, for which the Upper Sacramento River Daily Operations Model (USRDOM) daily time-step flow data are available, a new egg cohort begins each day of the spawning period. The spawning period is assumed to end 3 months prior to the end of the full spawning and incubation period. No daily time-step flow data were available for the Feather or American Rivers, so CALSIM II data, which have a monthly time-step, were used for redd dewatering analyses in these rivers. These analyses assume a new egg cohort begins each month of the spawning period. The use of monthly time-step flow estimates likely underestimates redd dewatering rates, but this potential bias is expected to affect all alternative scenarios equally.

#### 11N.2.1.1 Sacramento River

Table 11N-1 presents the spring-run spawning period and spawning distribution of Chinook salmon in the Sacramento River. The percentage of redds in the Sacramento River lost to dewatering was estimated using U.S. Fish and Wildlife (USFWS) (2006) tables that relate spawning and dewatering flows to percent reductions in species-specific spawning habitat weighted usable area (WUA) (see Appendix 11-K, *Spawning Weighted Usable Area Analysis*). These tables are reproduced in Table 11N-2 through Table 11N-9. USFWS (2006) developed the dewatering tables for winter-run, fall-run, and late fall-run Chinook salmon and steelhead but not for spring-run Chinook salmon. Therefore, as was done for the WUA curves, the fall-run salmon tables (Table 11N-4 and Table 11N-5) were used to estimate spring-run redd dewatering, but flows from the spring-run spawning period and spawning distribution (Table 11N-1) were used to look up the percent of spring-run redds dewatered. The validity of substituting the fall-run tables for spring-run is discussed below in Appendix 11K, *Habitat Weighted Usable Area*

*Analysis.* Separate tables were developed for periods when the Anderson-Cottonwood Irrigation District (ACID) Dam boards are installed (April through October) and for when the boards are out because installation of the boards affects water levels for some of the sampling transects used to produce the tables.

The field studies used for USFWS (2006) were conducted in the Sacramento River between Keswick Dam and Battle Creek at the same locations as the spawning WUA studies discussed in Appendix 11K. USRDOM flow data are available for three locations in the Keswick Dam to Battle Creek river section: Keswick Dam (River Mile [RM] 302), the Sacramento River at Clear Creek (RM 289), and the Sacramento River at Battle Creek (RM 271). In contrast to the WUA studies, a single relationship for flows was developed for the entire river section, but the flows used to estimate redd dewatering in the current analysis were those that best matched the longitudinal distribution of the redds of the different salmon runs in the river as estimated from aerial redd surveys conducted by California Department of Fish and Wildlife from 2003 through 2019 (Table 11N-1). The redd distributions of steelhead in the Sacramento River are poorly known but are expected to be similar to that of spring-run (USFWS 2003). Therefore, Keswick Dam flows were used for winter-run and late fall-run, Sacramento River at Clear Creek flows were used for spring-run and steelhead, and Sacramento River at Battle Creek flows were used for fall-run. Redd dewatering was computed for these flows under Alternatives 1A, 1B, 2, and 3 (hereinafter referred to as Alternatives 1–3) and the No Action Alternative (NAA).

**Table 11N-1. Average 2003–2019 Distributions of Spawning Redds of Chinook Salmon runs in the Sacramento River as Percent of Total, from Aerial Redd Surveys by California Department of Fish and Wildlife**

Description	River Miles	Winter-run	Spring-run	Fall-run	Late fall-run
Keswick to ACID <sup>a</sup>	302–298	44.6%	12.8%	19.5%	71.3%
ACID to Highway 44	298–296	38.8%	33.9%	6.6%	5.2%
Highway 44 to Airport Rd.	296–284	15.7%	29.7%	14.7%	3.9%
Airport Rd. to Balls Ferry Br.	284–275	0.6%	11.1%	19.4%	8.9%
Balls Ferry Br. To Battle Creek	275–271	0.2%	7.4%	12.5%	5.9%
Battle Creek to Jellys Ferry Br.	271–266	0.1%	1.5%	15.2%	3.1%
Jellys Ferry Br. to Bend Bridge	266–257	0.1%	2.6%	8.0%	1.2%
Bend Bridge to RBDD <sup>b</sup>	257–242	0.0%	0.8%	4.2%	0.6%

<sup>a</sup> ACID = Anderson-Cottonwood Irrigation District

<sup>b</sup> RBDD = Red Bluff Diversion Dam

**Table 11N-2. Percent Redd Dewatered Look-up Table for Winter-Run Chinook Salmon with ACID Dam Boards Out (the percent of redds dewatered are looked up at the intersection of the “Spawning Flow” columns and “Dewatering Flow” rows)**

	Spawning Flow																	
		3,500	3,750	4,000	4,250	4,500	4,750	5,000	5,250	5,500	6,000	6,500	7,000	7,500	8,000	9,000	10,000	11,000
Dewatering Flow	3,250	0.8	1.5	2.2	3	3.9	4.9	5.8	7	8.2	11	13.8	16.7	19.7	22.6	28.8	34.8	39.4
	3,500	-	0.6	1	1.4	2	2.7	3.4	4.2	5.1	7.2	9.5	12.1	14.7	17.4	23.4	29.5	34.3
	3,750	-	-	0.2	0.5	0.8	1.2	1.6	2.1	2.8	4.3	6.1	8.3	10.6	13.1	18.9	25.1	30
	4,000	-	-	-	0.2	0.4	0.7	1	1.4	2	3.2	4.7	7.6	8.9	11.3	16.9	23.1	27.9
	4,250	-	-	-	-	0.1	0.3	0.5	0.8	1.2	2.2	3.4	5.9	7	9.1	14.3	20.3	25
	4,500	-	-	-	-	-	0.2	0.3	0.6	0.8	1.7	2.6	3.9	5.5	7.6	12.2	17.8	22.3
	4,750	-	-	-	-	-	-	0.1	0.3	0.5	1.2	1.9	2.9	4.3	5.8	10.2	15.5	19.8
	5,000	-	-	-	-	-	-	-	0.2	0.4	0.9	1.5	2.4	3.5	4.8	8.7	13.8	17.9
	5,250	-	-	-	-	-	-	-	-	0.2	0.6	1.1	1.8	2.7	3.8	7	11.8	15.7
	5,500	-	-	-	-	-	-	-	-	-	0.3	0.8	1.4	2.1	3	5.8	10.3	14.1
	6,000	-	-	-	-	-	-	-	-	-	-	0.2	0.6	1.1	1.7	3.7	7.7	10.9
	6,500	-	-	-	-	-	-	-	-	-	-	-	0.1	0.4	0.8	2.2	5.5	8.4
	7,000	-	-	-	-	-	-	-	-	-	-	-	-	0.2	0.4	1.2	3.5	5.6
	7,500	-	-	-	-	-	-	-	-	-	-	-	-	-	0.2	0.7	2.6	4.3
	8,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	1.9	3.2
	9,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.2	1.8
	10,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.4
	11,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	13,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	14,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	15,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	17,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	19,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	21,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	23,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	25,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	27,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	29,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 11N-2 (cont.)

	Spawning Flow												
		12,000	13,000	14,000	15,000	17,000	19,000	21,000	23,000	25,000	27,000	29,000	31,000
Dewatering Flow	3,250	43.2	46.2	49.1	51.4	55	57.6	59.9	62.6	64.7	68.9	73.3	77.3
	3,500	38.3	41.5	44.6	47.1	51	53.6	56.1	58.8	61.1	65.4	70.2	74.5
	3,750	34.1	37.5	40.6	43.2	47.2	50	52.5	55.4	57.7	62.3	67.4	72
	4,000	32.1	35.5	38.6	41.2	45.4	48.2	50.7	53.6	56.1	60.8	66.1	70.8
	4,250	29.1	32.5	35.5	38.2	42.4	45.3	47.8	50.8	53.4	58.3	63.8	68.8
	4,500	26.3	29.6	32.6	35.3	39.6	42.5	45.1	48.2	51	56	61.7	66.9
	4,750	23.7	26.9	29.9	32.7	37	40	42.7	45.9	48.8	54	59.9	65.4
	5,000	21.6	24.7	27.7	30.4	34.8	37.9	40.6	43.8	44.1	52.3	58.4	64.1
	5,250	19.4	22.4	25.4	28.2	32.7	35.8	38.6	41.9	45.2	50.7	57	62.8
	5,500	17.6	20.6	23.5	26.2	30.7	33.9	36.8	40.1	43.5	49	55.5	61.5
	6,000	14	16.7	19.4	22	26.4	29.6	32.6	35.9	39.6	45.4	52.2	58.5
	6,500	11.2	13.6	16.2	18.8	23.1	26.2	29.3	32.7	36.5	42.6	49.7	56.4
	7,000	7.9	10.1	12.4	14.8	19	22.3	25.6	29.2	33.3	39.7	47.2	54.1
	7,500	6.3	8.1	10.2	12.4	16.3	19.7	23	26.7	31	37.6	45.3	52.5
	8,000	4.9	6.6	8.6	10.5	14.3	17.7	21.1	25	29.3	36.1	44.1	51.4
	9,000	3	4.4	6	7.8	11.4	14.7	18.3	22.1	26.6	33.6	41.9	49.5
	10,000	1.3	2.3	3.7	5.3	8.6	11.8	15.4	19.3	23.8	30.6	39.7	47.5
	11,000	0.6	1.2	2.2	3.5	6.4	9.5	13.2	17.1	21.7	28.5	37.6	45.6
	12,000	-	0.2	0.9	1.8	4.1	7	10.5	14.7	19.3	26.3	35.7	43.8
	13,000	-	-	0.4	1	2.8	5.3	8.7	13	17.5	24.5	34	42.3
	14,000	-	-	-	0.4	1.6	4.2	7.5	11.8	16.2	23	32.6	41
	15,000	-	-	-	-	0.9	2.8	5.9	10.6	14.9	21.8	31.5	40.1
	17,000	-	-	-	-	-	1.3	3.9	7.8	11.8	18.3	28.1	36.9
	19,000	-	-	-	-	-	-	1.4	4	7.1	13	22.5	31.7
	21,000	-	-	-	-	-	-	-	1.3	3.6	9.2	18.7	28
	23,000	-	-	-	-	-	-	-	-	1.4	6.2	15.4	24.6
	25,000	-	-	-	-	-	-	-	-	-	0	8.3	15.2
	27,000	-	-	-	-	-	-	-	-	-	-	1.6	3.6
	29,000	-	-	-	-	-	-	-	-	-	-	-	0.6

**Table 11N-3. Percent Redd Dewatered Look-up Table for Winter-Run Chinook Salmon with ACID Dam Boards In (the percent of redds dewatered are looked up at the intersection of the “Spawning Flow” columns and “Dewatering Flow” rows)**

	Spawning Flow																	
		3,500	3,750	4,000	4,250	4,500	4,750	5,000	5,250	5,500	6,000	6,500	7,000	7,500	8,000	9,000	10,000	11,000
Dewatering Flow	3,250	1.2	2.2	3.1	4.1	5.2	6.4	7.5	8.8	10.2	13	16	18.9	21.9	24.7	30.5	35.9	40.1
	3,500	-	0.9	1.4	2	2.7	3.6	4.4	5.3	6.3	8.5	11	13.6	16.2	18.9	24.7	30.4	34.8
	3,750	-	-	0.4	0.8	0.2	1.7	2.2	2.8	3.5	5.1	7	9.3	11.7	14.2	19.9	25.9	30.5
	4,000	-	-	-	0.4	0.7	1.1	1.4	1.9	2.5	3.8	5.4	7.5	9.8	12.2	17.7	23.7	28.3
	4,250	-	-	-	-	0.3	0.5	0.8	1.1	1.5	2.6	3.9	5.6	7.6	9.7	15	20.7	25.2
	4,500	-	-	-	-	-	0.3	0.5	0.8	1.1	1.9	2.9	4.3	5.9	7.9	12.6	18.1	22.4
	4,750	-	-	-	-	-	-	0.2	0.4	0.7	1.3	2.1	3.1	4.5	6.1	10.5	15.7	20
	5,000	-	-	-	-	-	-	-	0.3	0.5	1	1.6	2.5	3.7	5	9	14	18.1
	5,250	-	-	-	-	-	-	-	-	0.3	0.7	1.2	1.9	2.9	3.9	7.3	11.9	15.9
	5,500	-	-	-	-	-	-	-	-	-	0.4	0.9	1.5	2.3	3.2	6.1	10.5	14.3
	6,000	-	-	-	-	-	-	-	-	-	-	0.3	0.7	1.3	1.9	4	8	11.3
	6,500	-	-	-	-	-	-	-	-	-	-	-	0.2	0.5	1	2.4	5.8	8.8
	7,000	-	-	-	-	-	-	-	-	-	-	-	-	0.3	0.5	1.4	3.8	6.1
	7,500	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	0.9	2.9	4.8
	8,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.4	2.1	3.7
	9,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.3	2.4
	10,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.9
	11,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	13,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	14,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	15,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	17,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	19,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	21,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	23,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	25,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	27,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	29,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

**Table 11N-3 (cont.)**

	Spawning Flow												
		12,000	13,000	14,000	15,000	17,000	19,000	21,000	23,000	25,000	27,000	29,000	31,000
Dewatering Flow	3,250	43.4	46	48.4	50.3	53.5	56	58.9	62.4	65.4	69.5	73.7	77.2
	3,500	38.5	41.1	43.9	46.1	49.6	52.3	55.3	58.8	61.9	65.9	69.9	73.5
	3,750	34.4	37.3	40	42.4	46.1	49	52.1	55.7	58.8	62.8	66.7	70.2
	4,000	32.2	35.3	38	40.4	44.2	47.2	50.3	53.9	57	61.1	65	68.5
	4,250	29.2	32.2	34.9	37.4	41.4	44.4	47.5	51.2	54.4	58.5	62.3	65.7
	4,500	26.3	29.3	32	34.6	38.6	41.7	45	48.7	52	56	59.8	63.2
	4,750	23.7	26.7	29.5	32.1	36.3	39.5	42.8	46.6	49.9	53.9	57.6	61.1
	5,000	21.7	24.6	27.4	29.9	34.2	37.4	40.8	44.6	48	51.9	55.7	59.1
	5,250	19.5	22.5	25.2	27.9	32.2	35.6	39	42.8	46.4	50.3	54.1	57.5
	5,500	17.9	20.7	23.5	26.1	30.5	33.9	37.4	41.2	44.8	48.7	52.4	55.8
	6,000	14.5	17.1	19.8	22.3	26.8	30.2	33.7	37.5	41.3	45.1	48.8	52.2
	6,500	11.8	14.3	16.8	19.3	23.7	27.2	30.7	34.7	38.4	42.3	45.9	49.3
	7,000	8.7	10.9	13.3	15.7	20.1	23.7	27.5	31.5	35.4	39.4	42.9	46.2
	7,500	7	9	11.2	13.5	17.7	21.4	25.2	29.3	33.2	37.2	40.7	44
	8,000	5.7	7.6	9.7	11.8	15.9	19.6	23.5	27.7	31.6	35.7	39.1	42.4
	9,000	4	5.6	7.4	9.4	13.3	16.9	20.8	24.9	28.7	32.8	36.3	39.6
	10,000	2.2	3.6	5.2	7	10.5	14	17.7	18.6	25.4	28.9	32.6	35.8
	11,000	1.1	2	3.1	4.6	7.6	10.5	13.8	17.4	20.6	23.5	26.7	29.4
	12,000	-	0.5	1.2	2.2	4.2	6.4	9.1	12.1	14.6	16.8	19.1	21.1
	13,000	-	-	0.5	1.1	2.6	4.4	6.7	9.2	11.7	13.5	15.3	17
	14,000	-	-	-	0.5	1.7	3.5	5.5	8.2	10.1	11.7	13.4	14.9
	15,000	-	-	-	-	0.7	2.1	3.9	6.8	8.6	10.1	11.6	13
	17,000	-	-	-	-	-	0.9	2.5	4.9	6.5	7.7	9.1	10.4
	19,000	-	-	-	-	-	-	1	2.5	3.6	4.4	5.5	6.6
	21,000	-	-	-	-	-	-	-	0.9	1.6	2.1	3	4
	23,000	-	-	-	-	-	-	-	-	0.4	0.6	1.1	1.9
	25,000	-	-	-	-	-	-	-	-	-	0.3	0.9	1.6
	27,000	-	-	-	-	-	-	-	-	-	-	0.3	0.7
	29,000	-	-	-	-	-	-	-	-	-	-	-	0.3

**Table 11N-4. Percent Redd Dewatered Look-up Table for Fall-Run Chinook Salmon (Also Used for the Spring-Run Chinook Salmon Analysis) with ACID Dam Boards Out (the percent of redds dewatered are looked up at the intersection of the “Spawning Flow” columns and “Dewatering Flow” rows)**

	Spawning Flow																	
		3,500	3,750	4,000	4,250	4,500	4,750	5,000	5,250	5,500	6,000	6,500	7,000	7,500	8,000	9,000	10,000	11,000
Dewatering Flow	3,250	1	2	3.4	4.8	6.6	8.4	10.6	12.9	15.3	20.6	26.2	31.7	37	41.5	50.2	56.3	60.4
	3,500	-	1	2.1	3.2	4.6	6.2	8.1	10.1	12.2	17	22.2	27.4	29.2	37	45.9	52.8	57.3
	3,750	-	-	0.9	1.6	2.6	3.9	5.5	7.3	9.2	13.6	18.4	23.1	28	32.4	41.5	48.7	53.6
	4,000	-	-	-	0.9	1.7	2.8	4.1	5.7	7.3	11.4	15.8	20.3	24.8	29	38	45.7	50.7
	4,250	-	-	-	-	0.8	1.6	2.7	4	5.4	8.9	13	17.2	21.6	25.8	34.9	42.8	48
	4,500	-	-	-	-	-	0.8	1.7	2.8	4	6.9	10.4	14.2	18.2	22.1	30.9	38.8	44.2
	4,750	-	-	-	-	-	-	0.8	1.6	2.5	4.8	7.6	10.8	14.2	17.6	25.8	33.2	38.8
	5,000	-	-	-	-	-	-	-	0.7	1.3	3.2	5.6	8.6	11.6	14.7	22.6	30.2	36
	5,250	-	-	-	-	-	-	-	-	0.7	2.1	4.2	6.8	9.4	12.3	19.8	27.2	33.1
	5,500	-	-	-	-	-	-	-	-	-	1.4	3.2	5.4	7.7	10.3	17.6	24.9	31
	6,000	-	-	-	-	-	-	-	-	-	-	1.2	2.8	4.6	6.4	12.9	19.7	25.8
	6,500	-	-	-	-	-	-	-	-	-	-	-	1.3	2.6	4.2	9.8	15.6	21.1
	7,000	-	-	-	-	-	-	-	-	-	-	-	-	0.9	2	6.6	11.8	17.3
	7,500	-	-	-	-	-	-	-	-	-	-	-	-	-	0.8	4.4	9.1	14.1
	8,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.6	6.6	11.5
	9,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.2	5.5
	10,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.9
	11,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	13,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	14,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	15,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	17,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	19,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	21,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	23,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	25,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	27,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	29,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-



**Table Table 11N-4 (cont.)**

	Spawning Flow												
		12,000	13,000	14,000	15,000	17,000	19,000	21,000	23,000	25,000	27,000	29,000	31,000
<b>Dewatering Flow</b>	3,250	62.9	63.7	65.3	66.4	66.8	65.7	67.8	71.3	74.5	80.4	87.3	92
	3,500	60.1	61.1	63	64.2	64.9	63.8	66	69.5	73	79.1	86.2	91
	3,750	56.9	58.3	60.3	61.8	62.7	61.7	64	67.7	71.4	77.7	84.9	89.6
	4,000	54.3	55.9	58.2	59.9	61.2	60.2	62.7	66.5	70.4	77.1	84.1	88.8
	4,250	51.8	53.6	56	58.1	59.6	58.8	61.3	65	68.5	75.7	83.1	87.8
	4,500	48.3	50.2	52.8	55.1	57.1	56.4	59	62.7	66.2	73.3	81.8	86.5
	4,750	43.3	45.6	48.6	51.4	54	53.7	56.6	60.4	64.5	71.7	80.3	85
	5,000	40.6	43	46.1	49.1	52.2	52.2	55.2	59.1	63.3	70.6	79.4	84.1
	5,250	37.7	40.2	43.5	46.5	50	50.2	53.5	57.4	60.7	68	78.2	83
	5,500	35.8	38.4	41.7	44.8	48.3	48.8	52.3	56.1	60.1	67.5	77.3	82
	6,000	30.9	33.8	37.3	40.6	45	45.8	49.5	53.2	57.2	65	75.4	80
	6,500	26.5	29.2	32.7	36.1	41	42.4	46.5	50.4	54.8	63	73.3	77.7
	7,000	22.8	25.8	29.3	32.9	38.3	40	44.4	48.3	52.9	61.3	71.8	76.1
	7,500	20	23.2	26.9	30.7	36.4	38.2	42.8	46.8	51.9	60.5	70.9	75.3
	8,000	17.2	20.9	24.9	28.9	34.9	36.6	41.3	45.4	50.5	59.3	70.2	74.7
	9,000	10.6	14.4	18.4	22.5	29.2	31.9	37.4	41.8	47.7	57	68.2	72.6
	10,000	4.5	7.7	12	16.4	23.5	26.9	33	38.5	44.5	54.1	65.9	70.5
	11,000	2.7	5.3	9	13.6	21.4	24.8	30.2	35.3	41.8	51.6	63.7	68.4
	12,000	-	1.6	4.7	9	16.8	20.6	27	32.9	39.8	50	62.3	67.2
	13,000	-	-	1.6	4.8	12.2	16.9	24.4	31.3	38.1	48.4	60.8	65.9
	14,000	-	-	-	2.6	9.5	14.8	22.1	28.9	36.2	46.8	59.5	64.7
	15,000	-	-	-	-	5.3	11.1	18.5	26.2	33.5	44.6	57.6	63.1
	17,000	-	-	-	-	-	4.1	11.3	18.5	26.1	37.8	51.5	57.9
	19,000	-	-	-	-	-	-	4.6	10.8	18.8	30.4	44.2	51.1
	21,000	-	-	-	-	-	-	-	4.2	11.7	23.9	38.4	46.3
	23,000	-	-	-	-	-	-	-	-	6.7	17.8	31.2	38.9
	25,000	-	-	-	-	-	-	-	-	-	2.3	6.4	10.7
	27,000	-	-	-	-	-	-	-	-	-	-	1.8	5.3
	29,000	-	-	-	-	-	-	-	-	-	-	-	2.2

