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 will not 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 insufficient 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 EIR/EIS, including Appendix 11H, *Salmonid Population Modeling (SALMOD)*; Appendix 11I, *Winter-Run Chinook Salmon Life Cycle Modeling*; Appendix 11K, *Weighted Usable Area Analysis*; Appendix 11L, *Sturgeon Analyses*, and Appendix 11M, *Yolo and Sutter Bypass Flow and Weir Spill Analysis*. In addition, Chapter 11, *Aquatic Biological Resources*, 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 Final EIR/EIS 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) too low 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 2003; Liao 2007; Martin et al. 2015). While effects of uniform flow velocities on adult salmon bioenergetics are reasonably well understood (Enders 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 gives the spawning distributions 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 Service (USFWS) (2006) tables that relate spawning and dewatering flows to percent reductions in species-specific spawning habitat weighted usable area (WUA) (see Appendix 11K). 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. 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 U.S. Fish and Wildlife Service (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 the 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 (U.S. Fish and Wildlife Service 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)[1].

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	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 RBPP	257–242	0.0%	0.8%	4.2%	0.6%

ACID = Anderson-Cottonwood Irrigation District
RBPP = Red Bluff Pumping Plant

[1] The term *NAA*, which is identical to the No Project Alternative, is used throughout Chapter 11, *Aquatic Biological Resources*, and associated aquatic resources appendices in the presentation of modeled results and represents no material difference from the No Project Alternative, as discussed in Chapter 3, *Environmental Analysis*.

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																	
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	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											
Dewatering 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
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											
Dewatering 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
	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																
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	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 (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	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																
		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	1.0	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											
Dewatering 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
	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															
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
	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												
Dewatering 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
	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											
Dewatering 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
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																
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	1.2	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											
Dewatering 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
	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.)

		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	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.

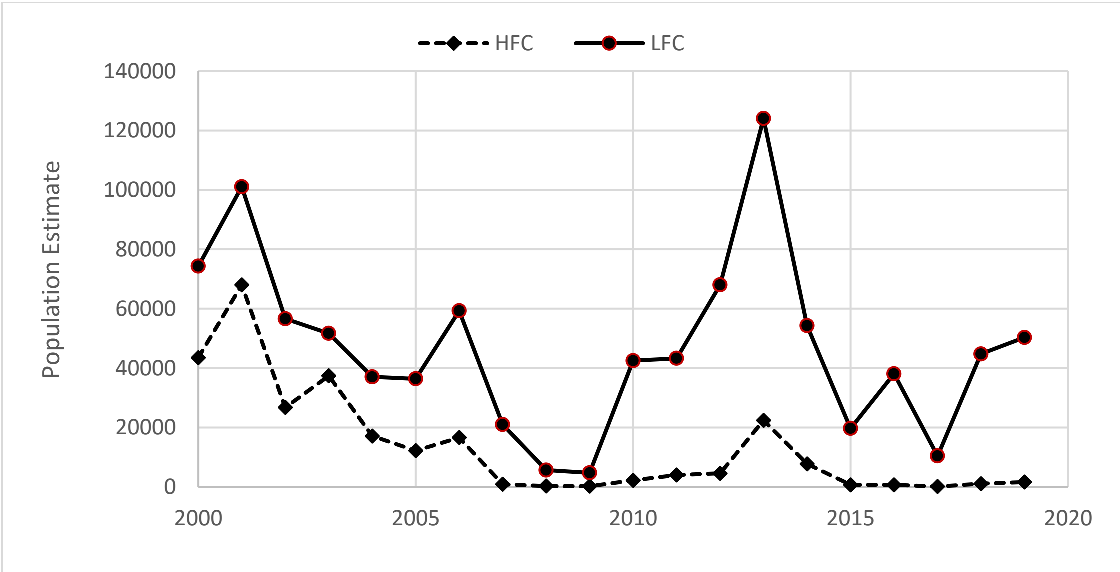


Figure 11N-1. Escapement Population Estimates for Fall-run Chinook Salmon in the Low-Flow Channel (LFC) and High-Flow Channel (HFC) of the Feather River from 2000 through 2019, from Escapement Surveys of DWR.