**Table 11N-5. Percent Redd Dewatered Look-up Table for Fall-Run Chinook Salmon (Also Used for the Spring-Run Chinook Salmon Analysis) with ACID Dam Boards In (the percent of redds dewatered are looked up at the intersection of the “Spawning Flow” columns and “Dewatering Flow” rows)**

		Spawning Flow																	
Dewatering Flow		3,500	3,750	4,000	4,250	4,500	4,750	5,000	5,250	5,500	6,000	6,500	7,000	7,500	8,000	9,000	10,000	11,000	
	3,250	1.0	2.0	3.3	4.7	6.2	7.8	9.7	11.7	13.6	17.8	22.2	26.3	30.2	33.4	39.5	43.5	46.0	
	3,500	-	1.0	2.0	3.1	4.4	5.7	7.4	9.2	10.9	14.8	18.8	22.8	23.9	29.8	36.2	40.8	43.6	
	3,750	-	-	0.9	1.6	2.5	3.6	5.1	6.7	8.3	11.9	15.6	19.3	23.0	26.2	32.8	37.7	40.9	
	4,000	-	-	-	0.9	1.7	2.6	3.8	5.3	6.6	10.0	13.5	16.9	20.4	23.5	30.1	35.4	38.7	
	4,250	-	-	-	-	0.8	1.5	2.5	3.7	5.0	7.8	11.1	14.4	17.8	20.9	27.5	33.1	36.6	
	4,500	-	-	-	-	-	0.8	1.6	2.6	3.7	6.0	8.9	11.9	15.0	17.8	24.4	29.9	33.6	
	4,750	-	-	-	-	-	-	0.8	1.6	2.4	4.3	6.6	9.1	11.8	14.3	20.3	25.7	29.5	
	5,000	-	-	-	-	-	-	-	0.7	1.3	2.9	4.9	7.2	9.6	11.9	17.7	23.1	26.9	
	5,250	-	-	-	-	-	-	-	-	0.6	1.9	3.5	5.6	7.7	9.7	15.3	20.4	24.1	
	5,500	-	-	-	-	-	-	-	-	-	1.2	2.7	4.4	6.2	8.1	13.5	18.5	22.3	
	6,000	-	-	-	-	-	-	-	-	-	-	1.0	2.3	3.7	5.1	9.8	14.5	18.3	
	6,500	-	-	-	-	-	-	-	-	-	-	-	1.1	2.1	3.3	7.4	11.5	15.0	
	7,000	-	-	-	-	-	-	-	-	-	-	-	-	0.7	1.6	5.0	8.6	12.1	
	7,500	-	-	-	-	-	-	-	-	-	-	-	-	-	0.6	3.4	6.7	9.9	
	8,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.0	4.9	8.1	
	9,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.6	3.8	
	10,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.2	
	11,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	12,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	13,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	14,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	15,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	17,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	19,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	21,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	23,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	25,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	27,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
29,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		

Table 11N-5 (cont.)

	Spawning Flow												
		12,000	13,000	14,000	15,000	17,000	19,000	21,000	23,000	25,000	27,000	29,000	31,000
Dewatering Flow	3,250	47.6	48.0	49.3	50.5	52.0	52.5	55.1	57.6	57.4	59.0	61.1	63.3
	3,500	45.5	46.0	47.4	48.8	50.4	50.8	53.4	55.9	55.7	57.2	59.3	61.6
	3,750	43.1	43.9	45.5	47.0	48.7	49.1	51.8	54.3	54.1	55.6	57.6	59.8
	4,000	41.2	42.2	43.8	45.5	47.5	47.9	50.5	53.1	52.9	54.5	56.3	58.5
	4,250	39.2	4.0	42.1	43.9	46.0	46.4	49.0	51.3	50.8	52.5	54.4	56.5
	4,500	36.4	37.6	39.4	41.4	43.6	43.9	46.4	48.7	47.8	49.1	51.6	53.7
	4,750	32.6	34.0	36.1	38.3	40.8	41.1	43.6	45.7	44.9	46.0	48.3	50.3
	5,000	30.0	31.2	33.2	35.3	37.6	37.6	39.8	41.7	40.5	41.3	43.2	45.1
	5,250	27.1	28.2	29.9	31.8	33.9	33.5	35.4	36.8	34.6	35.0	37.4	39.0
	5,500	25.3	26.4	28.0	29.7	31.5	31.0	32.7	33.8	31.7	31.9	33.6	35.1
	6,000	21.5	22.7	24.4	26.2	28.2	27.5	29.0	29.8	27.1	27.1	28.7	29.8
	6,500	18.3	19.5	21.1	23.0	25.2	24.7	26.4	27.1	24.4	24.2	25.3	26.3
	7,000	15.6	17.0	18.7	20.7	23.2	22.8	24.5	25.1	22.4	22.1	23.2	24.0
	7,500	13.7	15.3	17.1	19.3	21.9	21.5	23.3	23.9	21.3	21.0	21.9	22.7
	8,000	11.8	13.7	15.7	17.9	20.7	20.2	21.9	22.4	19.8	19.4	20.5	21.4
	9,000	7.2	9.2	11.3	13.6	16.8	16.8	18.9	19.6	17.2	16.8	17.9	18.5
	10,000	3.0	4.9	7.2	9.8	13.3	13.8	16.2	17.4	14.9	14.5	15.9	16.7
	11,000	1.9	3.4	5.4	8.2	12.1	12.2	14.5	15.6	13.3	12.8	14.1	15.0
	12,000	-	1.0	2.8	5.4	9.4	10.0	12.5	14.0	11.9	11.5	12.9	13.9
	13,000	-	-	1.0	3.0	6.9	8.1	11.1	13.1	11.0	10.7	12.1	13.1
	14,000	-	-	-	1.8	5.4	7.0	9.8	11.8	10.0	9.9	11.4	12.4
	15,000	-	-	-	-	2.8	4.8	7.7	10.2	8.6	8.7	10.4	11.5
	17,000	-	-	-	-	-	1.8	5.0	7.5	6.5	6.8	8.5	10.0
	19,000	-	-	-	-	-	-	2.3	4.8	4.6	5.0	6.9	8.4
	21,000	-	-	-	-	-	-	-	1.9	2.0	2.6	4.7	6.6
	23,000	-	-	-	-	-	-	-	-	0.7	1.6	3.6	5.7
	25,000	-	-	-	-	-	-	-	-	-	1.2	3.0	5.0
	27,000	-	-	-	-	-	-	-	-	-	-	1.2	3.3
	29,000	-	-	-	-	-	-	-	-	-	-	-	1.5

**Table 11N-6. Percent Redd Dewatered Look-up Table for Late Fall–Run Chinook Salmon with ACID Dam Boards Out (the percent of redds dewatered are looked up at the intersection of the “Spawning Flow” columns and “Dewatering Flow” rows)**

	Spawning Flow																
		3,500	3,750	4,000	4,250	4,500	4,750	5,000	5,250	5,500	6,000	6,500	7,000	7,500	8,000	9,000	10,000
Dewatering Flow	3,250	0.9	1.5	2.6	3.6	4.9	6.3	8	9.8	11.7	15.9	20.1	24.1	28	31.5	37.8	42.7
	3,500	-	0.9	1.6	2.4	3.4	4.5	6	7.6	9.3	13.1	17.1	21	24.9	28.2	35	40.2
	3,750	-	-	0.8	1.1	2	2.9	4.1	5.5	7	10.5	14.2	17.8	21.6	25	32	37.5
	4,000	-	-	-	0.7	1.2	2	3	4.2	5.5	8.8	12.1	15.6	19.2	22.5	29.5	35.3
	4,250	-	-	-	-	0.6	1.1	1.9	3	4.1	6.9	10	13.4	16.9	20.1	27.3	33.3
	4,500	-	-	-	-	-	0.6	1.2	2.1	3.1	5.5	8.3	11.3	14.6	17.7	24.8	30.8
	4,750	-	-	-	-	-	-	0.6	1.3	2	4	6.3	9	11.8	14.7	21.5	27.6
	5,000	-	-	-	-	-	-	-	0.5	1	2.6	4.6	7	9.6	12.2	18.9	25.2
	5,250	-	-	-	-	-	-	-	-	0.5	1.8	3.5	5.6	7.9	10.4	16.9	23.1
	5,500	-	-	-	-	-	-	-	-	-	1.3	2.7	4.6	6.7	8.9	15.3	21.5
	6,000	-	-	-	-	-	-	-	-	-	-	0.9	2.3	3.8	5.5	11.2	17.1
	6,500	-	-	-	-	-	-	-	-	-	-	-	1	2.1	3.5	8.3	13.4
	7,000	-	-	-	-	-	-	-	-	-	-	-	-	0.8	1.8	5.9	10.4
	7,500	-	-	-	-	-	-	-	-	-	-	-	-	-	0.7	3.9	7.9
	8,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.2	5.5
	9,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.7
	10,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	11,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	13,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	14,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	15,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	17,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	19,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	21,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	23,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	25,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	27,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	29,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 11N-6 (cont.)

	Spawning Flow													
		11,000	12,000	13,000	14,000	15,000	17,000	19,000	21,000	23,000	25,000	27,000	29,000	31,000
Dewatering Flow	3,250	45.6	47.8	48.9	50.6	52.6	55.5	57.5	61.6	67.3	73.5	79.8	86.6	91.1
	3,500	43.3	45.6	46.8	48.6	50.7	53.6	55.5	59.6	65.4	71.5	78.3	85.4	90.1
	3,750	40.7	43.3	44.6	46.5	48.6	51.5	53.3	57.4	63.3	69.6	76.6	83.9	88.5
	4,000	38.7	41.5	42.8	44.8	46.9	49.9	51.8	55.9	61.8	68.3	75.6	82.9	87.6
	4,250	36.8	39.7	41.1	43.1	45.3	48.4	50.2	54.3	60.2	66.6	74.2	81.7	86.5
	4,500	34.5	37.5	38.9	41	43.3	46.5	48.3	52.4	58.1	64.5	72.2	80.2	85
	4,750	31.5	34.6	36.6	38.5	40.9	44.2	46	50.1	55.3	62.4	70.2	78.4	83.3
	5,000	29.3	32.6	34.3	36.7	39.1	42.6	44.5	48.6	54.2	60.8	68.9	77.3	82.3
	5,250	27.4	30.8	32.5	34.9	37.5	41.1	42.9	47	52.6	58.9	67	76	81.1
	5,500	25.8	29.4	31.2	33.2	36.1	39.7	41.6	45.7	51.2	57.7	65.9	74.9	80
	6,000	21.7	25.5	27.5	29.9	32.6	36.4	38.3	42.3	47.7	54.1	62.7	72.1	77.3
	6,500	17.6	21.7	23.8	26.4	29.1	33.1	35.1	39.2	44.5	50.9	59.7	69.1	74
	7,000	14.4	18.6	20.7	23.2	26.1	30.3	32.4	36.4	41.6	48	57	66.6	71.6
	7,500	11.5	16	18.4	21.1	24	28.3	30.4	34.5	39.6	46.3	55.4	65.2	70.3
	8,000	8.9	13.3	16	18.9	21.9	26.3	28.3	32.5	37.6	44.3	53.7	63.7	69
	9,000	3.9	7.8	10.5	13.6	16.7	21.5	23.7	28.1	33.2	40.2	50	60.5	65.9
	10,000	1.2	3.1	5.6	8.8	12.1	17	19.6	24	29.8	36.7	46.7	57.4	62.9
	11,000	-	2.3	4.1	6.7	10	15.2	17.4	21.8	26.9	34	44.2	55.1	60.7
	12,000	-	-	1.2	3.4	6.5	11.7	14.2	18.7	24.5	31.8	42.2	53.3	58.9
	13,000	-	-	-	1.1	3.4	8.3	11.3	16.2	22.7	29.9	40.3	51.5	57.2
	14,000	-	-	-	-	1.9	6.4	9.8	14.6	21.1	28.3	38.8	50.1	55.9
	15,000	-	-	-	-	-	3.3	6.7	11.7	18.8	26	36.7	48.2	54.1
	17,000	-	-	-	-	-	-	3.5	7	13.1	20.3	31.1	42.9	49.1
	19,000	-	-	-	-	-	-	-	2.5	7.1	14.4	25.2	36.9	43.2
	21,000	-	-	-	-	-	-	-	-	3.1	9.3	20	32.1	39.1
	23,000	-	-	-	-	-	-	-	-	-	5.1	14.5	25.7	32.6
	25,000	-	-	-	-	-	-	-	-	-	-	1.8	5.2	9.4
	27,000	-	-	-	-	-	-	-	-	-	-	-	1.4	4.4
	29,000	-	-	-	-	-	-	-	-	-	-	-	-	1.6

**Table 11N-7. Percent Redd Dewatered Look-up Table for Late Fall–Run Chinook Salmon with ACID Dam Boards In (the percent of redds dewatered are looked up at the intersection of the “Spawning Flow” columns and “Dewatering Flow” rows)**

	Spawning Flow																	
		3,500	3,750	4,000	4,250	4,500	4,750	5,000	5,250	5,500	6,000	6,500	7,000	7,500	8,000	9,000	10,000	11,000
Dewatering Flow	3,250	0.9	1.7	2.6	3.7	4.9	6.2	7.8	9.5	11.3	15.1	18.9	22.5	26	29.1	34.9	39.4	42.3
	3,500	-	0.9	1.6	2.4	3.4	4.5	5.9	7.4	9	12.5	16.1	19.6	23.1	26.1	32.3	37.1	40.1
	3,750	-	-	0.8	1.1	2	2.9	4.1	5.5	6.9	10.1	13.4	16.7	20.1	23.1	29.5	34.6	37.8
	4,000	-	-	-	0.7	1.3	2	3	4.2	5.4	8.4	11.5	14.7	17.9	20.9	27.3	32.7	36
	4,250	-	-	-	-	0.7	1.2	2	3	4.1	6.7	9.6	12.6	15.8	18.7	25.2	30.8	34.2
	4,500	-	-	-	-	-	0.6	1.3	2.1	3.1	5.3	7.9	10.7	13.6	16.4	22.9	28.4	32
	4,750	-	-	-	-	-	-	0.6	1.3	2.1	3.9	6	8.5	11.1	13.7	19.9	25.4	29.1
	5,000	-	-	-	-	-	-	-	0.6	1.1	2.6	4.4	6.6	8.9	11.3	17.4	22.9	26.7
	5,250	-	-	-	-	-	-	-	-	0.5	1.7	3.3	5.2	7.3	9.5	15.3	20.7	24.4
	5,500	-	-	-	-	-	-	-	-	-	1.2	2.5	4.3	6.1	8.1	13.7	19.1	22.8
	6,000	-	-	-	-	-	-	-	-	-	-	0.9	2.1	3.4	5	10	15.1	19
	6,500	-	-	-	-	-	-	-	-	-	-	-	0.9	1.9	3.1	7.4	11.8	15.4
	7,000	-	-	-	-	-	-	-	-	-	-	-	-	0.8	1.6	5.2	9.1	12.5
	7,500	-	-	-	-	-	-	-	-	-	-	-	-	-	0.7	3.5	6.9	9.9
	8,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	4.9	7.7
	9,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.5	3.3
	10,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
	11,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	13,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	14,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	15,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	17,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	19,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	21,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	23,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	25,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	27,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	29,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

**Table 11N-7 (cont.)**

	Spawning Flow												
		12,000	13,000	14,000	15,000	17,000	19,000	21,000	23,000	25,000	27,000	29,000	31,000
<b>Dewatering Flow</b>	3,250	44.6	46	47.9	50.1	53.4	55.4	59.2	63.7	66.8	69.7	74.4	79.1
	3,500	42.6	44	46	48.2	51.5	53.5	57.2	61.8	64.6	67.8	72.6	77.3
	3,750	40.5	42	44	46.3	49.6	51.5	55.1	59.7	62.6	65.6	70.4	75.1
	4,000	38.8	40.4	42.4	44.8	48.1	50	53.6	58.3	61.1	64.3	68.9	73.5
	4,250	37.1	38.7	40.8	43.2	46.5	48.3	51.9	56.4	59	62.2	66.9	71.5
	4,500	34.9	36.5	38.6	41.1	44.4	46.1	49.6	53.9	56.3	59.2	64.1	68.7
	4,750	32.2	33.8	36	38.5	41.9	43.5	46.8	50.6	53.2	55.9	60.6	65.1
	5,000	29.8	31.4	33.5	35.9	39.1	40.5	43.6	47.5	49.3	51.9	56.3	60.6
	5,250	27.5	28.9	30.9	33.2	36.3	37.3	40.2	43.6	44.8	46.9	51.4	55.5
	5,500	25.9	27.3	28.9	31.4	34.2	35.1	37.8	41	42.1	43.9	48	51.9
	6,000	22.2	23.7	25.6	27.7	30.6	31.3	33.7	36.4	37	38.6	42.4	45.9
	6,500	18.8	20.3	22.3	24.5	27.4	28.1	30.5	33	33.3	34.5	37.8	40.8
	7,000	16	17.6	19.6	21.8	24.9	25.5	27.8	30.2	30.2	31.1	34.3	37.1
	7,500	13.7	15.5	17.6	20	23.1	23.8	26	28.3	28.4	29.2	32.2	35.2
	8,000	11.4	13.5	15.7	18.1	21.3	21.8	24.1	26.3	26.2	27	30.1	33.1
	9,000	6.6	8.7	11.1	13.6	17	17.7	20.1	22.2	22.1	22.8	25.8	28.7
	10,000	2.7	4.6	7	9.8	13.3	14.3	16.7	19.3	19	19.4	22.3	25.1
	11,000	2	3.4	5.4	8.1	12	12.6	16.6	17	16.7	17	19.9	22.6
	12,000	-	0.9	2.7	5.3	9.1	10	12.3	15	14.7	14.9	17.7	20.5
	13,000	-	-	0.9	2.8	6.5	7.8	10.4	13.7	13.3	13.6	16.3	19
	14,000	-	-	-	1.7	5.1	6.7	9.2	12.4	12.1	12.4	15	17.7
	15,000	-	-	-	-	2.5	4.2	6.9	10.6	10.3	10.8	13.3	16
	17,000	-	-	-	-	-	2.4	4.3	7.5	7.7	8.2	10.6	13.2
	19,000	-	-	-	-	-	-	1.7	4.2	5.1	5.8	8.1	10.5
	21,000	-	-	-	-	-	-	-	2	2.7	3.5	5.8	8.4
	23,000	-	-	-	-	-	-	-	-	1.1	2.1	4.3	7.4
	25,000	-	-	-	-	-	-	-	-	-	1.3	3.4	6.4
	27,000	-	-	-	-	-	-	-	-	-	-	1.3	4
	29,000	-	-	-	-	-	-	-	-	-	-	-	1.5

**Table 11N-8. Percent Redd Dewatered Look-up Table for CCV Steelhead with ACID Dam Boards Out (the percent of redds dewatered are looked up at the intersection of the “Spawning Flow” columns and “Dewatering Flow” rows)**

	Spawning Flow																	
		3,500	3,750	4,000	4,250	4,500	4,750	5,000	5,250	5,500	6,000	6,500	7,000	7,500	8,000	9,000	10,000	11,000
Dewatering Flow	3,250	1.2	2.6	3.7	4.9	6.8	8.9	10.9	13.3	15.7	19.9	23.4	26.2	28.5	31.1	37.2	43.5	49.8
	3,500	-	1.6	2.4	3.2	4.7	6.4	8	10.2	12.4	16.5	19.9	22.8	25.1	27.7	33.8	40.1	46.2
	3,750	-	-	0.5	1.2	2.5	3.8	5.3	7.3	9.1	12.7	15.9	18.9	21.1	23.9	30.3	36.5	42.4
	4,000	-	-	-	0.8	1.9	2.9	4	5.7	7.3	10.5	13.4	16	18.2	20.8	27.1	33.5	39.5
	4,250	-	-	-	-	1.1	2.2	3.2	4.8	6.2	9.3	12	14.6	16.7	19.1	25.3	31.5	37.3
	4,500	-	-	-	-	-	1.1	1.9	3.3	4.5	7.1	9.6	12	14	16.3	22.4	28.5	34.2
	4,750	-	-	-	-	-	-	0.8	2	2.8	5.1	7.4	9.7	11.6	13.8	19.8	25.8	31.4
	5,000	-	-	-	-	-	-	-	1.1	1.8	3.7	5.8	8	9.7	11.8	17.7	23.8	26.6
	5,250	-	-	-	-	-	-	-	-	0.8	2.4	4.2	6.2	7.7	9.4	14.9	21.1	26.8
	5,500	-	-	-	-	-	-	-	-	-	1.5	3.2	5	6.1	7.8	13	19.1	24.6
	6,000	-	-	-	-	-	-	-	-	-	-	1.3	2.7	3.8	5.3	10.2	15.9	21.2
	6,500	-	-	-	-	-	-	-	-	-	-	-	2.8	1.3	2.6	6.9	12.1	17.2
	7,000	-	-	-	-	-	-	-	-	-	-	-	-	0.5	1.3	4.8	9.4	14.3
	7,500	-	-	-	-	-	-	-	-	-	-	-	-	-	0.7	3.8	8.1	12.7
	8,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.8	6.7	10.9
	9,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.6	5.3
	10,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.9
	11,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	13,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	14,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	15,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	17,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	19,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	21,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	23,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	25,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	27,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	29,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 11N-8 (cont.)