The redd dewatering analyses for Chinook salmon and steelhead in the Feather River are based on estimates of river stage reduction and observed redd depth distributions. The California Department of Water Resources (DWR) provided redd depth distribution data for Chinook salmon in the Feather River HFC from results of sampling conducted in 2010 through 2021 (Kindopp pers. comm. 2022). During sampling, no distinction was made between spring-run and fall-run Chinook redds, so the same redd depth distribution is used for the redd dewatering analyses of both races. Figure 11N-2 shows the HFC cumulative depth distribution of the Chinook salmon redds. No sampling of steelhead redds was conducted in the HFC, so the depth distribution of steelhead redds from the American River redd dewatering study (Bratovich et al. 2017) was used for the HFC steelhead redd dewatering analysis. The use of redd depth distributions from a different river adds uncertainty to the analysis, but the proximity of the rivers and their steelhead populations likely reduces differences.

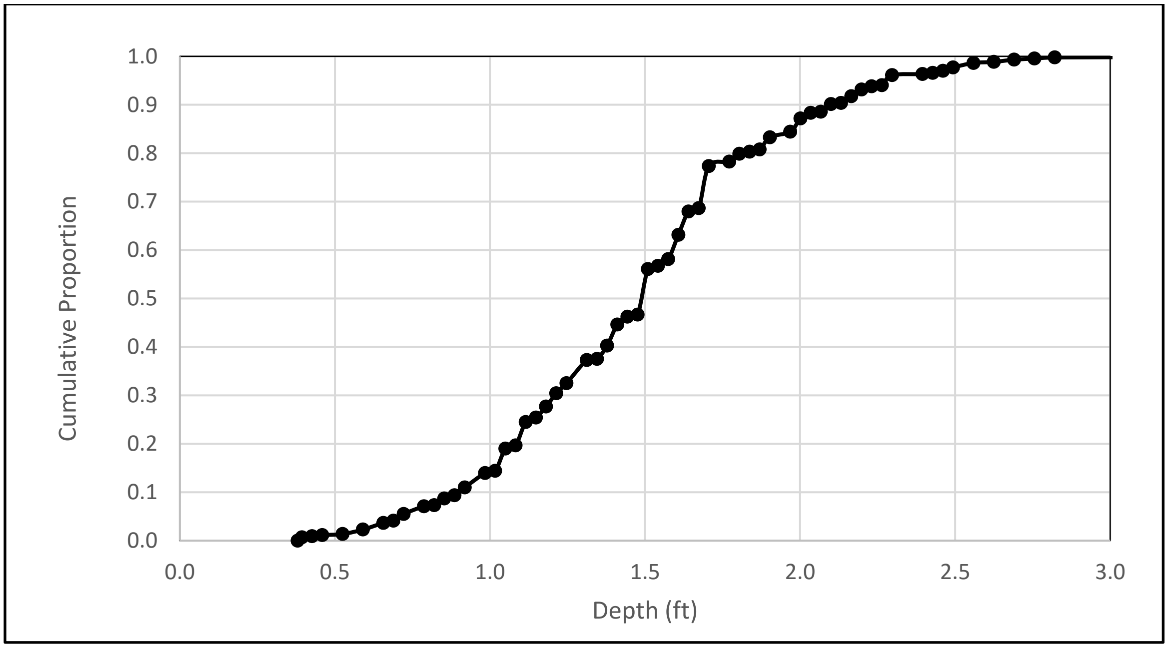


Figure 11N-2. Cumulative Proportion of Chinook Salmon Redd Depths in the Feather River below Thermalito Afterbay Outlet

The relationship between Feather River flow and depth at the Thermalito Afterbay outlet was estimated using stage-discharge tables for the Gridley gage on the Feather River (California Data Exchange Center 2022). This gage is 7 miles downstream of the Thermalito Afterbay outlet location, the closest CALSIM II node to Gridley. Despite the distance, the CALSIM II flow estimates for the Thermalito Afterbay outlet are expected to provide a reasonable approximation of flows at the Gridley gage because there are no major diversions or inflows on the Feather River between the Thermalito Afterbay outlet and the Gridley gage. Changes in water levels typically vary somewhat among different locations in the river, including the gage, but they are expected, on average, to be similar for similar changes in flow.

CALSIM II data, which have a monthly time-step, are used for the analysis, which assumes a new egg cohort begins each month of the spawning period. The change in river stage is tracked for the duration of each cohort. The duration of a cohort in a redd includes egg incubation and alevin development to emergence from the gravel. Eggs and alevins are assumed to be lost if the river stage drops below the stage at the spawning month.

Bratovich et al. (2017), in a redd dewatering study in the American River (see Section 11N.2.1.3, *American River*), determined cohort durations of about 3 months for fall-run Chinook salmon and 2 months for steelhead. If flows during the 2 or 3 months following spawning are all greater than the spawning flow, no dewatering is assumed to occur. The use of monthly time-step flow estimates likely underestimates redd dewatering rates, but this potential bias is expected to affect the Project and NAA scenarios equally.

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 3-month and 2-month incubation periods, respectively. The analysis compared CALSIM II flow and the corresponding stage 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.

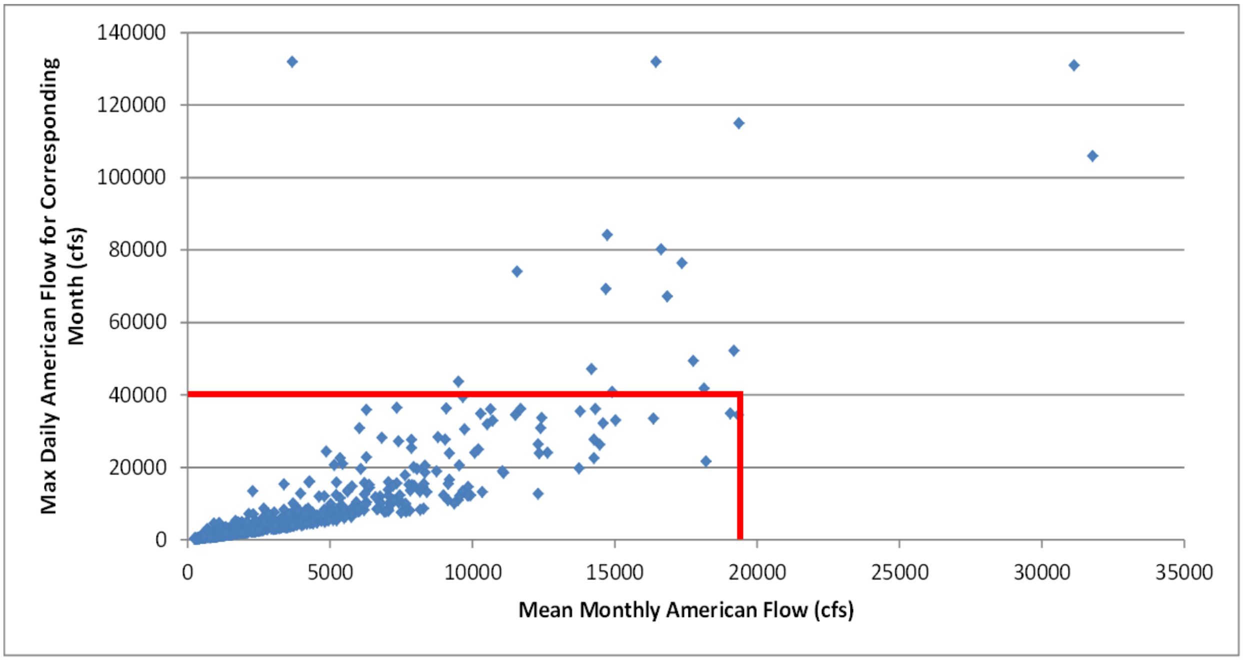
The probability of flows occurring that would be high enough to mobilize sediments and scour or entomb Chinook salmon and steelhead redds was estimated for the Sacramento and American Rivers. The amount of flow needed to mobilize sediments in these rivers has been little studied (Ayres Associates 2001), 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

River	Approximate Flow Ranges to Initiate Mobility (cfs)	References
Sacramento River	24,000–50,000	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 gage 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 gage location. The analysis of the Hazel Avenue gage 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-3). 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.



Note: Minimum monthly flow is identified in red.

Figure 11N-3. Relationship between Mean Monthly Flows and Maximum Daily Flows during December through April, American River Downstream of Hazel Avenue, 1950–2015.

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 (river stage) at an initial flow with that at the minimum flow during the following period. The minimum flow over 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 (U.S. Fish and Wildlife Service 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 (U.S. Fish and Wildlife Service 2006). Not all potential stranding areas were included in the study because the areas had to meet several criteria for inclusion (U.S. Fish and Wildlife Service 2006). Therefore, the stranding results provide relative rather than absolute estimates of numbers of juveniles stranded.

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										
Stranding Flow		3,500	3,750	4,000	4,250	4,500	4,750	5,000	5,250	5,500	6,000	6,500
	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.)