	Spawning Flow												
		12,000	13,000	14,000	15,000	17,000	19,000	21,000	23,000	25,000	27,000	29,000	31,000
Dewatering Flow	3,250	56.6	63.7	70.7	76.8	84.2	86.5	88.5	89.1	91	91.3	93.1	94.7
	3,500	52.9	60	67.1	73.6	81.4	84	86.4	87.4	89.9	90.5	92.3	94
	3,750	49	55.9	63	69.7	77.8	80.9	84.3	85.9	88.9	89.7	91.7	93.8
	4,000	46	52.9	60	66.8	74.9	78.2	82.1	84.1	88.1	89.4	91.6	93.7
	4,250	43.6	50.3	57.3	64.1	72.3	75.6	79.8	82	86.8	88.3	91	93.3
	4,500	40.3	46.9	53.7	60.5	69.4	73.1	77.4	79.4	84.3	86.3	89.7	92.2
	4,750	37.3	43.7	50.2	57	66.1	70.1	74.6	77	83.1	85.5	89.2	91.9
	5,000	35.4	41.7	48.2	55	64.1	68.2	72.8	75.2	82.1	85	88.8	91.6
	5,250	32.6	38.7	45.2	51.9	61.3	66.1	70.8	73.2	79.3	82.9	88.1	90.8
	5,500	30.1	36	42.2	48.8	58.2	63.6	69.2	71.9	78.2	82.1	87.2	89.9
	6,000	26.6	32.3	38.4	44.7	53.8	58.8	64.6	67.7	74.9	79.2	84.3	86.8
	6,500	22.9	28.7	34.5	40.4	48.6	52.6	58.2	61	69.2	74	79.2	81.4
	7,000	19.9	25.7	31.6	37.5	46.2	50.2	56	59.1	67.5	72.2	77.3	79.4
	7,500	18.2	24.1	30	35.8	44.4	48.2	54.1	57.3	66.2	71.1	76	78.2
	8,000	16.3	22	27.7	33.4	42.1	46.4	52.7	55.9	64.6	69.5	75	77.2
	9,000	9.6	14.5	19.7	25.7	35.2	40.4	47.2	50.7	60.2	65.3	71.1	73.5
	10,000	4.6	8.9	13.4	18.9	27.7	33.7	41.4	45.6	55.7	61.7	68.3	70.8
	11,000	2.8	6.8	10.9	15.7	24.3	29.5	37.4	42	52.8	58.7	65.1	67.7
	12,000	-	3.1	6.3	10.4	18.9	25.1	33.9	38.9	50.3	56.5	63	65.7
	13,000	-	-	5.4	5.4	12.7	19.7	29.1	36.4	48	54.6	61.2	64.1
	14,000	-	-	-	3	9.5	15.6	25.1	32.3	44.5	51.7	58.3	61.5
	15,000	-	-	-	-	5	10.9	20.7	29.5	42.1	49.3	55.8	58.8
	17,000	-	-	-	-	-	4.8	13.4	20.8	34.1	42.5	49.7	53
	19,000	-	-	-	-	-	-	7.3	13.3	26.4	35.7	43.1	46.6
	21,000	-	-	-	-	-	-	-	6.8	20	29.2	36.3	39.9
	23,000	-	-	-	-	-	-	-	-	13.5	20.5	26.9	31.2
	25,000	-	-	-	-	-	-	-	-	-	4	9.3	14.6
	27,000	-	-	-	-	-	-	-	-	-	-	3.9	9.2
	29,000	-	-	-	-	-	-	-	-	-	-	-	5.1

**Table 11N-9. Percent Redd Dewatered Look-up Table for CCV Steelhead with ACID Dam Boards In (the percent of redds dewatered are looked up at the intersection of the “Spawning Flow” columns and “Dewatering Flow” rows)**

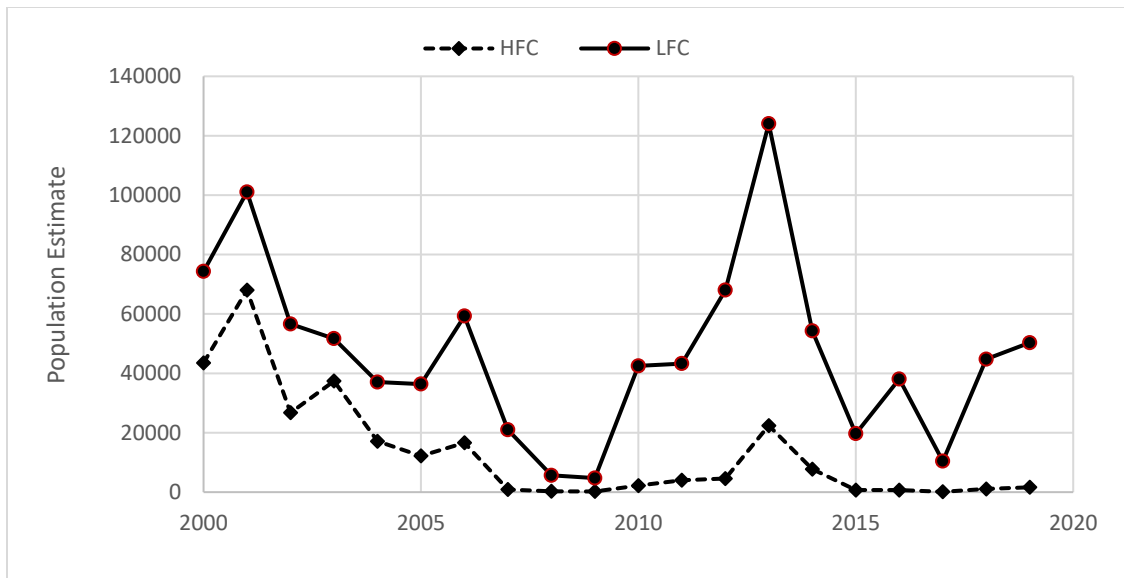
	Spawning Flow																	
		3,500	3,750	4,000	4,250	4,500	4,750	5,000	5,250	5,500	6,000	6,500	7,000	7,500	8,000	9,000	10,000	11,000
Dewatering Flow	3,250	1.1	2.3	3.3	4.7	6.5	8.7	11	13.6	16	20.3	23.9	26.9	29.3	31.8	37.6	42.3	46.7
	3,500	-	1.4	2.2	3.2	4.6	6.4	8.4	10.8	13	17.1	20.6	23.7	26.1	28.6	34.5	39.2	43.5
	3,750	-	-	0.6	1.3	2.6	4.1	5.9	8.1	10	13.6	17	20	22.5	25.1	31.2	35.9	40.3
	4,000	-	-	-	0.9	2.1	3.3	4.7	6.7	8.3	11.6	14.6	17.4	19.7	22.2	28.3	33.3	37.8
	4,250	-	-	-	-	1.3	2.6	4	5.8	7.2	10.3	13.2	15.9	18.1	20.5	26.5	31.3	35.7
	4,500	-	-	-	-	-	1.4	2.7	4.2	5.5	8.2	10.8	13.3	15.4	17.6	23.6	28.4	32.7
	4,750	-	-	-	-	-	-	1.5	2.9	3.8	6.2	8.5	11	12.9	15.1	20.9	25.7	30
	5,000	-	-	-	-	-	-	-	1.7	2.4	4.4	6.5	8.8	10.6	12.6	18.3	23.1	27.5
	5,250	-	-	-	-	-	-	-	-	1.1	2.6	4.6	6.5	8	9.6	15	19.7	24
	5,500	-	-	-	-	-	-	-	-	-	1.5	3.2	4.8	6.2	7.7	12.8	17.5	21.6
	6,000	-	-	-	-	-	-	-	-	-	-	1.3	2.7	3.8	5.1	9.9	14.3	18.3
	6,500	-	-	-	-	-	-	-	-	-	-	-	2.7	1.4	2.5	6.9	10.8	14.8
	7,000	-	-	-	-	-	-	-	-	-	-	-	-	0.5	1.3	4.9	8.4	12.2
	7,500	-	-	-	-	-	-	-	-	-	-	-	-	-	0.7	4	7.3	10.8
	8,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	5.9	9.2
	9,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.2	4.4
	10,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.6
	11,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	13,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	14,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	15,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	17,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	19,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	21,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	23,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	25,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	27,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	29,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

**Table 11N-9 (cont.)**

	<b>Spawning Flow</b>												
		12,000	13,000	14,000	15,000	17,000	19,000	21,000	23,000	25,000	27,000	29,000	31,000
<b>Dewatering Flow</b>	3,250	50.5	53.5	55.6	56.3	54.1	49.5	46.8	42.3	39.1	38.3	37.7	39.2
	3,500	47.4	50.6	52.9	54.1	52.3	48.1	45.6	41.3	38.2	37.6	37	38.5
	3,750	44.2	47.4	49.9	51.4	50.6	46.3	44.4	40.4	37.6	37	36.5	38.1
	4,000	41.7	45.1	47.7	49.4	48.3	44.8	43.2	39.4	37	36.5	36.2	37.8
	4,250	36.5	42.8	45.5	47.3	46.6	43.2	41.7	38.2	36	35.6	35.4	37.1
	4,500	36.6	39.8	42.6	44.6	44.5	41.5	40.1	36.5	34.2	34	34	35.8
	4,750	33.7	37	39.7	41.8	42.1	39.4	38.2	34.8	32.9	32.8	33	34.8
	5,000	31.2	34.4	37.2	39.4	39.8	37.2	36.2	32.8	31.1	31.1	31.1	32.8
	5,250	27.9	31.1	33.8	36.2	36.9	34.8	33.8	30.3	28.2	28.4	28.9	30.4
	5,500	25.3	28.4	31.1	33.5	34.5	32.8	32.3	28.9	26.8	27	27.3	28.8
	6,000	21.9	25.1	27.8	30.2	31.3	29.7	29.4	26.3	24.3	24.5	24.8	26
	6,500	18.7	22.1	27.8	27.1	28.1	26.2	25.9	22.9	21.2	21.5	21.7	22.8
	7,000	16.2	19.6	22.5	24.9	26.4	24.7	24.5	21.7	19.9	20.2	20.4	21.4
	7,500	14.8	18.3	21.2	23.7	25.2	23.5	23.5	20.7	19.1	19.3	19.4	20.4
	8,000	13.1	16.6	19.5	21.9	23.7	22.2	22.5	19.7	18	18.1	18.5	19.5
	9,000	7.6	10.8	13.6	16.6	19.4	18.7	19.3	16.8	15.2	15.4	15.9	17
	10,000	3.6	6.6	9.2	12.1	15.1	15.3	16.4	14.5	12.9	13.4	14.3	15.5
	11,000	2.3	5	7.5	10.1	13.1	13.1	14.5	12.8	11.5	11.9	12.8	14.1
	12,000	-	2.2	4.3	6.7	10.1	10.9	12.9	11.4	10.4	10.9	11.9	13.2
	13,000	-	-	3.7	3.6	6.8	8.3	10.7	10.5	9.6	10.3	11.3	12.7
	14,000	-	-	-	2.1	5.1	6.6	9.1	9	8.3	9.2	10.3	11.9
	15,000	-	-	-	-	2.6	4.2	7.2	7.9	7.4	8.3	9.4	10.9
	17,000	-	-	-	-	-	1.9	5.1	5.8	5.6	6.8	8.3	10
	19,000	-	-	-	-	-	-	3	3.7	3.8	5.1	6.7	8.4
	21,000	-	-	-	-	-	-	-	1.4	1.8	2.9	4.4	6.3
	23,000	-	-	-	-	-	-	-	-	0.9	2.2	3.8	5.7
	25,000	-	-	-	-	-	-	-	-	-	1.7	3.4	5.4
	27,000	-	-	-	-	-	-	-	-	-	-	1.8	3.8
	29,000	-	-	-	-	-	-	-	-	-	-	-	2.2

**11N.2.1.2 Feather River**

Spring-run, fall-run, and steelhead spawn in both the upper Feather River between the Fish Barrier Dam and Thermalito Afterbay Outlet (low-flow channel [LFC]) and the lower river downstream of the Thermalito Afterbay Outlet (high-flow channel [HFC]). Results of escapement surveys conducted since 2002 (Kindopp pers. comm. 2021a) show that the LFC is preferred for spawning over the HFC and that this preference has increased over time (Figure 11N-1). However, Alternatives 1–3 would have no effect on flow in the LFC, so differences in redd dewatering between the project alternatives and the NAA were estimated only for the HFC.



**Figure 11N-1. Escapement Population Estimates for Fall-run Chinook Salmon in the Low-Flow Channel (LFC) and High-Flow Channel (HFC) of the Feather River from 2000 through 2019, from Escapement Surveys of CDWR.**

No redd dewatering field data similar to that used for the Sacramento River (USFWS 2006) or the American River (see below) are available for salmon or steelhead in the Feather River; the direct reduction in flow between the spawning month and the month with the lowest flow during the following incubation period was used as a proxy for redd dewatering. The spawning and dewatering flows downstream of the Thermalito Afterbay outlet for each month of spring-run, fall-run, and steelhead spawning, as estimated by CALSIM II, were used to compute the reduction in flow under Alternatives 1–3 and the NAA. Larger reductions are assumed to increase the percent of redds dewatered and, therefore, to have a potentially negative effect on the species' populations. As previously noted, the use of monthly time-step flow estimates like those obtained from CALSIM II modeling likely underestimates redd dewatering rates. This potential bias is expected to equally affect the NAA and Alternatives 1–3.

#### **11N.2.1.3 American River**

The redd dewatering analysis for the lower American River used relationships between flow, river stage, and redd depth distribution developed by Bratovich et al. (2017). A composite redd depth frequency distribution was developed by combining results from several redd surveys conducted between 1996 and 2016. The stage versus flow relationship for the river was developed from a combination of field measurements and modeling. CALSIM II flow estimates at the Nimbus Dam location were used to compute stage at the spawning and dewatering flows, and the redd depth frequency distribution was queried to determine the percentage of the redds that occur between those two stages and would therefore be dewatered. The analyses were conducted for fall-run and steelhead spawning and incubation periods for each year of the CALSIM period of record. Based on ranges provided in Bratovich et al. 2017, fall-run and steelhead were estimated to have three-month and two-month incubation periods, respectively. The analysis compared CALSIM II flow estimates below Nimbus Dam for each spawning month with the minimum flow during 2 or 3 months following the spawning month to estimate the

percentage of redds dewatered. Absolute differences between Alternatives 1–3 and the NAA in the percentage of redds dewatered were used to compare the alternatives and the NAA. As noted above, the use of monthly time-step flow estimates like those obtained from CALSIM II modeling likely underestimates redd dewatering rates. This potential bias is expected to affect all alternative scenarios equally.

### 11N.2.2 Redd Scour/Entombment

Loss of redds to scouring or entombment occurs when flows are high enough to mobilize sediments, destroying redds and their incubating eggs and alevins, or entombing the redds when sediments are redeposited. Estimates of redd losses resulting from scouring flows in the Sacramento and American Rivers were based on estimates from various sources of the minimum flows required to mobilize sediments and the frequency of occurrence of those flows. Frequency of scouring flows was not estimated for the Feather River because information on minimum flows required to mobilize sediments could not be located for the Feather River.

The probability of flows occurring that would be high enough to mobilize sediments and scour or entomb Chinook salmon and steelhead redds was estimated for the Sacramento and American Rivers. The amount of flow needed to mobilize sediments in these rivers has been little studied (CALFED 2000; Ayres 2001), but the information available suggests that a minimum of roughly 40,000 cubic feet per second (cfs) of flow is required in both rivers for significant bed movement (scour flow threshold) (Table ). It should be noted that 40,000 cfs is likely to be a conservative estimate for redd scour because, due to the areas of a streambed that salmonids typically select for redd construction, the flows needed to scour redds may be significantly greater than those that initiate bed mobility (May et al. 2009). A search of the literature found no corresponding estimate of scouring flow for the Feather River.

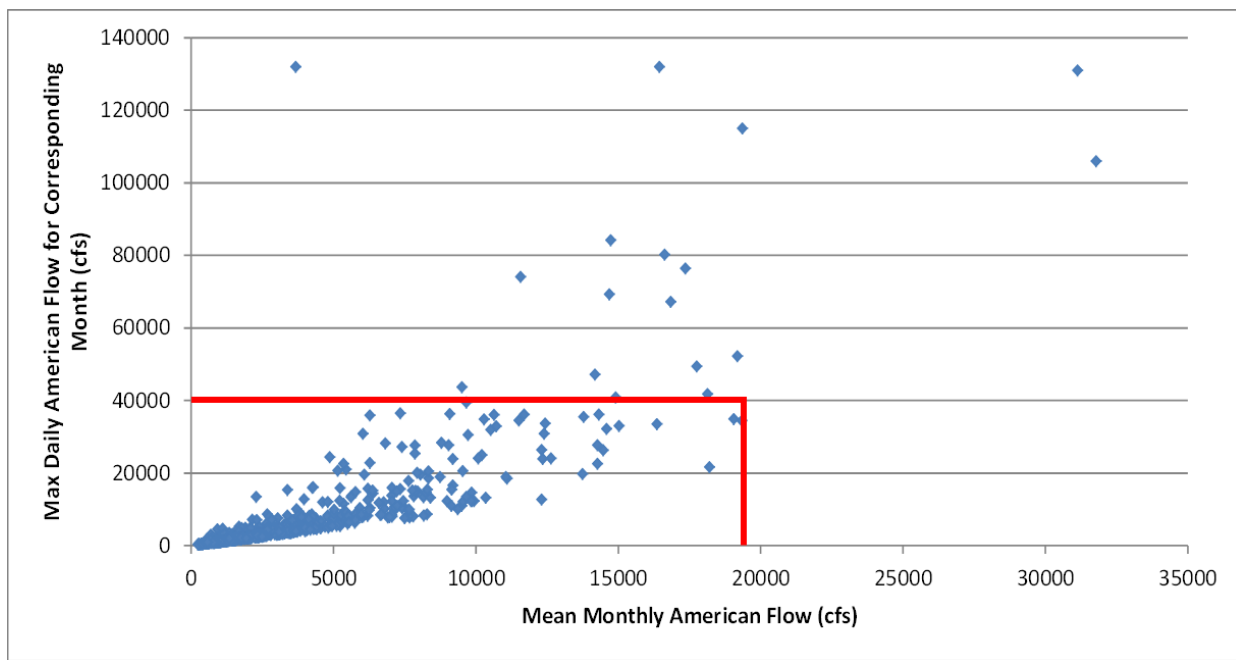
**Table 11N-10. Estimated Bed Mobility Flows for the Sacramento and American Rivers**

<b>River</b>	<b>Approximate flow ranges to initiate mobility (cfs)</b>	<b>References</b>
Sacramento River	24,000–50,000	CALFED 2000; Cain and Monohan 2008
American River	26,500–50,000	Ayres Associates 2001; Fairman 2007

For the Sacramento River, the frequency of flows exceeding 40,000 cfs for Alternatives 1–3 and the NAA during the spawning and egg incubation periods of winter-run, spring-run, fall-run and late fall-run Chinook salmon and steelhead were estimated from USRDOM estimates of daily flows.