		Initial Flow									
Stranding Flow		7,000	7,500	8,000	9,000	10,000	11,000	12,000	13,000	14,000	15,000
	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										
Stranding Flow		3,500	3,750	4,000	4,250	4,500	4,750	5,000	5,250	5,500	6,000	6,500
	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									
Stranding Flow		7,000	7,500	8,000	9,000	10,000	11,000	12,000	13,000	14,000	15,000
	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 juveniles most vulnerable 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, *Aquatic Species Life Histories*, 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 through 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 insufficient water depth or flow over natural or artificial barriers. Note that for salmonids, if periods of low flow are relatively brief and infrequent, they may have little effect on passage because the fish can wait in deeper water until passage conditions improve, although such delays may have significant metabolic costs (Newton et al. 2018). The specific flow level at which passage difficulties for migrating salmonid adults first appear is not known for the Sacramento, Feather, or American Rivers. Therefore, threshold flows for migrating salmonids 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 habitat 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 Sacramento River salmonid adults 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. 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.).

For upstream migrating adult sturgeon, a threshold flow of 5,300 cfs at Colusa was selected based on observations by Shaffter (1997). In a radio tagging study of white sturgeon during spawning migrations in the Sacramento River, Schaffter noted that when flow at Colusa dropped below a level of 5,300 cfs, adults tended to cease upstream migrations or drifted downstream. Schaffter does not speculate about the reason for the cessation of migration at this flow, but whether it has to do with river channel obstructions or another cause, the outcome is the same: interruption of the spawning migration. Schaffter's observations are for white sturgeon, but given their similar size and biology, green sturgeon are expected to have a similar flow threshold for upstream migration.

Threshold flows 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 (National Marine Fisheries Service 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 distinct population segment of green sturgeon lists removal or modification of the Sunset Pumps boulder weir as a high-priority recovery action (National Marine Fisheries Service 2018), but it is not clear when such measures would be implemented (Seesholtz pers. comm.).

For adult salmonids in the Sacramento River, flows at four locations (Keswick Dam, Battle Creek, Red Bluff Pumping Plant [RBPP], and Wilkins Slough) were used for analysis of low flows. USRDOM daily flow estimates were used for the Keswick Dam, Battle Creek, and RBPP locations and CALSIM II monthly flow estimates were used for Wilkins Slough. For adult sturgeon in the Sacramento River, USRDOM flow estimates downstream of the Colusa Weir were used for the analysis. For salmonids and green sturgeon in the Feather River, CALSIM II flows below the Thermalito Afterbay outlet were used and for the analysis and for salmonids in the American River, CALSIM II flow below Nimbus Dam was used. Neither sturgeon species currently spawns in the American River (National Marine Fisheries Service 2018). For each species and location, the percent of days (Keswick Dam, Battle Creek, RBPP, and Colusa Weir) or months (other locations) during the adult immigration period that modeled flows were lower than the minimum flow thresholds were calculated for Alternatives 1, 2, and 3 and the NAA, and the differences in these percentages between Alternatives 1, 2, and 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 May in Critically Dry Water Years is 0.3%, whereas the difference expressed as the percent change would be 20%. 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.

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 (e.g., >5 percent, absolute difference) in redd dewatering between the NAA and Alternatives 1–3, and all such changes result from reductions in redd dewatering (Table 11N-13). The largest reduction, 7 percent, occurs under Alternative 3 for spawning in July of Above Normal Water Years. Changes for most months and water year types under all the alternatives are less than 2 percent. Overall, Alternatives 1–3 are expected to have little effect on winter-run redd dewatering.

Table 11N-13. Percent of Winter-run Redds Dewatered in the Sacramento River and Differences in the Percentages for the NAA and Alternatives 1–3

Period	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
April–July	Wet	18.0	18 (0)	18 (0)	18 (0)	18 (0)
	Above Normal	7.6	7.5 (-0.1)	7.7 (0.1)	7.6 (0)	7.8 (0.1)
	Below Normal	2.6	2.8 (0.1)	2.8 (0.2)	2.8 (0.1)	2.7 (0.1)
	Dry	1.8	1.8 (0)	1.2 (-0.5)	1.8 (0)	1.2 (-0.6)

Period	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
	Critically Dry	1.0	0.9 (-0.1)	0.9 (0)	0.9 (-0.1)	1 (0)
	All	7.9	7.9 (0)	7.8 (-0.1)	7.9 (0)	7.8 (-0.1)
May–August	Wet	3.5	3.5 (0)	3.5 (0)	3.5 (0)	3.5 (0)
	Above Normal	2.1	2.1 (0)	2.1 (0)	2.1 (0)	2.1 (0)
	Below Normal	0.8	0.8 (0)	0.8 (0.1)	0.8 (0)	0.9 (0.2)
	Dry	0.7	0.7 (0)	0.6 (-0.1)	0.7 (0)	0.5 (-0.2)
	Critically Dry	1.9	1.6 (-0.3)	1.5 (-0.3)	1.5 (-0.4)	1.4 (-0.5)
	All	2.0	1.9 (0)	1.9 (-0.1)	1.9 (-0.1)	1.9 (-0.1)
June–September	Wet	1.5	1.5 (0)	1.5 (0.1)	1.5 (0)	1.5 (0)
	Above Normal	3.0	3.2 (0.3)	2.3 (-0.6)	3.2 (0.3)	1.6 (-1.4)
	Below Normal	11.3	12 (0.8)	10.8 (-0.5)	12 (0.8)	9.3 (-2)
	Dry	18.0	18.3 (0.3)	18.1 (0.1)	18.3 (0.3)	16.7 (-1.3)
	Critically Dry	13.5	10.8 (-2.8)	10.3 (-3.2)	10.8 (-2.8)	10.5 (-3)
	All	8.8	8.7 (-0.2)	8.2 (-0.6)	8.7 (-0.2)	7.6 (-1.2)
July–October	Wet	12.2	12.4 (0.3)	12.2 (0)	12.4 (0.3)	12.4 (0.2)
	Above Normal	20.4	19.9 (-0.6)	18.5 (-2)	19.8 (-0.7)	13.3 (-7.1)
	Below Normal	26.6	26.3 (-0.3)	26 (-0.7)	26.4 (-0.2)	24.3 (-2.3)
	Dry	28.7	29.4 (0.7)	29.2 (0.4)	29.4 (0.7)	28.2 (-0.5)
	Critically Dry	19.1	17.3 (-1.8)	17 (-2.1)	17.3 (-1.8)	17.3 (-1.8)
	All	20.5	20.3 (-0.2)	19.9 (-0.6)	20.3 (-0.1)	18.9 (-1.6)

[1] Water year type sorting is by hydrologic years.

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 (U.S. Fish and Wildlife Service 2006).

The results of the redd dewatering analysis for spring-run (Table 11N-14) show 2 percent increases in redd dewatering for spawning in August and September of Critically Dry Water Years under Alternatives 1, 2, and 3. Larger reductions occur under Alternative 3, including up to 6 percent lower for spawning in August of Above Normal Water Years. Changes for most months and water year types under all the alternatives are less than 2 percent. 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 NAA and Alternatives 1–3

Period	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
	Wet	22.5	22.7 (0.2)	22.3 (-0.2)	22.7 (0.2)	22.6 (0.1)

Period	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
August–November	Above Normal	21.6	21.1 (-0.5)	21 (-0.6)	20.5 (-1.1)	15.6 (-5.9)
	Below Normal	26.8	25.9 (-0.9)	25.7 (-1.1)	26 (-0.8)	23.4 (-3.4)
	Dry	27.2	28.5 (1.4)	27.7 (0.6)	28.6 (1.4)	27.3 (0.2)
	Critically Dry	21.1	23.4 (2.3)	23.2 (2.1)	23.4 (2.3)	23.3 (2.2)
	All	24.0	24.5 (0.5)	24.1 (0.1)	24.4 (0.4)	23 (-1)
September–December	Wet	26.1	26.4 (0.3)	25.3 (-0.8)	26.4 (0.3)	25.6 (-0.5)
	Above Normal	19.5	18.5 (-1)	19 (-0.5)	18.2 (-1.4)	20.7 (1.2)
	Below Normal	8.1	7.1 (-1)	7.4 (-0.7)	7.2 (-1)	5.9 (-2.2)
	Dry	4.7	4.8 (0.1)	4.7 (0)	4.8 (0.1)	4.6 (-0.1)
	Critically Dry	6.4	8.3 (1.9)	8.3 (1.9)	8.3 (1.9)	8 (1.6)
	All	14.4	14.5 (0.1)	14.2 (-0.2)	14.5 (0)	14.2 (-0.2)
October - January	Wet	12.1	12.2 (0.1)	12.2 (0.1)	12.2 (0)	13.2 (1.1)
	Above Normal	11.6	11.2 (-0.4)	11.7 (0.1)	11.7 (0.1)	11.6 (0)
	Below Normal	13.0	12.8 (-0.2)	13.2 (0.2)	12.8 (-0.2)	14.1 (1.1)
	Dry	12.4	12.6 (0.2)	12.9 (0.5)	12.6 (0.2)	14 (1.6)
	Critically Dry	10.7	10.9 (0.2)	10.9 (0.2)	10.7 (0)	11.2 (0.5)
	All	12.1	12.1 (0)	12.3 (0.2)	12.1 (0)	13 (1)

[1] Water year type sorting is by hydrologic years.