No estimated daily flows for the American River under Alternatives 1–3 and the NAA are available; only CALSIM II estimates are available. Redd scour can occur at a very small temporal scale (minutes to hours), whereas CALSIM II provides mean monthly flow estimates. In an attempt to overcome this discrepancy in temporal scales, historical monthly and daily flow data during December through April (when scour is most likely to occur) were plotted to determine whether the probability of occurrence of daily flows above the scour flow threshold

could be predicted with monthly flow data. The purpose was to find the minimum monthly flow value at which the maximum daily flow in that month would always be greater than the 40,000-cfs scour flow threshold. The actual monthly and daily flow data used in the analysis are from gauge records at Hazel Avenue, and the CALSIM II estimates used to compare probabilities of redd scour for Alternatives 1–3 and the NAA are for the Nimbus Dam location. The Nimbus Dam location is immediately upstream of the Hazel Avenue gauge location. The analysis of the Hazel Avenue gauge data shows that for months with a mean monthly flow of at least 19,350 cfs, the maximum daily flow in that month is always at least 40,000 cfs (Figure 11N-2). Therefore, redd scour probabilities for Alternatives 1–3 and the NAA were evaluated by comparing frequencies of CALSIM II flows greater than 19,350 cfs at Nimbus Dam during the fall-run and steelhead spawning and incubation periods.



**Figure 11N-2. Relationship between Mean Monthly Flows and Maximum Daily Flows during December through April, American River Downstream of Hazel Avenue, 1950–2015. Minimum monthly flow is identified in red.**

### 11N.2.3 Juvenile Stranding

A juvenile stranding analysis for the Sacramento River was developed using a functional relationship developed in field studies by USFWS (2006). The juvenile stranding analysis is conceptually similar to the redd dewatering analysis in that both compare water elevation at an initial flow with that at the minimum flow during the following period. A period of 3 months is used for the juvenile stranding analysis in this report because the juveniles are presumed to be most vulnerable to stranding during their first 3 months (i.e., fry stage). The juvenile stranding analysis (USFWS 2006) computes the area of salmonid rearing habitat inundated at the initial flow that is dewatered at the minimum (stranding) flow and converts this area to number of stranded juveniles using estimates of habitat capacity based on field study observations. The

estimates of area of rearing habitat available at different flows are based on a combination of field observations and modeling (USFWS 2006).

Juvenile stranding is computed using USRDOM daily flow estimates for Alternatives 1–3 and the NAA at three locations in the upper Sacramento River: Keswick Dam, Clear Creek, and Battle Creek. Separate tables for converting initial and stranding flows to number of juveniles stranded were developed for periods when the ACID Dam boards are in and when they are out (Table 11N-11 and Table 11N-12). Both tables are used for all the salmonid species and races.

**Table 11N-11. Juvenile Stranding Look-up Table for Chinook Salmon and Steelhead in the Sacramento River with ACID Dam Boards Out (numbers of juveniles stranded are looked up at the intersection of the “Initial Flow” columns and “Stranding Flow” rows)**

	Initial Flow											
		3,500	3,750	4,000	4,250	4,500	4,750	5,000	5,250	5,500	6,000	6,500
Stranding Flow	3,250	1,097	11,227	11,895	13,095	14,598	16,654	16,819	16,939	17,494	20,250	20,860
	3,500	-	10,130	10,798	11,998	13,501	15,557	15,722	15,842	16,397	19,153	19,763
	3,750	-	-	668	1,868	3,371	5,427	5,592	5,712	6,267	9,023	9,633
	4,000	-	-	-	1,200	2,703	4,759	4,925	5,044	5,599	8,355	8,965
	4,250	-	-	-	-	1,503	3,559	3,725	3,844	4,399	7,155	7,765
	4,500	-	-	-	-	-	2,056	2,222	2,341	2,896	5,652	6,262
	4,750	-	-	-	-	-	-	185	304	859	3,615	4,225
	5,000	-	-	-	-	-	-	-	139	694	3,450	4,060
	5,250	-	-	-	-	-	-	-	-	574	3,330	3,940
	5,500	-	-	-	-	-	-	-	-	-	2,775	3,385
	6,000	-	-	-	-	-	-	-	-	-	-	629
	6,500	-	-	-	-	-	-	-	-	-	-	-
	7,000	-	-	-	-	-	-	-	-	-	-	-
	7,500	-	-	-	-	-	-	-	-	-	-	-
	8,000	-	-	-	-	-	-	-	-	-	-	-
	9,000	-	-	-	-	-	-	-	-	-	-	-
	10,000	-	-	-	-	-	-	-	-	-	-	-
	11,000	-	-	-	-	-	-	-	-	-	-	-
	12,000	-	-	-	-	-	-	-	-	-	-	-
	13,000	-	-	-	-	-	-	-	-	-	-	-
	14,000	-	-	-	-	-	-	-	-	-	-	-

**Table 11N-11 (cont.)**

		<b>Initial Flow</b>									
		7,000	7,500	8,000	9,000	10,000	11,000	12,000	13,000	14,000	15,000
<b>Stranding Flow</b>	3,250	20,954	21,024	21,953	22,764	23,084	23,193	23,230	23,239	23,253	23,420
	3,500	19,857	19,927	20,856	21,668	21,987	22,096	22,133	22,142	22,156	22,323
	3,750	9,727	9,797	10,726	11,538	11,857	11,966	12,003	12,012	12,026	12,193
	4,000	9,059	9,129	10,059	10,870	11,189	11,298	11,335	11,344	11,358	11,525
	4,250	7,859	7,929	8,858	9,670	9,989	10,098	10,135	10,144	10,158	10,325
	4,500	6,356	6,426	7,355	8,167	8,486	8,595	8,632	8,641	8,655	8,822
	4,750	4,319	4,389	5,319	6,130	6,449	6,558	6,595	6,604	6,618	6,785
	5,000	4,154	4,224	5,153	5,964	6,284	6,393	6,430	6,439	6,453	6,620
	5,250	4,034	4,104	5,033	5,845	6,164	6,273	6,310	6,319	6,333	6,500
	5,500	3,479	3,549	4,479	5,290	5,609	5,718	5,755	5,764	5,778	5,945
	6,000	723	793	1,723	2,534	2,853	2,962	2,999	3,008	3,022	3,189
	6,500	114	183	1,113	1,924	2,243	2,353	2,390	2,399	2,413	2,579
	7,000	-	89	1,018	1,830	2,149	2,258	2,295	2,304	2,318	2,485
	7,500	-	-	949	1,760	2,079	2,188	2,226	2,234	2,249	2,415
	8,000	-	-	-	811	1,131	1,240	1,277	1,286	1,300	1,466
	9,000	-	-	-	-	319	428	466	474	489	655
	10,000	-	-	-	-	-	109	146	155	169	336
	11,000	-	-	-	-	-	-	37	46	60	227
	12,000	-	-	-	-	-	-	-	9	23	190
	13,000	-	-	-	-	-	-	-	-	14	181
	14,000	-	-	-	-	-	-	-	-	-	167

**Table 11N-12. Juvenile Stranding Look-up Table for Chinook Salmon and Steelhead in the Sacramento River with ACID Dam Boards In (numbers of juveniles stranded are looked up at the intersection of the “Initial Flow” columns and “Stranding Flow” rows)**

	Initial Flow											
		3,500	3,750	4,000	4,250	4,500	4,750	5,000	5,250	5,500	6,000	6,500
Stranding Flow	3,250	1,097	11,227	11,895	13,095	14,598	16,671	17,441	17,847	18,402	21,158	21,768
	3,500	-	10,130	10,798	11,998	13,501	15,574	16,344	16,750	17,305	20,061	20,671
	3,750	-	-	668	1,868	3,371	5,444	6,214	6,620	7,175	9,931	10,541
	4,000	-	-	-	1,200	2,703	4,776	5,546	5,953	6,507	9,264	9,873
	4,250	-	-	-	-	1,503	3,576	4,346	4,753	5,307	8,063	8,673
	4,500	-	-	-	-	-	2,073	2,843	3,249	3,804	6,560	7,170
	4,750	-	-	-	-	-	-	789	1,196	1,751	4,507	5,116
	5,000	-	-	-	-	-	-	-	426	981	3,737	4,346
	5,250	-	-	-	-	-	-	-	-	574	3,330	3,940
	5,500	-	-	-	-	-	-	-	-	-	2,775	3,385
	6,000	-	-	-	-	-	-	-	-	-	-	629
	6,500	-	-	-	-	-	-	-	-	-	-	-
	7,000	-	-	-	-	-	-	-	-	-	-	-
	7,500	-	-	-	-	-	-	-	-	-	-	-
	8,000	-	-	-	-	-	-	-	-	-	-	-
	9,000	-	-	-	-	-	-	-	-	-	-	-
	10,000	-	-	-	-	-	-	-	-	-	-	-
	11,000	-	-	-	-	-	-	-	-	-	-	-
	12,000	-	-	-	-	-	-	-	-	-	-	-
	13,000	-	-	-	-	-	-	-	-	-	-	-
	14,000	-	-	-	-	-	-	-	-	-	-	-

**Table 11N-12 (cont.)**

		Initial Flow									
		7,000	7,500	8,000	9,000	10,000	11,000	12,000	13,000	14,000	15,000
Stranding Flow	3,250	21,893	21,932	22,861	23,823	23,602	23,711	23,753	23,757	23,771	23,938
	3,500	20,796	20,835	21,765	22,186	22,505	22,614	22,656	22,660	22,675	22,841
	3,750	10,666	10,705	11,635	12,056	12,375	12,485	12,526	12,531	12,545	12,711
	4,000	9,998	10,037	10,967	11,388	11,708	11,817	11,858	11,863	11,877	12,044
	4,250	8,798	8,837	9,767	10,188	10,508	10,617	10,658	10,663	10,677	10,843
	4,500	7,295	7,334	8,264	8,685	9,004	9,114	9,155	9,160	9,174	9,340
	4,750	5,241	5,281	6,210	6,631	6,951	7,060	7,101	7,106	7,120	7,287
	5,000	4,471	4,510	5,440	5,861	6,181	6,290	6,331	6,336	6,350	6,517
	5,250	4,065	4,104	5,033	5,455	5,774	5,883	5,925	5,929	5,943	6,110
	5,500	3,510	3,549	4,479	4,900	5,219	5,329	5,370	5,375	5,389	5,555
	6,000	754	793	1,723	2,144	2,463	2,572	2,614	2,618	2,633	2,799
	6,500	144	183	1,113	1,534	1,854	1,963	2,004	2,009	2,023	2,190
	7,000	-	58	988	1,409	1,729	1,838	1,879	1,884	1,898	2,065
	7,500	-	-	949	1,370	1,690	1,799	1,840	1,845	1,859	2,025
	8,000	-	-	-	421	741	850	891	896	910	1,077
	9,000	-	-	-	-	319	428	470	474	489	655
	10,000	-	-	-	-	-	109	151	155	169	336
	11,000	-	-	-	-	-	-	41	46	60	227
	12,000	-	-	-	-	-	-	-	5	19	185
	13,000	-	-	-	-	-	-	-	-	14	181
	14,000	-	-	-	-	-	-	-	-	-	167

As noted above, fry are likely the most vulnerable juveniles to the stranding flows and, therefore, stranding flows are assumed to cause the greatest mortality to the salmon runs or steelhead during the months that the fry are present. The seasonal presence of fry and early juveniles of each of the salmonid races and species was estimated from information on the spawning, incubation, and fry emergence periods in Appendix 11A and results of the USFWS RBDD Rotary Screw Trap and Sacramento River Beach Seine sampling efforts. The estimated fry and early juvenile rearing periods are: (1) July through October for winter-run; (2) November through February for spring-run; (3) December through March for fall-run; (4) March to June for late fall-run; and (5) February through May for steelhead.

#### **11N.2.4 Low-Flow Passage Effects on Immigrating Salmon and Sturgeon Adults**

Low flow can interfere with passage of upstream migrating adult salmon or sturgeon due to inadequate water depth or flow over natural or artificial barriers. Note that if periods of low flow last only a few days and are not very frequent, they probably have little effect on the fish because the fish can wait in deeper water until passage conditions improve. The specific flow level at which passage difficulties for migrating adults first appear is not known for the Sacramento, Feather, or American Rivers. Therefore, threshold flows were selected based on the expert judgment of biologists who have experience from observing fish in these rivers at many different flows.

The required minimum flow release from Keswick Dam is 3,250 cfs (Northern California Water Association 2019). This flow was selected as the threshold for potential obstruction of upstream passage for the Sacramento River because the river's flow rarely drops below this level and salmonid adults have not been observed experiencing any passage difficulties at flows approaching this level (Killam pers. comm.). As such, it represents a conservative minimum flow above which fish do not experience migration difficulties. However, there have not been opportunities to observe whether fish experience passage difficulties below this level. A 1,000 cfs flow threshold was selected for the American River in this analysis because this is the approximate flow at which adult fall-run Chinook salmon have been first observed to delay upstream movement to spawning grounds (Kundargi pers. comm.).

A threshold flow for upstream passage in the lower Feather River was more difficult to determine. The primary Feather River passage obstruction is a boulder weir at the Sunset Pumps in the Feather River at Live Oak (NMFS 2018; Seesholtz pers. comm.). This weir creates a partial barrier to the only confirmed spawning location of green sturgeon in the Feather River (Seesholtz et al. 2015). USFWS (2016) indicates that the boulder weir is a barrier to upstream passage of green sturgeon when Feather River flow is less than 6,000 cfs. Given the absence of information indicating passage at lower flows, 6,000 cfs flow was selected as the threshold flow for upstream passage of sturgeon in the Feather River. Adult salmonids are able to pass above the Sunset Pumps weir at 1,500 cfs or less (Kindopp pers. comm. 2021b), so 1,500 cfs was selected as the threshold flow for upstream passage of salmonids. The recovery plan for the southern DPS of green sturgeon lists removal or modification of the Sunset Pumps boulder weir as a high priority recovery action (NMFS 2018), but it is not clear when such measures would be implemented (Seesholtz pers. comm.).

Three locations in the Sacramento River (Keswick Dam, RBDD, and Wilkins Slough), one location in the Feather River (below Thermalito Afterbay outlet), and one location in the American River (below Nimbus Dam) were selected for this analysis of low flows. For the Sacramento River, USRDOM daily flow estimates at Keswick Dam and the RBDD and CALSIM II monthly flow estimates at Wilkins Slough were used. CALSIM II monthly flow estimates were also used for the locations on the Feather and American Rivers. For each species and location, the percent of days (Keswick Dam and RBDD) or months (other locations) during the adult immigration period that modeled flows were lower than the minimum flow thresholds were calculated for Alternatives 1–3 and the NAA, and the differences in these percentages between Alternatives 1–3 and the NAA were determined.

## 11N.3 Results

### 11N.3.1 Redd Dewatering

Differences in redd dewatering between Alternatives 1–3 and the NAA for all the salmonid runs/species in the three rivers (Sacramento, Feather and American) are presented using the grand mean percentages of redds dewatered for each month that the species/run spawns and each water year type and all water year types combined (see Table 11N-13). For all redd dewatering tables in this appendix (Table 11N-13 through Table 11N-21), the complete spawning and egg/alevin incubation periods are provided because changes in project-related flow any time

during these periods can affect the redd dewatering results. The means of the redd dewatering estimates under the NAA and Alternatives 1–3 are compared using absolute differences rather than relative differences (percent change) because many of the values for percentages of redds dewatered are small. Expressing changes of small values as percent changes may result in very large values that may be misleading. For instance, in Table 11N-13 below, the absolute difference in percentages of redds dewatered between Alternative 1A and the NAA for April in Dry Water Years is 0.5%, whereas the difference expressed as the percent change would be 38%. Note that the absolute differences in this table and the others giving redd dewatering results (Table 11N-13 through Table 11N-21) are given without the percent symbol (“%”) to guard against confusing them with percent changes. Absolute differences in the tables greater than equal to 2% are highlighted in green when they refer to reductions in percent of redds dewatered and in red when they refer to increases in percent of redds dewatered. The highlighting is provided for convenience to flag the largest differences in the results.

### 11N.3.1.1 Sacramento River

#### Winter-run Chinook Salmon

Spawning of winter-run occurs primarily between Keswick Dam and the confluence with Clear Creek (Table 11N-1), so Keswick Dam flows were used to analyze winter-run redd dewatering.

The results show few large changes in redd dewatering between the NAA and Alternatives 1–3 (Table 11N-13). The largest reductions in redd dewatering occur under Alternative 3 during the spawning and incubation period for eggs spawned in June of Above Normal and Below Normal Water Years and in July of Above Normal Water Years. Changes for most months and water year types under all the alternatives are less than 2%. Overall, the effects of Alternatives 1–3 on winter-run redd dewatering are minor.

**Table 11N-13. Percent of Winter-run Redds Dewatered in the Sacramento River and Differences in the Percentages for the No Action Alternative (NAA) and Alternatives 1–3**

Period	Water Year Type	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
April–July	Wet	18.5	18.6 (0.1)	18.6 (0.1)	18.6 (0.1)	18.6 (0.1)
	Above Normal	6.5	6.8 (0.2)	6.8 (0.2)	6.8 (0.2)	6.8 (0.2)
	Below Normal	2.3	2.6 (0.4)	2.7 (0.4)	2.6 (0.4)	2.7 (0.4)
	Dry	1.3	1.8 (0.5)	1.7 (0.5)	1.8 (0.5)	1.6 (0.3)
	Critically Dry	1.0	1 (-0.1)	0.9 (-0.1)	1 (-0.1)	1.1 (0.1)
	All	7.6	7.9 (0.2)	7.9 (0.2)	7.9 (0.2)	7.9 (0.2)
May–August	Wet	3.8	3.6 (-0.3)	3.6 (-0.3)	3.6 (-0.3)	3.6 (-0.3)
	Above Normal	2.3	2 (-0.4)	2.1 (-0.3)	2 (-0.4)	2.1 (-0.3)
	Below Normal	0.8	0.6 (-0.1)	0.6 (-0.1)	0.6 (-0.1)	0.8 (0)
	Dry	0.9	0.6 (-0.3)	0.6 (-0.3)	0.6 (-0.3)	0.6 (-0.4)
	Critically Dry	1.7	1.2 (-0.4)	1.2 (-0.5)	1.2 (-0.4)	1.2 (-0.5)
	All	2.1	1.8 (-0.3)	1.8 (-0.3)	1.8 (-0.3)	1.9 (-0.3)
June–September	Wet	1.5	1.7 (0.2)	1.7 (0.2)	1.7 (0.2)	1.7 (0.2)
	Above Normal	3.8	3.6 (-0.2)	2 (-1.8)	3.5 (-0.2)	1.5 (-2.3)*

Period	Water Year Type	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
	Below Normal	11.1	11.3 (0.2)	10.4 (-0.7)	11.4 (0.3)	8.2 (-2.9)*
	Dry	17.6	16 (-1.6)	16.4 (-1.2)	16 (-1.5)	15.9 (-1.7)
	Critically Dry	13.7	12.5 (-1.2)	11.9 (-1.7)	12.4 (-1.2)	12 (-1.6)
	All	8.8	8.3 (-0.4)	7.9 (-0.8)	8.3 (-0.4)	7.4 (-1.4)
July–October	Wet	10.4	11.3 (0.9)	11.3 (0.9)	11.3 (0.9)	11.3 (0.9)
	Above Normal	19.7	20.8 (1.1)	18.7 (-1)	20.7 (1)	15.6 (-4.1)*
	Below Normal	24.1	26 (1.9)	25.2 (1.1)	26.1 (2)^	23.5 (-0.6)
	Dry	27.6	26.8 (-0.8)	27.4 (-0.3)	26.7 (-0.9)	26.4 (-1.2)
	Critically Dry	18.6	17.6 (-0.9)	17.4 (-1.2)	17.7 (-0.8)	17.3 (-1.3)
	All	19.1	19.5 (0.4)	19.2 (0.1)	19.5 (0.5)	18.2 (-0.9)

\* Results for which redds dewatered under Alternative 1, 2, or 3 are more than 2% below redds dewatered under the NAA are highlighted green.

^ Results for which redds dewatered under Alternative 1, 2, or 3 are more than 2% above redds dewatered under the NAA are highlighted red.

### Spring-run Chinook Salmon

Spawning of spring-run occurs primarily between the ACID Dam and Airport Road (Table 11N-1), so Sacramento River at Clear Creek flows were used to analyze spring-run redd dewatering. However, as discussed earlier, percentage of redd dewatering was computed from predicted flows using the fall-run flows versus redd dewatering relationship because field data for spring-run were inadequate for developing the relationship and fall-run spawning distributions and timing are most similar to those of spring-run (USFWS 2006).