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 no large differences in redd dewatering between the NAA and Alternatives 1–3. The largest differences are 1.5 percent increases under Alternatives 1A, 1B, and 2 for spawning in September of Critically Dry Water Years. Most other changes for all months and water year types under all the alternatives are less than 1 percent. The results indicate that Alternatives 1–3 would have little effect on fall-run redd dewatering.

Table 11N-15. Percent of Fall-run Redds Dewatered in the Sacramento River and Differences in the Percentages for the NAA and Alternatives 1–3

Period	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
September - December	Wet	18.3	18.5 (0.2)	17.8 (-0.4)	18.5 (0.2)	18.2 (-0.1)
	Above Normal	13.7	13.1 (-0.6)	13.7 (0)	12.8 (-0.8)	14.7 (1)
	Below Normal	4.0	4.2 (0.2)	4.2 (0.2)	4.2 (0.2)	3.4 (-0.7)
	Dry	2.8	3.1 (0.3)	2.9 (0.1)	3.1 (0.3)	3 (0.1)
	Critically Dry	4.2	5.7 (1.5)	5.7 (1.5)	5.7 (1.5)	5.4 (1.2)
	All	9.7	10 (0.3)	9.8 (0.1)	10 (0.2)	9.9 (0.2)
October–January	Wet	8.0	8.3 (0.3)	8.2 (0.3)	8.3 (0.3)	9 (1)
	Above Normal	8.7	8.6 (-0.2)	8.8 (0)	8.9 (0.2)	8.8 (0.1)
	Below Normal	6.7	6.8 (0.1)	7 (0.3)	6.8 (0.1)	7.6 (1)

Period	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
	Dry	8.2	8.4 (0.2)	8.6 (0.4)	8.4 (0.2)	9.4 (1.2)
	Critically Dry	7.9	8.4 (0.4)	8.3 (0.4)	8.2 (0.3)	8.6 (0.7)
	All	7.9	8.1 (0.2)	8.2 (0.3)	8.1 (0.2)	8.8 (0.9)
November - February	Wet	12.9	12.2 (-0.6)	12.4 (-0.5)	12.2 (-0.7)	12.9 (0)
	Above Normal	12.6	12.4 (-0.2)	12.5 (-0.2)	12.4 (-0.2)	12.8 (0.2)
	Below Normal	9.5	9.3 (-0.2)	9.5 (0)	9.3 (-0.1)	9.5 (0.1)
	Dry	15.5	14.9 (-0.7)	15.9 (0.4)	14.9 (-0.7)	15.4 (-0.1)
	Critically Dry	9.3	8.4 (-1)	8.4 (-1)	8.2 (-1.1)	10.1 (0.8)
	All	12.3	11.8 (-0.5)	12.1 (-0.2)	11.7 (-0.6)	12.5 (0.1)

[1] Water year type sorting is by hydrologic years.

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 Alternatives 1A and 1B, with no differences from the NAA greater than 1.5 percent (Table 11N-16). Alternative 3 has several larger increases in redd dewatering, including 3 percent increases for spawning in December of Wet and Dry Water Years and February of Above Normal Water Years. Most other differences under Alternative 3 are small, but almost all consitute increases in redd dewatering. The results indicate that Alternatives 1A, 1B, and 2 would have little effect on late fall–run redd dewatering, but Alternative 3 would result in moderately greater redd dewatering than that under the NAA.

Table 11N-16. Percent of Late Fall–run Redds Dewatered in the Sacramento River and Differences in the Percentages for the NAA and Alternatives 1–3

Period	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
December–March	Wet	25.1	25.6 (0.5)	26.4 (1.3)	25.7 (0.7)	27.7 (2.6)
	Above Normal	10.7	11.3 (0.6)	11.2 (0.5)	11.4 (0.6)	11.9 (1.1)
	Below Normal	9.3	9.5 (0.2)	9.7 (0.4)	9.5 (0.2)	9.8 (0.5)
	Dry	7.0	7.7 (0.7)	8.2 (1.2)	7.7 (0.7)	9.7 (2.7)
	Critically Dry	4.2	3.8 (-0.5)	3.7 (-0.5)	3.7 (-0.5)	3.5 (-0.7)
	All	13.3	13.7 (0.4)	14 (0.7)	13.7 (0.4)	14.8 (1.6)
January–April	Wet	33.6	34.1 (0.5)	34.4 (0.8)	34.1 (0.5)	34.8 (1.2)
	Above Normal	16.0	16.4 (0.4)	16.4 (0.4)	16.4 (0.4)	18 (2)
	Below Normal	6.3	6.2 (-0.1)	6.2 (0)	6.2 (-0.1)	6.3 (0.1)
	Dry	2.9	2.8 (0)	2.9 (0)	2.8 (0)	2.9 (0)
	Critically Dry	1.1	1.1 (0)	1.1 (0)	1.1 (0)	1.1 (0)
	All	14.9	15.1 (0.2)	15.2 (0.3)	15.1 (0.2)	15.5 (0.7)
	Wet	44.5	44.5 (0)	45.2 (0.7)	44.5 (0)	45.8 (1.3)

Period	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
February–May	Above Normal	29.0	30.2 (1.2)	30.5 (1.5)	30.2 (1.2)	32.1 (3.1)
	Below Normal	12.2	12.3 (0.1)	12.8 (0.5)	12.5 (0.3)	13.2 (1)
	Dry	2.6	2.5 (-0.1)	2.7 (0)	2.5 (-0.1)	2.9 (0.3)
	Critically Dry	1.3	1.3 (0)	1.4 (0.1)	1.3 (0)	1.4 (0.1)
	All	21.2	21.4 (0.2)	21.7 (0.5)	21.4 (0.2)	22.3 (1.1)
March–June	Wet	37.0	37.1 (0)	37 (0)	37 (0)	37.6 (0.6)
	Above Normal	27.8	28 (0.2)	28 (0.2)	28 (0.2)	28.1 (0.3)
	Below Normal	8.2	8.2 (0)	8.2 (0)	8.2 (0)	8.1 (-0.1)
	Dry	3.8	4.3 (0.5)	3.9 (0.1)	4.3 (0.5)	4.7 (0.9)
	Critically Dry	1.6	1.7 (0.1)	3 (1.5)	1.7 (0.1)	3.2 (1.7)
	All	18.3	18.5 (0.2)	18.5 (0.2)	18.4 (0.2)	18.9 (0.6)

[1] Water year type sorting is by hydrologic years.

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 little effect from Alternatives 1A, 1B, and 2, with few differences of more than 1 percent from the NAA (Table 11N-17). Alternative 3 has several larger increases in redd dewatering, including 2 to 3 percent increases for spawning in December of Wet and Dry Water Years and January and February of Above Normal Water Years. Most other differences under Alternative 3 are small, but almost all represent increases in redd dewatering. These results indicate that Alternatives 1A, 1B, and 2 would have little effect on steelhead redd dewatering, but Alternative 3 would result in moderately greater redd dewatering than that under the NAA.

Table 11N-17. Percent of Steelhead Redds Dewatered in the Sacramento River and Differences in the Percentages for the NAA and Alternatives 1–3

Period	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
November–February	Wet	11.3	10.7 (-0.6)	10.8 (-0.5)	10.7 (-0.6)	11.5 (0.2)
	Above Normal	11.3	11.4 (0.1)	11.4 (0.1)	11.4 (0.1)	12 (0.8)
	Below Normal	9.7	9.4 (-0.3)	9.8 (0.1)	9.4 (-0.2)	9.8 (0.1)
	Dry	14.1	13.8 (-0.3)	14.8 (0.7)	13.8 (-0.3)	14.7 (0.6)
	Critically Dry	10.8	9.6 (-1.2)	9.5 (-1.3)	9.3 (-1.5)	11.7 (0.9)
	All	11.6	11.1 (-0.5)	11.4 (-0.2)	11 (-0.5)	12 (0.5)
December–March	Wet	29.9	30.5 (0.6)	31.1 (1.2)	30.7 (0.7)	32.4 (2.5)
	Above Normal	14.0	14.4 (0.4)	14.3 (0.3)	14.4 (0.4)	15.1 (1.1)