The results of the redd dewatering analysis for spring-run (Table 11N-14) show relatively large (greater than 2%) increases in redd dewatering for eggs spawned in October of Critically Dry Water Years under Alternatives 1–3, September of Above Normal Water Years under Alternatives 1B and 3, and relatively large reductions in redd dewatering for eggs spawned in August of Above Normal Water Years under Alternative 3. Changes for most months and water year types under all the alternatives are less than 2%. In general, Alternatives 1–3 are not expected to substantially affect spring-run redd dewatering.

**Table 11N-14. Percent of Spring-run Redds Dewatered in the Sacramento River and Differences in the Percentages for the No Action Alternative (NAA) and Alternatives 1–3**

Period	Water Year Type	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
August–November	Wet	21.3	20.6 (-0.7)	20.9 (-0.4)	20.6 (-0.7)	20.8 (-0.5)
	Above Normal	20.5	21.3 (0.8)	20.5 (0)	21.3 (0.8)	16.9 (-3.6)*
	Below Normal	24.3	25.3 (1)	24.6 (0.3)	25.3 (1.1)	23.1 (-1.2)
	Dry	27.2	27.6 (0.4)	27.4 (0.2)	27.6 (0.4)	26.1 (-1.2)
	Critically Dry	23.1	21.7 (-1.4)	22.2 (-0.8)	22.7 (-0.3)	22.4 (-0.7)
	All	23.3	23.2 (-0.1)	23.1 (-0.1)	23.4 (0.1)	22 (-1.2)
September–December	Wet	25.6	25.6 (0)	25.6 (0)	25.6 (0)	25.5 (-0.1)
	Above Normal	16.2	16.8 (0.6)	18.5 (2.3)^	16.8 (0.6)	20.7 (4.5)^

Period	Water Year Type	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
	Below Normal	6.9	7.6 (0.7)	7.4 (0.5)	7.6 (0.7)	6.9 (0)
	Dry	5.0	6.1 (1.1)	5.3 (0.3)	6.1 (1.1)	5 (0)
	Critically Dry	6.1	7.3 (1.2)	7.1 (1)	7.3 (1.2)	7.1 (1)
	All	13.7	14.3 (0.6)	14.3 (0.6)	14.3 (0.6)	14.4 (0.8)
October - January	Wet	19.3	19.2 (0)	19 (-0.2)	19.2 (0)	19.1 (-0.2)
	Above Normal	13.9	14.2 (0.3)	14.4 (0.5)	14.2 (0.3)	16.1 (2.2)^
	Below Normal	11.9	11.8 (-0.1)	11.9 (0)	11.9 (0)	12 (0)
	Dry	7.9	8 (0.1)	7.1 (-0.8)	8.1 (0.2)	7.7 (-0.2)
	Critically Dry	8.4	13 (4.6)^	11.6 (3.2)^	11.5 (3.1)^	11.4 (3)^
	All	13.2	13.8 (0.7)	13.4 (0.3)	13.7 (0.5)	13.8 (0.7)

\* Results for which redds dewatered under Alternative 1, 2, or 3 are more than 2% below redds dewatered under the NAA are highlighted green.

^ Results for which redds dewatered under Alternative 1, 2, or 3 are more than 2% above redds dewatered under the NAA are highlighted red.

### Fall-run Chinook Salmon

Spawning of fall-run occurs primarily between Highway 44 and Jellys Ferry (Table 11N-1), so Sacramento River at Battle Creek flows were used to analyze fall-run redd dewatering. The results of the redd dewatering analysis for fall-run (Table 11N-15) show large (greater than 2%) increases in redd dewatering for eggs spawned in September of Above Normal Water Years under Alternatives 1B and 3, and for eggs spawned in October of critically dry years under Alternatives 1A and 2. The results show large reductions in redd dewatering for eggs spawned in November of Above Normal Water Years under Alternatives 1, 2 and 3. Most other changes for all months and water year types under all the alternatives are less than 1%. The results indicate that Alternatives 1–3 would result in minor increases in fall-run redd dewatering during Above Normal and Critically Dry Water Years. These increases are not expected to substantially affect fall-run redd dewatering.

**Table 11N-15. Percent of Fall-run Redds Dewatered in the Sacramento River and Differences in the Percentages for the No Action Alternative (NAA) and Alternatives 1–3**

Period	Water Year Type	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
September–December	Wet	18.1	17.9 (-0.2)	18 (-0.1)	17.9 (-0.2)	18 (-0.1)
	Above Normal	11.6	12.2 (0.6)	13.6 (2)	12.2 (0.6)	15.7 (4.1)
	Below Normal	3.8	4 (0.3)	4 (0.2)	4.1 (0.4)	3.8 (0.1)
	Dry	2.9	3.3 (0.4)	3.1 (0.2)	3.3 (0.4)	2.9 (0)
	Critically Dry	4.6	4.7 (0.1)	4.6 (0)	5.1 (0.5)	4.6 (0.1)
	All	9.4	9.6 (0.2)	9.7 (0.3)	9.7 (0.3)	10 (0.6)
October–January	Wet	12.9	12.9 (0)	12.7 (-0.2)	12.9 (0)	12.8 (-0.2)
	Above Normal	9.0	9.1 (0.1)	9.3 (0.2)	9.1 (0.1)	10.7 (1.6)
	Below Normal	8.4	8.1 (-0.3)	8.2 (-0.2)	8.3 (-0.1)	8.5 (0.1)
	Dry	4.2	4.5 (0.3)	4.2 (0)	4.5 (0.3)	4.4 (0.1)
	Critically Dry	6.6	9.5 (2.8)	8.4 (1.7)	8.8 (2.1)	8.4 (1.8)

Period	Water Year Type	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
	All	8.8	9.2 (0.4)	8.9 (0.2)	9.1 (0.4)	9.2 (0.5)
November - February	Wet	14.7	14.7 (0)	14.1 (-0.5)	14.7 (0)	14.2 (-0.5)
	Above Normal	20.7	18.6 (-2.1)*	17.9 (-2.8)*	18.6 (-2.1)*	17.8 (-2.9)*
	Below Normal	13.5	12.5 (-1)	12.8 (-0.7)	12.4 (-1)	12.9 (-0.6)
	Dry	8.9	8 (-0.9)	9.8 (0.9)	8 (-0.9)	10.6 (1.7)
	Critically Dry	10.8	10.7 (-0.1)	10.9 (0.2)	10.8 (0)	10.5 (-0.3)
	All	13.5	12.8 (-0.7)	13 (-0.5)	12.8 (-0.7)	13.2 (-0.3)

\* Results for which redds dewatered under Alternative 1, 2, or 3 are more than 2% below redds dewatered under the NAA are highlighted green.

^ Results for which redds dewatered under Alternative 1, 2, or 3 are more than 2% above redds dewatered under the NAA are highlighted red.

### Late Fall–run Chinook Salmon

Spawning of late fall–run occurs primarily between Keswick Dam and the confluence with Clear Creek (Table 11N-1), so Keswick Dam flows were used to analyze late fall–run redd dewatering.

The results for late fall–run redd dewatering show little effect from the alternatives, with no greater than 2% differences from the NAA (Table 11N-16). All increases in redd dewatering are less than 1%, except for a 1.7% increase for the February through May period of Above Normal Water Years under Alternative 3. The biggest reductions in redd dewatering occur during Wet and Above Normal Water Years of the December through March spawning and incubation period. In general, Alternatives 1–3 are expected to have little effect on late fall–run redd dewatering.

**Table 11N-16. Percent of Late Fall–run Redds Dewatered in the Sacramento River and Differences in the Percentages for the No Action Alternative (NAA) and Alternatives 1–3**

Period	Water Year Type	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
December–March	Wet	16.8	15.8 (-1)	15.8 (-1)	15.6 (-1.2)	15.6 (-1.2)
	Above Normal	14.2	12.5 (-1.7)	13.2 (-1)	12.5 (-1.7)	13.3 (-0.9)
	Below Normal	19.1	18.6 (-0.5)	19 (-0.1)	18.6 (-0.5)	19.8 (0.7)
	Dry	13.9	13.5 (-0.4)	13.8 (-0.1)	13.4 (-0.5)	14.8 (0.9)
	Critically Dry	1.9	1.5 (-0.4)	1.6 (-0.3)	1.7 (-0.3)	1.7 (-0.2)
	All	14.0	13.2 (-0.8)	13.4 (-0.5)	13.2 (-0.8)	13.8 (-0.2)
January–April	Wet	33.6	33.3 (-0.3)	33.5 (-0.1)	33.3 (-0.3)	33.7 (0.1)
	Above Normal	16.5	16.6 (0.1)	16.7 (0.2)	16.6 (0.1)	16.8 (0.3)
	Below Normal	6.6	6.6 (0)	6.5 (-0.1)	6.6 (0)	6.5 (-0.1)
	Dry	2.8	2.8 (0)	2.9 (0)	2.8 (0)	2.9 (0.1)
	Critically Dry	2.3	2.8 (0.5)	2.1 (-0.2)	2.2 (-0.1)	2 (-0.3)
	All	15.2	15.1 (0)	15.1 (0)	15.1 (-0.1)	15.2 (0)
February–May	Wet	44.0	44.1 (0.2)	44.4 (0.4)	44.1 (0.2)	44.7 (0.8)

Period	Water Year Type	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
	Above Normal	29.6	30 (0.4)	29.8 (0.3)	30 (0.4)	31.3 (1.7)
	Below Normal	12.3	12.4 (0)	12.7 (0.3)	12 (-0.4)	13 (0.7)
	Dry	2.6	2.5 (-0.1)	2.5 (-0.1)	2.5 (-0.1)	2.6 (-0.1)
	Critically Dry	1.6	1.5 (-0.1)	1.5 (-0.1)	1.5 (-0.1)	1.5 (-0.1)
	All	21.2	21.3 (0.1)	21.3 (0.2)	21.2 (0)	21.8 (0.6)
March–June	Wet	36.9	37.3 (0.4)	37.3 (0.4)	37 (0.1)	37.4 (0.5)
	Above Normal	27.3	27.4 (0.1)	27.4 (0.1)	27.4 (0.1)	27.4 (0.1)
	Below Normal	8.0	8.2 (0.2)	8.1 (0.2)	8.1 (0.2)	8.1 (0.2)
	Dry	3.4	3.5 (0.1)	3.6 (0.2)	3.6 (0.1)	4.2 (0.8)
	Critically Dry	3.0	3.5 (0.5)	3.1 (0.1)	3.5 (0.5)	3.3 (0.3)
	All	18.3	18.5 (0.2)	18.5 (0.2)	18.4 (0.2)	18.7 (0.4)

\* Results for which redds dewatered under Alternative 1, 2, or 3 are more than 2% below redds dewatered under the NAA are highlighted green.

^ Results for which redds dewatered under Alternative 1, 2, or 3 are more than 2% above redds dewatered under the NAA are highlighted red.

## Steelhead

The spawning distribution of steelhead is uncertain, as previously noted, but most spawning is assumed to occur between Keswick Dam and Battle Creek, where most salmon spawning occurs and where temperature conditions are most suitable. Therefore, Clear Creek flows, which are near the center of this reach, were used to analyze steelhead redd dewatering.

The results for steelhead redd dewatering show large (greater than 2%) reductions in redd dewatering for eggs spawned in November of Above Normal Water Years under all four alternatives and in December of Above Normal Water Years for Alternatives 1A and 2 (Table 11N-17). All increases in steelhead redd dewatering are less than 1%, except for a 1.5% increase in Dry Water Years for the November through February period. In general, Alternatives 1–3 are expected to have a minor benefit on steelhead redd dewatering for eggs spawned in November and December.

**Table 11N-17. Percent of Steelhead Redds Dewatered in the Sacramento River and Differences in the Percentages for the No Action Alternative (NAA) and Alternatives 1–3**

Period	Water Year Type	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
November–February	Wet	13.8	13.5 (-0.4)	13 (-0.9)	13.4 (-0.4)	13 (-0.8)
	Above Normal	21.2	19.1 (-2.1)*	18.6 (-2.6)*	19.1 (-2.1)*	18.3 (-2.8)*
	Below Normal	13.0	11.8 (-1.2)	12.4 (-0.6)	11.8 (-1.2)	12.5 (-0.5)
	Dry	9.0	7.7 (-1.3)	9.4 (0.4)	7.9 (-1.1)	10.5 (1.5)
	Critically Dry	9.3	9.3 (0)	9.7 (0.4)	9.4 (0.1)	9.1 (-0.3)
	All	13.0	12.1 (-0.9)	12.4 (-0.6)	12.2 (-0.9)	12.6 (-0.5)
December–March	Wet	20.3	19.3 (-1)	19.3 (-1)	19.1 (-1.2)	19.1 (-1.2)

Period	Water Year Type	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
	Above Normal	18.3	16.3 (-2)*	17 (-1.3)	16.3 (-2)*	17.3 (-0.9)
	Below Normal	23.4	23 (-0.4)	23.4 (0)	23 (-0.4)	24.2 (0.8)
	Dry	17.7	17.1 (-0.6)	17.6 (0)	17.1 (-0.6)	18.8 (1.1)
	Critically Dry	3.3	3 (-0.3)	3.1 (-0.2)	3.1 (-0.2)	3.1 (-0.1)
	All	17.5	16.6 (-0.8)	16.9 (-0.5)	16.6 (-0.9)	17.3 (-0.1)
January–April	Wet	39.5	39.2 (-0.2)	39.4 (-0.1)	39.2 (-0.2)	39.6 (0.1)
	Above Normal	22.5	22.5 (0)	22.6 (0.1)	22.5 (0)	22.7 (0.2)
	Below Normal	10.8	10.9 (0.1)	10.7 (-0.1)	10.9 (0.1)	10.8 (-0.1)
	Dry	4.8	4.7 (-0.1)	4.8 (0)	4.7 (-0.1)	4.9 (0.1)
	Critically Dry	4.3	4.6 (0.4)	4.1 (-0.2)	4.2 (-0.1)	4 (-0.3)
	All	19.3	19.3 (0)	19.3 (-0.1)	19.2 (-0.1)	19.4 (0)
February - May	Wet	52.0	52.3 (0.3)	52.6 (0.7)	52.3 (0.3)	53 (1)
	Above Normal	37.2	37.3 (0.2)	37.2 (0.1)	37.3 (0.2)	38.6 (1.4)
	Below Normal	19.6	19.7 (0.1)	20.1 (0.5)	19.4 (-0.2)	20.5 (0.9)
	Dry	7.4	7.2 (-0.1)	7.3 (-0.1)	7.2 (-0.1)	7.4 (0)
	Critically Dry	4.0	3.9 (-0.2)	3.8 (-0.2)	3.8 (-0.2)	3.9 (-0.2)
	All	27.4	27.5 (0.1)	27.7 (0.3)	27.5 (0)	28.1 (0.7)

\* Results for which redds dewatered under Alternative 1, 2, or 3 are more than 2% below redds dewatered under the NAA are highlighted green.

^ Results for which redds dewatered under Alternative 1, 2, or 3 are more than 2% above redds dewatered under the NAA are highlighted red.

### 11N.3.1.2 Feather River

As described previously, redd dewatering for Feather River salmon and steelhead was estimated directly from changes in flow. The spawning and dewatering flows downstream of the Thermalito Afterbay outlet for each month of spring-run, fall-run, and steelhead spawning, as estimated by CALSIM II, were used to compute the reductions under Alternatives 1–3 and the NAA. Larger flow reductions are assumed to increase the percent of redds dewatered and, therefore, to have a potentially negative effect on the species' populations. Flow reductions >100 cfs are flagged in the results table (Table 11N-18 and Table 11N-19) as a convenience to help locate the results with the largest reductions. As previously noted, the use of monthly time-step flow estimates like those obtained from CALSIM II modeling likely underestimates redd dewatering rates. This potential bias is expected to affect all project scenarios equally. Although spring-run, fall-run, and steelhead spawn more in the LFC of the Feather River than in the HFC (Figure 11N-1), Alternatives 1–3 would have no effect on flow in the LFC, so differences in redd dewatering between the project alternatives and the NAA were estimated only for the HFC.

### Spring-run Chinook Salmon

The results for Feather River spring-run and fall-run are combined in Table 11N-18 because their spawning and incubation periods partially overlap (September through February for spring-run and October through March for fall-run). The results for spring-run show large reductions in

Feather River flow for Alternatives 1–3 following September through November spawning (Table 11N-18). These reductions potentially result in high levels of redd dewatering for spring-run spawning in the HFC. The reductions are especially large in October, when the majority of the mean reductions under Alternatives 1–3 are more than 200 cfs greater than those under the NAA. The greatest reductions are in Dry Water Years.

These results indicate that Alternatives 1–3 would substantially increase spring-run redd dewatering in the Feather River. However, given that most spawning of Feather River salmonids occurs in the LFC (Figure 11N-1) (Kindopp pers. comm. 2021a), the expected increased redd dewatering in the HFC is not expected to severely affect the Feather River spring-run population.

**Table 11N-18. Feather River Maximum Flow Reduction at Thermalito Afterbay Outlet during the 3 Months of Egg/Alevin Incubation, Used as a Proxy for Percentage of Spring-run and Fall-run Redds Dewatered, and Differences in the Percentages for the No Action Alternative (NAA) and Alternatives 1–3**

Incubating Egg/Alevin Cohort	Water Year Type	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
September–December	Wet	4,322	4,319 (-4)	4,313 (-9)	4,305 (-18)	4,277 (-46)
	Above Normal	5,563	5,566 (2)	5,532 (-31)	5,566 (2)	5,509 (-55)
	Below Normal	1,097	1,102 (6)	1,189 (93)	1,103 (6)	1,157 (60)
	Dry	19	52 (33)	67 (48)	80 (62)	63 (44)
	Critically Dry	409	577 (168)	617 (208)	612 (203)	570 (161)
	All	2,397	2,430 (32)	2,448 (51)	2,437 (40)	2,419 (22)
October–January	Wet	1,662	1,722 (61)	1,720 (58)	1,723 (61)	1,746 (85)
	Above Normal	1,993	1,972 (-19)	2,033 (40)	1,974 (-19)	2,017 (24)
	Below Normal	362	719 (354)	662 (300)	716 (354)	523 (161)
	Dry	65	639 (574)	633 (568)	545 (479)	465 (400)
	Critically Dry	176	510 (334)	477 (301)	438 (262)	259 (83)
	All	920	1,172 (221)	1,165 (244)	1,141 (221)	1,078 (158)
November–February	Wet	698	698 (0)	698 (0)	698 (0)	699 (0)
	Above Normal	497	496 (-1)	467 (-30)	496 (-1)	445 (-52)
	Below Normal	0	127 (129)	128 (127)	130 (129)	117 (117)
	Dry	38	248 (211)	171 (133)	187 (150)	117 (79)
	Critically Dry	4	74 (70)	72 (68)	66 (62)	69 (65)
	All	303	381 (78)	360 (57)	367 (64)	342 (39)
December–March	Wet	2,287	2,306 (18)	2,305 (17)	2,314 (26)	2,292 (5)

Incubating Egg/Alevin Cohort	Water Year Type	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
	Above Normal	1,178	1,130 (-48)	1,127 (-51)	1,129 (-48)	1,221 (44)
	Below Normal	149	141 (-8)	141 (-8)	164 (14)	140 (-9)
	Dry	426	428 (2)	430 (4)	428 (2)	439 (13)
	Critically Dry	787	787 (0)	787 (0)	787 (0)	794 (7)
	All	1,132	1,130 (-2)	1,129 (-2)	1,136 (4)	1,142 (10)

\* Results for which redds dewatered under Alternative 1, 2, or 3 are more than 100 cfs below redds dewatered under the NAA are highlighted green.

^ Results for which redds dewatered under Alternative 1, 2, or 3 are more than 100 cfs above redds dewatered under the NAA are highlighted red.

### Fall-run Chinook Salmon

The results for the Feather River fall-run spawning and incubation period (October through March) are similar to those for spring-run because the periods of the two runs are similar (Table N11-18). The large flow reductions following October and November spawning are expected to result in high levels of redd dewatering for fall-run. These results indicate that Alternatives 1–3 would substantially increase fall-run redd dewatering in the Feather River. However, given that most spawning of Feather River salmonids occurs in the LFC (Figure 11N-1) (Kindopp pers. comm. 2021a), the expected increased redd dewatering in the HFC is not expected to severely affect the Feather River fall-run population.

### Steelhead

The results for the Feather River steelhead spawning and incubation period (Table 11N-19), which begins 3 months later than the spring-run period, show a great deal less effect of Alternatives 1–3 on flow reductions and, by extension, on steelhead redd dewatering. The results show no changes in mean flow of greater than 100 cfs, indicating that Alternatives 1–3 would not substantially affect steelhead redd dewatering in the Feather River.

**Table 11N-19. Feather River Maximum Flow Reduction at Thermalito Afterbay Outlet during the 3 Months of Egg/Alevin Incubation, Used as a Proxy for Percentage of Steelhead Redds Dewatered, and Differences in the Percentages for the No Action Alternative (NAA) and Alternatives 1–3**

Incubating Egg/Alevin Cohort	Water Year Type	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
December–March	Wet	2,287	2,306 (18)	2,305 (17)	2,314 (26)	2,292 (5)
	Above Normal	1,178	1,130 (-48)	1,127 (-51)	1,129 (-48)	1,221 (44)
	Below Normal	149	141 (-8)	141 (-8)	164 (14)	140 (-9)
	Dry	426	428 (2)	430 (4)	428 (2)	439 (13)
	Critically Dry	787	787 (0)	787 (0)	787 (0)	794 (7)
	All	1,132	1,130 (-2)	1,129 (-2)	1,136 (4)	1,142 (10)

Incubating Egg/Alevin Cohort	Water Year Type	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
January–April	Wet	6,935	6,902 (-33)	6,902 (-33)	6,902 (-33)	6,934 (-2)
	Above Normal	1,394	1,394 (0)	1,394 (0)	1,394 (0)	1,453 (58)
	Below Normal	374	369 (-4)	382 (8)	370 (-4)	378 (5)
	Dry	318	324 (6)	323 (5)	324 (6)	323 (5)
	Critically Dry	222	232 (10)	223 (1)	223 (1)	222 (-1)
	All	2,569	2,561 (-8)	2,561 (-8)	2,560 (-10)	2,579 (10)
February–May	Wet	6,769	6,825 (57)	6,789 (21)	6,827 (58)	6,830 (62)
	Above Normal	3,483	3,462 (-21)	3,505 (21)	3,471 (-12)	3,558 (75)
	Below Normal	1,541	1,538 (-3)	1,548 (7)	1,538 (-3)	1,546 (5)
	Dry	469	494 (25)	493 (24)	494 (25)	470 (1)
	Critically Dry	415	415 (0)	415 (0)	415 (0)	414 (0)
	All	3,083	3,102 (20)	3,099 (16)	3,104 (22)	3,114 (31)
March–June	Wet	8,798	8,797 (-1)	8,800 (2)	8,797 (-1)	8,808 (10)
	Above Normal	4,097	4,084 (-12)	4,087 (-9)	4,084 (-12)	4,086 (-11)
	Below Normal	738	739 (1)	739 (1)	739 (1)	739 (1)
	Dry	393	416 (23)	415 (23)	416 (23)	393 (0)
	Critically Dry	611	612 (1)	608 (-3)	612 (1)	607 (-4)
	All	3,691	3,694 (3)	3,695 (4)	3,694 (3)	3,692 (1)

\* Results for which redds dewatered under Alternative 1, 2, or 3 are more than 100 cfs below redds dewatered under the NAA are highlighted green.

^ Results for which redds dewatered under Alternative 1, 2, or 3 are more than 100 cfs above redds dewatered under the NAA are highlighted red.

### 11N.3.1.3 American River

The redd dewatering analysis for the lower American River used relationships between flow, river stage, and redd depth distribution developed by Bratovich et al. (2017). For this report, the effects of flow changes under Alternatives 1–3 were analyzed for the fall-run and steelhead egg and alevin incubation periods for each year of the CALSIM II period of record. Based on ranges provided in Bratovich et al. (2017), American River fall-run and steelhead were estimated to have 3-month and 2-month incubation periods, respectively. The analysis compared CALSIM II flow estimates below Nimbus Dam for each spawning month with the minimum flow during 2 or 3 months following the spawning month to estimate the percentage of redds dewatered.

#### Fall-run Chinook Salmon

The results of the redd dewatering analysis for American River fall-run (Table 11N-20) show large increases in redd dewatering under all the alternatives for eggs spawned in October of Dry and/or Critically Dry Water Years and November of all water year types except Wet Water Years. The largest increases in redd dewatering are in November, including increases of 4.5% and 6.3% for Critically Dry and Above Normal Water Years, respectively, under Alternative 3.

Alternatives 1–3 are predicted to moderately increase fall-run redd dewatering in the American river.

**Table 11N-20. Percent of Fall-run Redds Dewatered in the American River and Differences in the Percentages for the No Action Alternative (NAA) and Alternatives 1–3**

Month	Water Year Type	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
October–January	Wet	0.4	0.3 ( -0.1)	0.3 ( -0.1)	0.3 ( -0.1)	0.3 ( -0.1)
	Above Normal	0.1	0.1 ( 0)	0.1 ( 0)	0.1 ( 0)	0.1 ( 0)
	Below Normal	2.9	2.9 ( 0)	1.5 ( -1.3)	2.9 ( 0)	1.5 ( -1.3)
	Dry	0.4	1.7 ( 1.3)	4.5 ( 4.1)	1.7 ( 1.3)	4.4 ( 4)
	Critically Dry	8.7	12 ( 3.8)	12 ( 3.8)	12 ( 3.8)	7.4 ( -1.3)
	All	2.0	2.8 ( 0.8)	3.2 ( 1.2)	2.8 ( 0.8)	2.4 ( 0.4)
November–February	Wet	31.0	32 ( 1.3)	31 ( 0.2)	32 ( 1.4)	32 ( 1.3)
	Above Normal	3.5	4.8 ( 1.4)	7.7 ( 4.2)	4.8 ( 1.3)	9.8 ( 6.3)
	Below Normal	7.5	8.4 ( 0.8)	8.4 ( 0.8)	8.4 ( 0.8)	11 ( 3.8)
	Dry	6.8	11 ( 3.7)	6.6 ( -0.2)	11 ( 3.7)	5.7 ( -1.2)
	Critically Dry	0.9	0.2 ( -0.7)	0.6 ( -0.3)	0.6 ( -0.3)	5.4 ( 4.5)
	All	13.3	15 ( 1.5)	14 ( 0.7)	15 ( 1.5)	16 ( 2.4)
December–March	Wet	22.2	22 ( -0.1)	22 ( 0)	22 ( -0.6)	22 ( -0.3)
	Above Normal	19.4	19 ( -0.1)	20 ( 0.4)	19 ( -0.1)	19 ( 0)
	Below Normal	27.1	27 ( -0.2)	28 ( 1.1)	27 ( -0.2)	28 ( 1)
	Dry	19.3	20 ( 0.4)	22 ( 2.3)	19 ( -0.3)	20 ( 0.8)
	Critically Dry	0.0	3.4 ( 3.4)	2.9 ( 2.8)	1.4 ( 1.4)	0 ( 0)
	All	18.7	19 ( 0.5)	20 ( 1.2)	19 ( -0.1)	19 ( 0.3)

\* Results for which redds dewatered under Alternative 1, 2, or 3 are more than 2% below redds dewatered under the NAA are highlighted green.

^ Results for which redds dewatered under Alternative 1, 2, or 3 are more than 2% above redds dewatered under the NAA are highlighted red.

## Steelhead

The results for steelhead redd dewatering in the American River show little effect from the alternatives (Table 11N-21). Note that the incubation period for steelhead in the American River is 2 months rather than 3 months. The only large (greater than 2%) changes in steelhead redd dewatering are a 2% reduction in Critically Dry Water Years of the December through February period under Alternative 1A and a 5.3% reduction for Critically Dry Water Years of the February through April period under Alternative 3. In general, Alternatives 1–3 are expected to have little effect on steelhead redd dewatering.

**Table 11N-21. Percent of Steelhead Redds Dewatered in the American River and Differences in the Percentages for the No Action Alternative (NAA) and Alternatives 1–3**

Month	Water Year Type	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
December–February	Wet	16.9	17 ( 0)	17 ( 0)	17 ( -0.3)	17 ( -0.2)
	Above Normal	14.2	14 ( -0.1)	14 ( 0.3)	14 ( -0.1)	14 ( 0)
	Below Normal	22.3	22 ( -0.1)	23 ( 0.7)	22 ( -0.1)	23 ( 0.6)
	Dry	15.5	16 ( 0.2)	17 ( 1.4)	15 ( -0.3)	16 ( 0.4)
	Critically Dry	0.0	2 ( 2)	1.6 ( 1.6)	0.7 ( 0.7)	0 ( 0)
	All	14.6	15 ( 0.3)	15 ( 0.7)	15 ( -0.1)	15 ( 0.1)
January–March	Wet	44.7	45 ( -0.2)	45 ( -0.2)	45 ( -0.2)	45 ( -0.2)
	Above Normal	29.7	30 ( 0)	30 ( 0)	30 ( 0)	30 ( 0)
	Below Normal	12.0	12 ( 0.1)	12 ( 0.2)	12 ( 0.1)	12 ( 0.2)
	Dry	3.4	3.5 ( 0.1)	3.5 ( 0.1)	3.5 ( 0.1)	4.4 ( 1)
	Critically Dry	3.9	4.3 ( 0.4)	3.1 ( -0.8)	4.3 ( 0.4)	4.5 ( 0.6)
	All	21.9	22 ( 0)	22 ( -0.1)	22 ( 0)	22 ( 0.3)
February–April	Wet	61.2	61 ( 0)	61 ( 0)	61 ( 0.1)	61 ( 0.1)
	Above Normal	45.7	46 ( 0)	46 ( 0)	46 ( 0)	46 ( 0)
	Below Normal	40.9	41 ( 0)	41 ( 0)	41 ( 0)	40 ( -0.6)
	Dry	10.1	10 ( 0)	10 ( 0)	10 ( 0)	12 ( 1.8)
	Critically Dry	7.4	5.6 ( -1.9)	7.3 ( -0.1)	7.3 ( -0.1)	2.1 ( -5.3)
	All	36.4	36 ( -0.3)	36 ( 0)	36 ( 0)	36 ( -0.5)
March–May	Wet	21.4	21 ( 0)	22 ( 0.2)	21 ( 0)	21 ( 0)
	Above Normal	23.3	24 ( 0.3)	24 ( 0.7)	24 ( 0.3)	25 ( 1.7)
	Below Normal	1.1	1.1 ( 0)	1.1 ( 0)	1.1 ( 0)	1.4 ( 0.3)
	Dry	7.1	5.3 ( -1.8)	5.2 ( -1.9)	6 ( -1.1)	7 ( -0.2)
	Critically Dry	4.1	5.5 ( 1.4)	5.5 ( 1.4)	5.5 ( 1.4)	4 ( 0)
	All	12.5	12 ( -0.2)	12 ( -0.1)	13 ( 0)	13 ( 0.3)

\* Results for which redds dewatered under Alternative 1, 2, or 3 are more than 2% below redds dewatered under the NAA are highlighted green.

^ Results for which redds dewatered under Alternative 1, 2, or 3 are more than 2% above redds dewatered under the NAA are highlighted red.

### 11N.3.2 Redd Scour/Entombment

The amount of flow needed to mobilize sediments and scour or entomb Chinook salmon and steelhead redds in both the Sacramento and American Rivers was estimated as 40,000 cfs (Table 11N-10). No information on minimal flows that mobilize sediment was located for the Feather River and, therefore, no redd scour/entombment analysis was conducted for this river.

### 11N.3.2.1 Sacramento River

The probability of redd scour/entombment was estimated for the salmon runs and steelhead in the Sacramento River by computing the percentage of days in the USRDOM 82-year daily flow record (29,952 days in total) at four locations between Keswick Dam and the RBDD during the months of spawning and incubation for the salmon run or steelhead (Table 11N-22 through Table 11N-25). The results show that the probability of scour/entombment is consistently highest for late fall–run and steelhead and lowest for winter–run and spring–run (Table 11N-22 through Table 11N-25). The probability for fall–run is intermediate. These differences reflect the months of the spawning and incubation periods, which include the wettest months of the year for late fall–run and steelhead and few wet months for winter–run and spring–run. The highest percentage of days with greater than 40,000 cfs daily flows, 7.1%, occurs for steelhead at the Battle Creek confluence under the NAA (Table 11N-24).

Alternatives 1–3 have very little effect on the frequency of scouring/entombment flows and almost all differences result from a reduction in the probability of scouring flows (Table 11N-22 through Table 11N-25). The largest differences are reductions for steelhead at Battle Creek from 7.1% of days under the NAA to 6% of days for Alternatives 1-2 and 6.1% of days for Alternative 3 (Table 11N-24). The only increases in the percentage of greater than 40,000 cfs flows (0.4% to 0.5%) are predicted for late fall–run at RBDD (Table 11N-25). Overall, these results indicate that Alternatives 1–3 would have little effect on redd scour/entombment for salmon and steelhead in the Sacramento River.

**Table 11N-22. Percent of Days with Flows Greater Than the 40,000 cfs Threshold for Redd Scour/Entombment for Chinook Salmon Runs and Steelhead below Keswick Dam under the No Action Alternative (NAA) and Alternatives 1–3, and Differences in the Percentages (in parentheses)**

Species/Run	Months Spawning and Incubation	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
Winter-run	April–October	0.3	0.3 (0)	0.3 (0)	0.3 (0)	0.3 (0)
Spring-run	August–December	0.4	0.3 (-0.1)	0.3 (-0.1)	0.3 (-0.1)	0.3 (-0.1)
Fall-run	September–January	1.4	1 (-0.4)	1 (-0.4)	1 (-0.4)	1.1 (-0.4)
Late fall-run	December–June	3.2	3.2 (0)	3.2 (0)	3.2 (0)	3.2 (0)
Steelhead	November–April	3.8	3.2 (-0.6)	3.2 (-0.6)	3.2 (-0.6)	3.2 (-0.5)

**Table 11N-23. Percent of Days with Flows Greater Than the 40,000 cfs Threshold for Redd Scour/Entombment for Chinook Salmon Runs and Steelhead at Clear Creek under the No Action Alternative (NAA) and Alternatives 1–3, and Differences in the Percentages (in parentheses)**

Species/Run	Months Spawning and Incubation	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
Winter-run	April–October	0.3	0.3 (0)	0.3 (0)	0.3 (0)	0.3 (0)
Spring-run	August–December	0.5	0.3 (-0.1)	0.3 (-0.1)	0.4 (-0.1)	0.4 (-0.1)
Fall-run	September–January	1.7	1.2 (-0.5)	1.2 (-0.5)	1.2 (-0.5)	1.2 (-0.5)

Species/Run	Months Spawning and Incubation	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
Late fall-run	December–June	3.6	3.5 (0)	3.5 (0)	3.5 (0)	3.5 (0)
Steelhead	November–April	4.2	3.6 (-0.6)	3.6 (-0.6)	3.6 (-0.6)	3.6 (-0.6)

**Table 11N-24. Percent of Days with Flows Greater Than the 40,000 cfs Threshold for Redd Scour/Entombment for Chinook Salmon Runs and Steelhead at Battle Creek under the No Action Alternative (NAA) and Alternatives 1–3, and Differences in the Percentages (in parentheses)**

Species/Run	Months Spawning and Incubation	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
Winter-run	April–October	0.5	0.5 (0)	0.5 (0)	0.5 (0)	0.5 (0)
Spring-run	August–December	1.1	0.8 (-0.3)	0.8 (-0.3)	0.8 (-0.3)	0.8 (-0.3)
Fall-run	September–January	3.2	2.3 (-0.9)	2.3 (-0.9)	2.3 (-0.9)	2.3 (-0.9)
Late fall-run	December–June	6.0	6 (0)	6 (0)	6 (0)	6 (0)
Steelhead	November–April	7.1	6 (-1.1)	6 (-1.1)	6 (-1.1)	6.1 (-1)

**Table 11N-25. Percent of Days with Flows Greater Than the 40,000 cfs Threshold for Redd Scour/Entombment for Chinook Salmon Runs and Steelhead at RBDD under the No Action Alternative (NAA) and Alternatives 1–3, and Differences in the Percentages (in parentheses)**

Species/Run	Months Spawning and Incubation	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
Winter-run	April–October	0.5	0.5 (0)	0.5 (0)	0.5 (0)	0.5 (0)
Spring-run	August–December	1.0	0.8 (-0.1)	0.8 (-0.1)	0.8 (-0.1)	0.9 (-0.1)
Fall-run	September–January	2.9	2.4 (-0.5)	2.4 (-0.5)	2.4 (-0.5)	2.4 (-0.4)
Late fall-run	December–June	5.7	6.1 (0.4)	6.1 (0.4)	6.1 (0.4)	6.1 (0.5)
Steelhead	November–April	6.7	6.1 (-0.5)	6.1 (-0.5)	6.1 (-0.5)	6.2 (-0.5)

### 11N.3.2.2 American River

As noted above, a low-flow threshold for sediment mobilization of 40,000 cfs was used for the American River redd scour/entombment analysis. Redd scour/entombment can occur at very small temporal scales (hours to days), but estimates of daily flow under the project alternatives are not available for the American River. Therefore, CALSIM II flow data, which has a monthly time step, were used with a redd scour/entombment threshold developed for monthly flows. As previously described, historical American River flows were used to determine that the lowest monthly flow that always includes at least one daily flow greater than 40,000 cfs is 19,350 cfs (Figure 11N-1), and this flow was used as the CALSIM II flow threshold for American River redd scour/entombment.

The results indicate that there are very few months in the 82-year CALSIM II record for the American River with flow greater than the redd scour/entombment threshold of 19,350 cfs (Table 11N-26). There are only 2 months with such flows under the NAA and Alternatives 1 and 2, and there are 3 such months for Alternative 3. These results indicate that Alternatives 1–3 would have little or no effect on redd scour/entombment for fall-run and steelhead in the American River.

**Table 11N-26. Total Number and Percentages (in parentheses) of Months with Flows Greater Than the 19,350 cfs Threshold for Redd Scour/Entombment in the American River during the Spawning and Incubation Periods for Fall-run and Steelhead under the No Action Alternative (NAA) and Alternatives 1–3**

Species	Total Months of Active Redds	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
Fall-run	492	2 [0.5%]	2 [0.5%]	2 [0.5%]	2 [0.5%]	3 [0.7%]
Steelhead	410	2 [0.4%]	2 [0.4%]	2 [0.4%]	2 [0.4%]	3 [0.6%]

### 11N.3.3 Juvenile Stranding

A juvenile stranding analysis for salmonids was conducted in the Sacramento River only. No information is available from the Feather and American Rivers for relating changes in flow to numbers of juvenile salmonids stranded. Furthermore, daily flow data are needed to reliably estimate juvenile stranding, and only monthly data are available for these rivers.

The juvenile stranding estimation procedure for the Sacramento River computes the area of salmonid rearing habitat inundated at an initial flow that is dewatered at a subsequent minimum (stranding) flow and then converts this area to number of stranded juveniles using estimates of habitat capacity based on field study observations (USFWS 2006). A period of 3 months is used for the juvenile stranding analysis in this report because the juveniles are presumed to be most vulnerable to stranding during their first 3 months (i.e., fry stage).

Levels of juvenile stranding potentially attributable to Alternatives 1–3 and the NAA were computed using USRDOM daily flow data at three locations in the upper Sacramento River: Keswick Dam, Clear Creek, and Battle Creek. The results are presented using the grand mean number of juveniles stranded for each month of the year under each water year type and all water year types combined (Table N11-28 through Table 11N-30). The analysis assumes that under equal flow conditions the fry stage of all runs and species are equally vulnerable to stranding and therefore the tables combine results of all races and species. To determine the results for a given species or run, the estimated months for which the fry stage are most likely to be present (Table 11N-27) are consulted in Table 11N-28 through Table 11N-30.

**Table 11N-27. Estimated Months of Greatest Occurrences of the Complete Juvenile Life Stage and the Fry Stage Portion, Used for Juvenile Stranding Analyses of Sacramento River Salmonids**

Species/Run	Juvenile	Fry (<60mm)
Winter-run	July–November	July–October
Spring-run	Year-round	November–February
Fall-run	December–June	December–March
Late fall-run	March–July	March–June
Steelhead	Year-round	February–May

The results for the three river locations are generally similar (Table 11N-28 through Table 11N-30). All three show very high increases and reductions in stranding during certain months and water year types. The magnitude of the changes between the NAA and Alternatives 1–3 may be biased high because the analysis methodology assumes no movement of juveniles out of rearing habitat as the water level drops (USFWS 2006). Juveniles may be able to avoid stranding by moving into deeper areas as habitat is dewatered. This bias likely affects all the alternatives similarly and therefore is not expected to affect their relative values.

The three locations show the greatest differences between Alternatives 1–3 and the NAA during April through July (Table 11N-28 through Table 11N-30). May generally has the largest differences, and all the May differences are reductions in juvenile stranding, with the largest reduction, 55%, occurring at the Battle Creek location under Alternative 1B in May of Critically Dry Water Years. However, the greatest reduction for all months, 57%, is in June of above normal years at the Battle Creek location. The largest increases in juvenile stranding occur in April at all three locations, ranging as high as 30% in dry years under Alternatives 1A, 1B and 2 at the Keswick Dam location.

As noted above, because of the fry stage's greater vulnerability, the probability of effects on juvenile stranding of Alternatives 1–3 on the different salmon runs and steelhead are expected to be greatest during the months of greatest occurrence of fry (Table 11N-27). Late fall-run fry are most abundant from March through June and, therefore, are especially likely to be affected by Alternatives 1–3 during the April through July period. Although large increases and reductions in juvenile stranding are predicted for this period at all three locations, the large reductions are more frequent and larger, on average, than the increases, so Alternatives 1–3 are expected to have no adverse effect on late fall-run juvenile stranding.

The steelhead period of greatest fry abundance includes April and May, and therefore is also vulnerable to the effects of Alternatives 1–3 on juvenile stranding. However, as described for late fall-run, because of the greater magnitude and frequency of large reductions in juvenile stranding over large increases, Alternatives 1–3 are expected to have no overall adverse effect on steelhead juvenile stranding. Spring-run and fall-run fry are expected not to be present during any month with large differences in juvenile stranding. Winter-run fry are most abundant during July through October, when some large reductions and increases in juvenile stranding occur, but large reductions in juvenile stranding are more frequent than large increases and therefore

Alternatives 1–3 are not expected to affect winter-run juvenile stranding. In general, although Alternatives 1–3 are expected to have substantial effects on juvenile stranding of winter-run, late fall–run and steelhead, the analysis indicates that reductions in stranding would exceed increases and, therefore, no overall adverse effect is expected.

**Table 11N-28. Estimated Number (thousands) of Juvenile Chinook Salmon or Steelhead Stranded by Flow Reductions at Keswick and the Percent Differences (in parentheses) for the No Action Alternative (NAA) and Alternatives 1–3**

Month	Water Year Type	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
January	Wet	14.7	14.5 (-0.9%)	14.6 (-0.2%)	14.5 (-0.9%)	14.5 (-1.3%)
	Above Normal	10.5	10.4 (-0.8%)	10.5 (0.4%)	10.4 (-0.8%)	10.5 (0.5%)
	Below Normal	7.5	7.5 (-0.4%)	7.3 (-1.9%)	7.5 (-0.4%)	7.4 (-1.7%)
	Dry	3.4	3.2 (-6.7%)	3.3 (-4.8%)	3.2 (-6.9%)	3.5 (0.5%)
	Critically Dry	3.5	3.5 (-1.5%)	3.4 (-3.8%)	3.4 (-3%)	3.2 (-9.2%)
	All	8.7	8.6 (-1.4%)	8.7 (-1%)	8.6 (-1.5%)	8.6 (-1.3%)
February	Wet	17.9	18 (0.5%)	18.1 (0.9%)	18 (0.6%)	18.2 (1.7%)
	Above Normal	14.7	14.5 (-1%)	14.5 (-1.1%)	14.5 (-1%)	14.7 (0.3%)
	Below Normal	11.9	11.6 (-2.2%)	11.7 (-1.8%)	11.6 (-2.5%)	11.6 (-2.8%)
	Dry	4.0	3.6 (-9.1%)	3.5 (-12.4%)*	3.6 (-9.2%)	3.9 (-2.3%)
	Critically Dry	4.0	3.7 (-6.4%)	3.7 (-6.4%)	3.7 (-6.2%)	3.8 (-4.5%)
	All	11.3	11.2 (-1.4%)	11.2 (-1.4%)	11.2 (-1.4%)	11.3 (0%)
March	Wet	15.9	16.3 (2.6%)	16.3 (2.8%)	16 (0.5%)	16.4 (3%)
	Above Normal	13.6	13.7 (0.4%)	13.7 (0.3%)	13.7 (0.4%)	13.7 (0.3%)
	Below Normal	6.6	6.7 (1.7%)	6.7 (1.4%)	6.7 (1.7%)	6.7 (2.1%)
	Dry	3.3	3.2 (-2.7%)	3.3 (1.5%)	3.3 (-0.5%)	3.7 (11.8%)^
	Critically Dry	3.9	4 (1.7%)	4.1 (3.4%)	4 (1.5%)	3.6 (-8.4%)
	All	9.5	9.6 (1.6%)	9.6 (2.1%)	9.5 (0.6%)	9.7 (2.3%)
April	Wet	9.2	9.3 (1.9%)	9.3 (1.9%)	9.3 (1.9%)	9.4 (2%)
	Above Normal	5.4	5.4 (0%)	5.4 (-0.1%)	5.4 (0%)	5.4 (-0.2%)
	Below Normal	2.9	3.1 (8.4%)	3.1 (9.2%)	3.1 (8.4%)	3.1 (9.3%)
	Dry	1.7	2.2 (30%)^	2.2 (30.3%)^	2.2 (30.3%)^	2.2 (27.6%)^
	Critically Dry	2.1	2.3 (7.8%)	2.2 (5.2%)	2.3 (7.7%)	2.5 (20.5%)^
	All	4.9	5.1 (4.8%)	5.1 (4.7%)	5.1 (4.8%)	5.1 (5.5%)
May	Wet	2.1	1.6 (-21.8%)*	1.6 (-21.8%)*	1.6 (-21.8%)*	1.6 (-21.5%)*
	Above Normal	1.4	0.9 (-39.2%)*	0.9 (-36.2%)*	0.9 (-39.2%)*	0.9 (-35.3%)*
	Below Normal	0.4	0.3 (-28.5%)*	0.3 (-27%)*	0.3 (-28.4%)*	0.4 (-16.5%)*
	Dry	0.7	0.4 (-44.9%)*	0.4 (-46.8%)*	0.4 (-45.3%)*	0.4 (-43.8%)*
	Critically Dry	2.5	2.2 (-10.3%)*	2.2 (-12.9%)*	2.2 (-10.7%)*	2.2 (-9.6%)
	All	1.5	1.1 (-24.3%)*	1.1 (-24.6%)*	1.1 (-24.4%)*	1.1 (-22.7%)*

## Other Flow-Related Upstream Analyses

Month	Water Year Type	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
June	Wet	0.5	0.6 (24.7%)^	0.6 (24.4%)^	0.6 (24.6%)^	0.6 (23.2%)^
	Above Normal	1.0	1 (-1.1%)	0.6 (-45.9%)*	1 (-2%)	0.5 (-54%)*
	Below Normal	3.8	3.9 (3.4%)	3.7 (-2.8%)	4 (4.1%)	3.3 (-13.6%)*
	Dry	7.0	6.5 (-6.8%)	6.3 (-9%)	6.5 (-6.5%)	6.5 (-6.5%)
	Critically Dry	7.8	6.9 (-12%)*	6.8 (-12.4%)*	6.9 (-11.8%)*	6.8 (-12.8%)*
	All	3.6	3.5 (-5%)	3.3 (-9%)	3.5 (-4.7%)	3.3 (-10.4%)*
July	Wet	2.1	2.3 (10.3%)^	2.3 (10.5%)^	2.3 (10.3%)^	2.3 (9.9%)
	Above Normal	4.0	3.9 (-1.7%)	3.5 (-12.6%)*	3.9 (-1.9%)	3 (-24.7%)*
	Below Normal	6.7	7.3 (9.5%)	7.1 (6.5%)	7.3 (10%)	6.2 (-6.8%)
	Dry	10.4	9.4 (-9.6%)	9.4 (-9.7%)	9.4 (-9.6%)	9.4 (-9.8%)
	Critically Dry	10.4	9.7 (-7.1%)	9.6 (-8.3%)	9.9 (-5.2%)	9.6 (-8.3%)
	All	6.2	6 (-2.6%)	5.9 (-4.5%)	6.1 (-2%)	5.7 (-8.1%)
August	Wet	6.1	5.9 (-2.3%)	6.1 (-0.3%)	6 (-2.2%)	6 (-0.8%)
	Above Normal	5.6	6.2 (10.1%)^	5.7 (1.9%)	6.2 (10%)	5.3 (-5.4%)
	Below Normal	9.3	10.1 (9.6%)	9.8 (5.9%)	10.2 (9.7%)	8.8 (-5.5%)
	Dry	13.1	13 (-1.3%)	12.8 (-2.8%)	12.9 (-2%)	12 (-8.5%)
	Critically Dry	12.4	13 (4.6%)	12.9 (3.9%)	12.9 (4.3%)	12.8 (3%)
	All	9.0	9.3 (2.6%)	9.1 (1%)	9.2 (2.4%)	8.7 (-3.7%)
September	Wet	10.8	10.9 (0.8%)	10.9 (0.6%)	10.9 (0.8%)	10.8 (-0.1%)
	Above Normal	10.5	10.9 (3.7%)	11.1 (5.8%)	10.9 (3.8%)	11.4 (8.7%)
	Below Normal	10.2	10.8 (5.8%)	10.6 (4.2%)	10.7 (5.1%)	9.1 (-11.3%)*
	Dry	11.3	11.6 (3%)	11.3 (0.8%)	11.6 (2.9%)	10.5 (-7.1%)
	Critically Dry	12.6	14.2 (12.7%)^	13.8 (9.4%)	13.9 (10.2%)^	13.7 (8.8%)
	All	11.0	11.5 (4.5%)	11.4 (3.4%)	11.5 (4%)	10.9 (-0.8%)
October	Wet	14.6	14.7 (0.9%)	14.6 (0.6%)	14.7 (0.9%)	14.6 (0.6%)
	Above Normal	16.7	16.8 (0.9%)	16.9 (1.3%)	16.8 (0.9%)	17.2 (3%)
	Below Normal	14.8	14.9 (0.6%)	14.8 (0%)	14.9 (0.5%)	13.9 (-6.2%)
	Dry	15.6	15.5 (-0.5%)	15.3 (-1.8%)	15.6 (-0.1%)	14.7 (-6.2%)
	Critically Dry	14.7	16.9 (15.2%)^	16.3 (10.9%)^	15.8 (7.9%)^	16.3 (11.2%)^
	All	15.2	15.5 (2.5%)	15.4 (1.5%)	15.4 (1.6%)	15.1 (-0.2%)
November	Wet	12.1	12.3 (1.9%)	12.2 (0.7%)	12.3 (1.9%)	12.2 (0.9%)
	Above Normal	16.3	15.7 (-3.5%)	15.6 (-4.6%)	15.7 (-3.5%)	15.4 (-5.6%)
	Below Normal	13.8	13.5 (-2.2%)	13.8 (0%)	13.5 (-2.6%)	13.1 (-5.1%)
	Dry	13.4	12.6 (-6%)	13.4 (0%)	12.6 (-5.9%)	13.7 (2.1%)
	Critically Dry	12.1	11.6 (-4.5%)	11.9 (-2.1%)	11.7 (-3.5%)	11.6 (-4.3%)
	All	13.3	13 (-2.4%)	13.2 (-0.9%)	13 (-2.3%)	13.1 (-1.8%)
December	Wet	10.7	10.3 (-4%)	10.3 (-4%)	10.2 (-4.7%)	10.3 (-4.3%)

Month	Water Year Type	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
	Above Normal	12.1	11.4 (-5.7%)	11.5 (-5.1%)	11.5 (-5.7%)	10.8 (-11%)*
	Below Normal	13.3	13.3 (-0.5%)	13.6 (2.2%)	13.3 (-0.4%)	14.4 (7.7%)
	Dry	11.4	11.4 (0.2%)	12 (5.2%)	11.3 (-0.7%)	12.2 (6.7%)
	Critically Dry	3.6	3.4 (-5.5%)	3.6 (-0.4%)	3.5 (-1.3%)	3.5 (-2.1%)
	All	10.5	10.2 (-2.6%)	10.4 (-0.5%)	10.2 (-2.8%)	10.5 (-0.1%)

\* Results for which juvenile stranding under Alternative 1, 2, or 3 are more than 10% below juvenile stranding under the NAA are highlighted green.

^ Results for which juvenile stranding under Alternative 1, 2, or 3 are more than 10% higher than juvenile stranding under the NAA are highlighted red.

**Table 11N-29. Estimated Number (thousands) of Juvenile Chinook Salmon or Steelhead Stranded by Flow Reductions at the Clear Creek Confluence and the Percent Differences (in parentheses) for the No Action Alternative (NAA) and Alternatives 1–3**

Month	Water Year Type	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
January	Wet	11.0	10.9 (-0.9%)	10.9 (-0.9%)	10.9 (-1.1%)	10.8 (-2.3%)
	Above Normal	11.4	11.4 (0.1%)	11.5 (0.9%)	11.4 (0.1%)	11.5 (1.1%)
	Below Normal	11.4	11.5 (0.3%)	11.4 (-0.4%)	11.5 (0.2%)	11.4 (-0.6%)
	Dry	8.5	8.2 (-2.8%)	8.3 (-1.7%)	8.2 (-2.9%)	8.4 (-0.5%)
	Critically Dry	9.1	9.1 (-0.2%)	9 (-1.1%)	9 (-0.9%)	8.9 (-1.9%)
	All	10.3	10.2 (-0.8%)	10.2 (-0.7%)	10.2 (-1%)	10.2 (-1.1%)
February	Wet	16.8	16.9 (0.8%)	16.9 (1%)	16.9 (0.7%)	17 (1.3%)
	Above Normal	16.3	16.1 (-1.4%)	16 (-2%)	16.1 (-1.4%)	16.1 (-1.2%)
	Below Normal	16.2	16 (-0.7%)	16.1 (-0.5%)	16 (-0.8%)	16 (-0.7%)
	Dry	11.0	10.6 (-3.3%)	10.6 (-3.5%)	10.6 (-3.3%)	10.7 (-2.5%)
	Critically Dry	8.7	8.6 (-1%)	8.6 (-1.8%)	8.6 (-1.4%)	8.5 (-2%)
	All	14.1	14 (-0.7%)	14 (-0.8%)	14 (-0.8%)	14.1 (-0.5%)
March	Wet	15.6	16 (2.2%)	16 (2.3%)	15.8 (1.2%)	16 (2.4%)
	Above Normal	14.0	14.1 (0.6%)	14 (-0.3%)	14.1 (0.6%)	14 (-0.3%)
	Below Normal	11.5	11.6 (0.8%)	11.6 (0.8%)	11.6 (1%)	11.6 (0.7%)
	Dry	8.5	8.7 (2.5%)	8.7 (3.2%)	8.7 (2.7%)	8.9 (4.7%)
	Critically Dry	7.7	7.8 (1%)	7.5 (-2.5%)	7.8 (0.8%)	7.3 (-5.9%)
	All	12.0	12.2 (1.6%)	12.1 (1.3%)	12.1 (1.3%)	12.1 (1.2%)
April	Wet	10.3	10.5 (1.7%)	10.5 (1.7%)	10.5 (1.7%)	10.5 (1.7%)
	Above Normal	5.7	6.3 (9.9%)	6.2 (7.9%)	6.3 (9.9%)	6.2 (7.6%)
	Below Normal	4.6	5 (8.7%)	5 (8.9%)	5 (8.8%)	5 (9.1%)
	Dry	2.7	3.3 (21.8%)^	3.2 (21.3%)^	3.3 (22.1%)^	3.2 (20.5%)^
	Critically Dry	2.4	2.6 (6.8%)	2.3 (-2.8%)	2.6 (6.6%)	2.8 (15.7%)^

## Other Flow-Related Upstream Analyses

Month	Water Year Type	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
	All	5.8	6.2 (6.2%)	6.1 (5.3%)	6.2 (6.2%)	6.2 (6.3%)
May	Wet	2.2	1.7 (-19.5%)*	1.7 (-19.5%)*	1.7 (-19.5%)*	1.7 (-19.2%)*
	Above Normal	1.0	0.8 (-22.2%)*	0.8 (-23.3%)*	0.8 (-22.2%)*	0.8 (-21.8%)*
	Below Normal	0.4	0.4 (-20.4%)*	0.4 (-20.1%)*	0.4 (-20.3%)*	0.4 (-9.9%)
	Dry	0.7	0.4 (-38.2%)*	0.4 (-43.9%)*	0.4 (-38.3%)*	0.4 (-38.5%)*
	Critically Dry	2.6	2.3 (-11.5%)*	2.2 (-14.4%)*	2.3 (-11.9%)*	2.3 (-12%)*
	All	1.4	1.2 (-19.7%)*	1.1 (-21.2%)*	1.2 (-19.8%)*	1.2 (-19.2%)*
June	Wet	0.5	0.6 (16.2%)*^	0.6 (16.2%)*^	0.6 (16.2%)*^	0.6 (15.3%)*^
	Above Normal	1.1	1.1 (0.5%)	0.6 (-44.2%)*	1.1 (-0.4%)	0.5 (-52.2%)*
	Below Normal	4.0	4.1 (3.7%)	3.9 (-2.9%)	4.2 (4.4%)	3.5 (-13.1%)*
	Dry	6.9	6.6 (-4.2%)	6.5 (-6%)	6.6 (-4%)	6.7 (-3.1%)
	Critically Dry	8.0	6.9 (-14.1%)*	6.8 (-14.3%)*	6.9 (-14.1%)*	6.9 (-13.8%)*
	All	3.7	3.5 (-4.8%)	3.4 (-8.7%)	3.5 (-4.6%)	3.3 (-9.6%)
July	Wet	1.9	2 (7.2%)	2 (7.5%)	2 (7.2%)	2 (7.1%)
	Above Normal	3.5	3.5 (-0.2%)	3.1 (-12.5%)*	3.5 (-0.4%)	2.7 (-25%)*
	Below Normal	6.4	6.9 (7.6%)	6.6 (3%)	6.9 (7.9%)	6 (-6.5%)
	Dry	9.8	9.1 (-7.6%)	9.2 (-5.8%)	9.1 (-7.5%)	9.3 (-5.1%)
	Critically Dry	10.4	9 (-13.4%)*	9.1 (-12.1%)*	9.1 (-12.1%)*	9.5 (-8.1%)
	All	5.9	5.6 (-4.1%)	5.6 (-5%)	5.7 (-3.7%)	5.5 (-6.6%)
August	Wet	4.7	4.5 (-4.2%)	4.7 (-1.7%)	4.5 (-4.2%)	4.6 (-2.1%)
	Above Normal	4.7	5.2 (10.8%)*^	4.7 (0.7%)	5.2 (10.6%)*^	4.3 (-7.9%)
	Below Normal	7.7	8.2 (6.7%)	7.6 (-0.5%)	8.2 (7%)	7.2 (-6.3%)
	Dry	10.8	10.4 (-3.5%)	10.3 (-4.3%)*^	10.4 (-3.5%)	10.2 (-5.3%)
	Critically Dry	11.2	10.3 (-7.7%)	10.5 (-6.6%)	11.3 (0.6%)	10.9 (-2.6%)
	All	7.5	7.4 (-1.5%)	7.3 (-3.2%)	7.5 (0.4%)	7.2 (-4.5%)
September	Wet	7.7	7.7 (0%)	7.6 (-0.7%)	7.7 (0.1%)	7.6 (-0.9%)
	Above Normal	7.5	8.1 (7.9%)	8.4 (12%)*^	8.1 (8%)	8.7 (16.2%)*^
	Below Normal	6.0	6.2 (3.5%)	5.7 (-4.9%)	6.2 (3.6%)	5.1 (-15%)*
	Dry	6.1	6.2 (1.7%)	5.9 (-1.9%)	6.2 (1.7%)	5.9 (-2.7%)
	Critically Dry	10.8	11.8 (9%)	11.5 (6.6%)	11.9 (10.7%)*^	11.6 (7.6%)
	All	7.5	7.8 (3.9%)	7.6 (1.9%)	7.8 (4.3%)	7.6 (1.2%)
October	Wet	10.5	10.7 (1.3%)	10.5 (-0.5%)	10.7 (1.3%)	10.5 (-0.5%)
	Above Normal	13.1	13 (-0.7%)	13 (-0.4%)	13 (-0.7%)	13.6 (3.7%)
	Below Normal	10.5	10.7 (2.6%)	10.4 (-0.9%)	10.8 (3%)	10 (-4.6%)
	Dry	8.9	8.8 (-0.6%)	8.5 (-4.4%)	8.9 (0.1%)	8.7 (-2.2%)
	Critically Dry	13.8	15.9 (14.7%)*^	15.3 (10.5%)*^	15.1 (9.2%)	14.9 (7.8%)
	All	11.0	11.4 (3.3%)	11.1 (0.8%)	11.3 (2.5%)	11.1 (0.8%)

Month	Water Year Type	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
November	Wet	9.4	9.7 (3.5%)	9.4 (0.6%)	9.7 (3.4%)	9.5 (1%)
	Above Normal	13.3	12.7 (-4.9%)	12.5 (-6.1%)	12.7 (-4.9%)	12.8 (-4.1%)
	Below Normal	10.8	10.4 (-3.4%)	10.4 (-3.8%)	10.5 (-3%)	10 (-7.7%)
	Dry	9.5	9.2 (-3.2%)	9.6 (1.4%)	9.2 (-2.9%)	9.9 (5.1%)
	Critically Dry	13.3	13 (-2%)	13.2 (-0.8%)	13.1 (-1.7%)	12.8 (-3.9%)
	All	10.8	10.6 (-1.5%)	10.6 (-1.5%)	10.6 (-1.3%)	10.6 (-1.5%)
December	Wet	9.1	8.9 (-2.4%)	8.8 (-3.3%)	8.9 (-3.1%)	8.8 (-3.6%)
	Above Normal	11.6	11 (-4.8%)	11 (-4.9%)	11 (-4.8%)	10.7 (-7.7%)
	Below Normal	11.2	11.4 (1.2%)	11.4 (1%)	11.4 (1%)	11.7 (4%)
	Dry	11.2	11.1 (-0.6%)	11.4 (1.9%)	11.1 (-1.2%)	11.3 (0.7%)
	Critically Dry	6.4	6.8 (5.8%)	6.9 (8.7%)	6.5 (1.8%)	6.9 (8.1%)
	All	9.9	9.8 (-0.9%)	9.9 (-0.3%)	9.7 (-1.7%)	9.8 (-0.7%)

\* Results for which juvenile stranding under Alternative 1, 2, or 3 are more than 10% below juvenile stranding under the NAA are highlighted green.

^ Results for which juvenile stranding under Alternative 1, 2, or 3 are more than 10% **higher than** juvenile stranding under the NAA are highlighted red.

**Table 11N-30. Estimated Number (thousands) of Juvenile Chinook Salmon or Steelhead Stranded by Flow Reductions at the Battle Creek Confluence and the Percent Differences (in parentheses) for the No Action Alternative (NAA) and Alternatives 1–3**

Month	Water Year Type	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
January	Wet	2.4	2.4 (-0.8%)	2.4 (-0.7%)	2.4 (-0.4%)	2.4 (-2.7%)
	Above Normal	4.6	4.5 (-0.8%)	4.5 (-0.8%)	4.5 (-0.8%)	4.5 (-1.2%)
	Below Normal	4.2	4.2 (1.9%)	4.2 (1.1%)	4.2 (1.9%)	4.2 (0.9%)
	Dry	3.5	3.8 (7.7%)	3.8 (8.3%)	3.8 (7.7%)	3.6 (2.1%)
	Critically Dry	4.4	4.8 (7.3%)	4.5 (2%)	4.6 (2.8%)	4.6 (3.5%)
	All	3.6	3.7 (3%)	3.6 (2.1%)	3.6 (2.3%)	3.6 (0.4%)
February	Wet	3.4	3.5 (2.6%)	3.5 (2.8%)	3.5 (2.6%)	3.5 (1.5%)
	Above Normal	4.4	4.7 (6.5%)	4.7 (7.1%)	4.7 (6.5%)	4.7 (7.3%)
	Below Normal	5.4	5.5 (2.6%)	5.5 (3.1%)	5.5 (2.6%)	5.5 (2.8%)
	Dry	4.8	4.9 (3.5%)	5 (4.2%)	4.9 (3.5%)	4.9 (3.4%)
	Critically Dry	4.6	4.7 (3.6%)	4.6 (1.9%)	4.7 (2.2%)	4.7 (4.2%)
	All	4.4	4.5 (3.6%)	4.5 (3.7%)	4.5 (3.4%)	4.5 (3.5%)
March	Wet	3.1	3.2 (2.8%)	3.2 (2.8%)	3.2 (2.1%)	3.2 (3%)
	Above Normal	4.1	4.5 (8.8%)	4.5 (9.4%)	4.5 (8.8%)	4.5 (9.3%)
	Below Normal	4.0	4.2 (5.5%)	4.3 (6.2%)	4.2 (5.5%)	4.3 (6.1%)
	Dry	4.7	4.9 (3.7%)	4.9 (5%)	4.9 (3.7%)	4.9 (4.6%)
	Critically Dry	4.2	4.5 (5.7%)	4.4 (4.6%)	4.5 (5.6%)	4.4 (4%)

## Other Flow-Related Upstream Analyses

Month	Water Year Type	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
	All	3.9	4.1 (4.9%)	4.1 (5.3%)	4.1 (4.7%)	4.1 (5.1%)
April	Wet	1.9	2 (3.6%)	2 (3.6%)	2 (3.6%)	2 (3.6%)
	Above Normal	2.1	2.6 (26.6%)^	2.6 (27.8%)^	2.6 (26.6%)^	2.6 (27.8%)^
	Below Normal	2.0	2.3 (15.5%)^	2.3 (16.4%)^	2.3 (15.5%)^	2.4 (16.9%)^
	Dry	2.1	2.3 (8.8%)	2.3 (10%)	2.3 (8.9%)	2.3 (8.1%)
	Critically Dry	1.5	1.5 (4.5%)	1.5 (2%)	1.5 (4.4%)	1.7 (14.4%)^
	All	1.9	2.1 (10.7%)^	2.1 (11%)^	2.1 (10.7%)^	2.2 (12.1%)^
May	Wet	0.7	0.5 (-27.9%)*	0.5 (-27.9%)*	0.5 (-27.9%)*	0.5 (-28%)*
	Above Normal	0.5	0.3 (-36.1%)*	0.4 (-20.3%)*	0.3 (-36.1%)*	0.4 (-13.7%)*
	Below Normal	0.5	0.2 (-52.6%)*	0.2 (-50.3%)*	0.2 (-52.9%)*	0.3 (-38.8%)*
	Dry	0.5	0.3 (-41.1%)*	0.3 (-38.9%)*	0.3 (-41.5%)*	0.3 (-37.1%)*
	Critically Dry	0.8	0.4 (-52.2%)*	0.3 (-55.3%)*	0.3 (-54%)*	0.4 (-44.2%)*
	All	0.6	0.4 (-39.2%)*	0.4 (-37.1%)*	0.4 (-39.6%)*	0.4 (-32.4%)*
June	Wet	0.3	0.4 (18%)^	0.4 (17.9%)^	0.4 (18%)^	0.4 (17.2%)^
	Above Normal	0.9	0.8 (-4.6%)	0.5 (-41.6%)*	0.8 (-6.7%)	0.4 (-56.9%)*
	Below Normal	3.2	3.3 (5.2%)	3.1 (-1%)	3.4 (6.5%)	2.9 (-9.6%)
	Dry	4.7	4.5 (-2.8%)	4.5 (-4.3%)	4.6 (-2.4%)	4.6 (-1.2%)
	Critically Dry	6.1	5.6 (-9.3%)	5.5 (-11.2%)*	5.6 (-9.6%)	5.4 (-11.7%)*
	All	2.7	2.6 (-2.7%)	2.5 (-6.8%)	2.6 (-2.4%)	2.5 (-8.3%)
July	Wet	1.2	1.3 (12.1%)^	1.3 (12.5%)^	1.3 (12.1%)^	1.3 (11.8%)^
	Above Normal	2.3	2.3 (-1%)	2 (-11.1%)*	2.2 (-2.1%)	1.8 (-21.4%)*
	Below Normal	4.7	5.2 (9.8%)	5 (5.3%)	5.3 (11.3%)^	4.5 (-5.1%)
	Dry	6.5	6.3 (-3.7%)	6.4 (-2.1%)	6.3 (-3.4%)	6.4 (-2.3%)
	Critically Dry	8.3	7.4 (-10.7%)*	7.3 (-12%)*	7.6 (-9%)	7.1 (-14.1%)*
	All	4.2	4.1 (-1.5%)	4 (-3%)	4.1 (-0.7%)	3.9 (-6.6%)
August	Wet	2.3	2.4 (5.8%)	2.4 (7.4%)	2.4 (5.8%)	2.4 (7%)
	Above Normal	2.8	3 (5.7%)	2.7 (-2.2%)	2.9 (4.8%)	2.8 (-0.1%)
	Below Normal	5.0	5.4 (9.1%)	5.1 (3.6%)	5.5 (11.2%)^	4.6 (-6.4%)
	Dry	6.8	6.7 (-1.6%)	6.7 (-1.2%)	6.7 (-1.6%)	6.5 (-4.7%)
	Critically Dry	8.7	7.3 (-16%)*	7.2 (-16.5%)*	7.8 (-10.6%)*	7.1 (-18.5%)*
	All	4.7	4.7 (-1.8%)	4.6 (-3.2%)	4.7 (0%)	4.4 (-6.5%)
September	Wet	3.4	3.5 (1.9%)	3.5 (1.1%)	3.5 (1.9%)	3.5 (1.1%)
	Above Normal	3.9	4.1 (5.8%)	4.3 (11.5%)^	4.1 (6.1%)	4.6 (20.1%)^
	Below Normal	2.4	2.5 (2.9%)	2.4 (0.5%)	2.6 (5.1%)	2.3 (-5.4%)
	Dry	2.7	2.8 (1.8%)	2.8 (3.4%)	2.8 (1.7%)	2.6 (-5.1%)
	Critically Dry	5.7	5 (-11.9%)*	4.9 (-14.4%)*	5.4 (-5.7%)	4.9 (-13.6%)*
	All	3.5	3.5 (-0.6%)	3.5 (-0.6%)	3.5 (1.1%)	3.5 (-1.2%)

Month	Water Year Type	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
October	Wet	4.3	4.3 (0.8%)	4.2 (-1%)	4.3 (0.8%)	4.2 (-0.9%)
	Above Normal	5.4	5.4 (-0.4%)	5.4 (-0.1%)	5.4 (-0.3%)	5.6 (4.1%)
	Below Normal	4.5	4.5 (-1%)	4.4 (-1.9%)	4.5 (0.2%)	4.3 (-4.6%)
	Dry	3.7	3.6 (-1.3%)	3.5 (-4.5%)	3.7 (0.3%)	3.6 (-1.4%)
	Critically Dry	7.2	7.6 (6.3%)	7.3 (1.1%)	7.4 (3.2%)	7.1 (-1.2%)
	All	4.8	4.8 (1.2%)	4.7 (-1.1%)	4.8 (1%)	4.7 (-0.8%)
November	Wet	4.0	4.1 (2.6%)	4 (-0.6%)	4.1 (2.5%)	4 (-0.3%)
	Above Normal	6.1	5.9 (-2.6%)	5.8 (-5%)	5.9 (-2.6%)	5.7 (-6.7%)
	Below Normal	4.8	4.7 (-2.2%)	4.7 (-3.3%)	4.7 (-2.1%)	4.5 (-7.1%)
	Dry	3.8	3.5 (-6.7%)	3.9 (2.6%)	3.6 (-4.8%)	4.1 (7.9%)
	Critically Dry	6.5	6.5 (-0.8%)	6.5 (0.1%)	6.4 (-1%)	6.3 (-2.5%)
	All	4.8	4.7 (-1.5%)	4.7 (-1.2%)	4.7 (-1.2%)	4.7 (-1.7%)
December	Wet	3.7	3.6 (-1.6%)	3.6 (-2.4%)	3.6 (-2.2%)	3.6 (-2.8%)
	Above Normal	4.9	4.8 (-2%)	4.8 (-2.6%)	4.8 (-2%)	4.7 (-3.5%)
	Below Normal	4.5	4.6 (2.1%)	4.6 (2.4%)	4.6 (2.3%)	4.6 (2.1%)
	Dry	4.4	4.7 (6.8%)	4.7 (7.1%)	4.7 (6.5%)	4.5 (2.7%)
	Critically Dry	3.5	3.6 (3.2%)	3.6 (1.9%)	3.5 (0.3%)	3.4 (-2.4%)
	All	4.1	4.2 (1.6%)	4.2 (1.2%)	4.2 (1%)	4.1 (-0.7%)

\* Results for which juvenile stranding under Alternative 1, 2, or 3 are more than 10% below juvenile stranding under the NAA are highlighted green.

^ Results for which juvenile stranding under Alternative 1, 2, or 3 are more than 10% **higher than** juvenile stranding under the NAA are highlighted red.

### 11N.3.4 Low-Flow Passage Effects on Migrating Salmon and Sturgeon Adults

The low-flow threshold used for determination of potential interference with upstream passage is 3,250 cfs for migrating salmonid and sturgeon adults in the Sacramento River; 6,000 cfs for sturgeon and 1,500 cfs for salmonids in the Feather River; and 1,000 cfs for salmonids the American River. The frequency of flows below these thresholds was examined for the immigration periods of the four Chinook salmon runs, steelhead, and green sturgeon in the Sacramento River; for spring-run, fall-run, steelhead, and green sturgeon in the Feather River; and for fall-run and steelhead in the American River.

#### 11N.3.4.1 Sacramento River

The frequency of flows below the 3,250 cfs threshold in the Sacramento River was determined for daily flows using USRDOM model outputs at Keswick Dam and RBDD and for monthly flows using CALSIM II data at Wilkins Slough. Using monthly data underestimates the frequency of flows lower than 3,250 cfs because such low flows are generally not sustained for a full month, but this bias is expected to affect the NAA and Alternatives 1–3 equally.

Keswick Dam has a much greater frequency of flows less than 3,250 cfs under all scenarios than the RBDD or Wilkins Slough (Tables 11N-31 through Table 11N-33). The maximum frequency

for Keswick Dam is 11% of days with flows less than 3,250 cfs during the steelhead upstream migration period under the NAA (Table 11N-31). Differences at Keswick Dam between the percent of days with low flows under the NAA and Alternatives 1–3 are generally small (less than or equal to 4%) and all are negative, indicating a reduction in the frequency of low flows under all the alternatives as compared to the NAA. At RBDD and Wilkins Slough, Alternatives 1–3 consistently have a greater frequency of less than 3,250 cfs flows than the NAA. However, frequencies of low flows and the differences between Alternatives 1–3 and the NAA are consistently very small (less than 0.2% for RBDD and less than 1.5% for Wilkins Slough). These results indicate that Alternatives 1–3 would not appreciably affect low-flow passage conditions for upstream migrating adult salmonids or green sturgeon in the Sacramento River.

**Table 11N-31. Percent of Days with Flows below the Low-Flow Threshold (3,250 cfs) for Passage of Migrating Adult Salmonids and Green Sturgeon in the Sacramento River at Keswick Dam and Differences in Percentages (in parentheses) for the No Action Alternative (NAA) and Alternatives 1–3**

Species/Run	Immigration Period	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
Winter-run	December–August	7.42	7.37 (-0.05)	7.39 (-0.04)	7.45 (0.03)	7.36 (-0.06)
Spring-run	March–September	4.58	3.65 (-0.93)	3.68 (-0.9)	3.68 (-0.9)	3.69 (-0.9)
Fall-run	August–March	6.59	5.59 (-1)	5.59 (-1.01)	5.7 (-0.89)	5.54 (-1.06)
Late fall-run	July–December	1.78	0.96 (-0.82)	0.92 (-0.86)	1.02 (-0.76)	0.87 (-0.91)
Steelhead	November–April	11.34	7.35 (-4)	7.36 (-3.99)	7.44 (-3.9)	7.3 (-4.04)
Green Sturgeon	February–June	7.2	4.87 (-2.36)	4.91 (-2.31)	4.92 (-2.3)	4.94 (-2.29)

**Table 11N-32. Percent of Days with Flows below the Low-Flow Threshold (3,250 cfs) for Passage of Migrating Adult Salmonids and Green Sturgeon in the Sacramento River at RBDD and Differences in Percentages (in parentheses) for the No Action Alternative (NAA) and Alternatives 1–3**

Species/Run	Immigration Period	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
Winter-run	December–August	0.01	0.19 (0.18)	0.16 (0.16)	0.2 (0.19)	0.16 (0.16)
Spring-run	March–September	0.00	0.05 (0.05)	0.05 (0.05)	0.07 (0.07)	0.05 (0.05)
Fall-run	August–March	0.01	0.19 (0.18)	0.16 (0.15)	0.2 (0.19)	0.16 (0.15)
Late fall-run	July–December	0.01	0.06 (0.05)	0.06 (0.04)	0.06 (0.05)	0.06 (0.04)
Steelhead	November–April	0.01	0.19 (0.17)	0.16 (0.15)	0.2 (0.19)	0.16 (0.15)
Green Sturgeon	February–June	0.00	0.06 (0.06)	0.06 (0.06)	0.08 (0.08)	0.06 (0.06)

**Table 11N-33. Percent of Months with Mean Flows below the Low-Flow Threshold (3,250 cfs) for Passage of Migrating Adult Salmonids and Green Sturgeon in the Sacramento River at Wilkins Slough and Differences in Percentages (in parentheses) for the No Action Alternative (NAA) and Alternatives 1–3**

Species/Run	Immigration Period	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
Winter-run	December–August	0.0	0.54 (0.54)	0 (0)	0 (0)	0 (0)
Spring-run	March–September	0.0	0.7 (0.7)	1.05 (1.05)	0.7 (0.7)	0.7 (0.7)
Fall-run	August–March	0.0	0 (0)	0 (0)	0 (0)	0 (0)
Late fall-run	July–December	0.0	0 (0)	0 (0)	0 (0)	0 (0)
Steelhead	November–April	0.0	0 (0)	0 (0)	0 (0)	0 (0)
Green Sturgeon	February–June	0.0	0.98 (0.98)	1.46 (1.46)	0.98 (0.98)	0.98 (0.98)

#### **11N.3.4.2 Feather River**

The frequencies of flows below the 1,500 cfs threshold during the immigration periods for spring-run and fall-run and the 6,000 cfs threshold during the immigration period for green sturgeon in the HFC of the Feather River were determined for monthly flows using CALSIM II outputs at the Thermalito Afterbay outlet. The results show that the frequencies are high for all species and runs under Alternatives 1–3 and the NAA, and for green sturgeon in particular (Table 11N-34). For spring-run and fall-run, the frequencies of months with flows less than 1,500 cfs under Alternatives 1–3 were similar to or smaller than those under the NAA. For green sturgeon, the frequency of months with flows less than 6,000 cfs was substantially lower under Alternatives 1–3 than the NAA. These results indicate that Alternatives 1–3 would have little effect on low-flow passage conditions for immigrating adult salmonids in the Feather River and would benefit low-flow passage conditions for immigrating adult green sturgeon.

**Table 11N-34. Percent of Months with Mean Flows below the Low-Flow Threshold for Passage of Migrating Adult Salmonids (1,500 cfs) and Green Sturgeon (6,000 cfs) in the Feather River below Thermalito Afterbay Outlet and Differences in Percentages (in parentheses) for the No Action Alternative (NAA) and Alternatives 1–3**

Species/Run	Immigration Period	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
Spring-run^	March–June	33.8	33.8 (0)	34.5 (0.61)	33.5 (-0.3)	34.5 (0.61)
Fall-run^	August–December	28.5	24.4 (-4.15)	23.9 (-4.63)	24.4 (-4.15)	26.1 (-2.44)
Steelhead^	August–March	29.3	26.6 (-2.64)	26.6 (-2.64)	26.8 (-2.44)	27.8 (-1.42)
Green Sturgeon*	February–June	77.8	62.4 (-15.4)	62.9 (-14.9)	62.4 (-15.4)	62.4 (-15.4)

^For adult salmonids used 1,500 cfs as threshold.

\*For green sturgeon used 6,000 cfs as threshold.

### 11N.3.4.3 American River

The frequencies of flows below the 1,000 cfs threshold during the immigration periods for fall-run and steelhead in the American River were determined using monthly flows from CALSIM II outputs at Nimbus Dam. The results show a high percent of months with flows below the threshold for both species under Alternatives 1–3 and the NAA (Table 11N-35). However, there is little difference in the results between Alternatives 1–3 and the NAA (all differences less than 1%), so Alternatives 1–3 are not expected to affect low-flow passage conditions for fall-run or steelhead immigrating in the American River.

**Table 11N-35. Percent of Months with Mean Flows below the Low-Flow Threshold (1,000 cfs) for Passage of Migrating Adult Fall-run Chinook Salmon and Steelhead in the American River at Nimbus Dam and Differences in Percentages (in parentheses) for the No Action Alternative (NAA) and Alternatives 1–3**

Species/Run	Immigration Period	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
Fall-run	August–December	20.7	20.7 (0)	20.1 (-0.61)	20.4 (-0.3)	19.8 (-0.91)
Steelhead	October–April	17.8	18.1 (0.35)	17.8 (0)	17.9 (0.17)	17.2 (-0.52)

## 11N.4 Conclusions

This appendix describes the methods and results of analyses used to examine four flow-related effects of Alternatives 1–3 on Chinook salmon and steelhead in the Sacramento, Feather, and American Rivers: redd dewatering, redd scour/entombment, juvenile stranding, and low-flow passage interference with adult immigration. The low-flow passage interference analysis included green sturgeon as well. All analyses made use of operations model outputs simulating flow conditions under Alternatives 1–3 and the NAA. Monthly time-step CALSIM II outputs were used for all the Feather and American River analyses. Daily time-step USRDOM outputs, which provide more realistic simulations of flow conditions, were used for most of the Sacramento River analyses.

The results generally show little evidence of major overall effects of Alternatives 1–3. The redd dewatering and juvenile stranding analyses found many increases in potential negative effects balanced by many reductions in such effects. For some results, such as all the results for juvenile stranding, reductions in potential negative effects were more numerous and on average larger than increases. For other results, such as the redd dewatering results for spring-run and fall-run in the Feather River, increases in potential negative effects were much greater than reductions. However, other factors, such as the low level of spawning in the portion of the Feather River affected by Alternatives 1–3, reduce this potential negative effect.

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### **11N.5.2 Personal Communications**

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