Period	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
	Below Normal	11.7	12.1 (0.3)	12.3 (0.6)	12 (0.3)	12.4 (0.7)
	Dry	9.8	10.7 (0.9)	11.1 (1.3)	10.7 (0.9)	13.2 (3.4)
	Critically Dry	6.3	5.7 (-0.5)	5.6 (-0.7)	5.7 (-0.5)	5.4 (-0.9)
	All	16.6	17 (0.4)	17.3 (0.7)	17.1 (0.5)	18.3 (1.7)
January–April	Wet	39.5	40 (0.5)	40.3 (0.7)	40 (0.5)	40.7 (1.2)
	Above Normal	21.8	21.9 (0.2)	22 (0.2)	21.9 (0.2)	23.9 (2.1)
	Below Normal	10.5	10.4 (-0.1)	10.4 (0)	10.4 (-0.1)	10.5 (0.1)
	Dry	4.9	4.7 (-0.2)	4.8 (-0.1)	4.7 (-0.2)	4.8 (-0.1)
	Critically Dry	2.8	2.8 (-0.1)	2.8 (0)	2.8 (0)	2.8 (-0.1)
	All	19.0	19.1 (0.1)	19.2 (0.2)	19.1 (0.1)	19.7 (0.7)
February - May	Wet	52.8	52.9 (0.1)	53.5 (0.7)	52.9 (0.1)	54.3 (1.5)
	Above Normal	36.6	37.5 (0.9)	37.7 (1.1)	37.5 (0.8)	39.5 (2.9)
	Below Normal	19.6	19.5 (-0.1)	20.2 (0.6)	19.9 (0.3)	20.8 (1.2)
	Dry	7.5	7.3 (-0.2)	7.5 (0)	7.3 (-0.2)	7.7 (0.2)
	Critically Dry	3.6	3.6 (0)	3.7 (0.1)	3.6 (0)	3.7 (0.1)
	All	27.6	27.7 (0.1)	28.1 (0.5)	27.7 (0.1)	28.7 (1.1)

[1] Water year type sorting is by hydrologic years.

11N.3.1.2 Feather River

As described in Section 11N.2, *Methods*, redd dewatering for Feather River salmon and steelhead was estimated from the depth distributions of their redds and changes in river stage (depth) at the Gridley gage on the Feather River at different flows. The redd depth distributions were determined from DWR studies of Feather River salmon (Figure 11N-2) or American River studies of steelhead (Bratovich et al. 2017). The river depths were estimated from CALSIM II monthly flow results at the Thermalito Afterbay outlet and DWR's stage-discharge tables for the Gridley gage.

Comparisons of the means of the redd dewatering estimates under Alternatives 1, 2, and 3 to means under the NAA use 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. The use of monthly time-step flow estimates 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 increases in redd dewatering under Alternatives 1–3 for September spawning, especially in Wet Water Years (Table 11N-18). The largest increases occur under Alternatives 1B and 3, including a 7 percent increase under Alternative 3 for spawning in September of Below Normal Water Years and 5 percent increases under Alternative 1B for spawning in September of Wet Water Years and October of Below Normal Water Years. These increases potentially indicate high levels of redd dewatering for spring-run spawning in the HFC.

These results indicate that Alternatives 1B and 3 would substantially increase spring-run redd dewatering in the Feather River, especially for spawning during September. 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 greatly affect the Feather River spring-run population.

Table 11N-18. Percent of Spring-run and Fall-run Redds Dewatered in the Feather River at Thermalito Afterbay Outlet and Differences in the Percentages for the NAA and Alternatives 1–3

Period	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
September–December	Wet	75	77 (2.2)	80 (5.4)	77 (2.3)	78 (2.7)
	Above Normal	100	100 (0)	100 (0)	100 (0)	100 (0)
	Below Normal	24	25 (1)	27 (2.8)	25 (1.1)	31 (7.2)
	Dry	0	0 (0.2)	0 (0.2)	0 (0.2)	0 (0.1)
	Critically Dry	3	3 (0.2)	4 (1)	4 (0.6)	3 (0)
	All	42	43 (0.9)	44 (2.4)	43 (1.1)	44 (2.1)
October–January	Wet	20	21 (1.2)	20 (0.1)	20 (0.9)	20 (0.8)
	Above Normal	32	31 (-1)	31 (-1)	31 (-1)	30 (-1.7)
	Below Normal	24	24 (0.8)	29 (5.4)	24 (0.9)	24 (0.6)
	Dry	28	27 (-1.3)	27 (-1.1)	26 (-1.4)	26 (-1.5)
	Critically Dry	8	8 (0.1)	8 (0.5)	8 (0)	8 (0.1)
	All	22	22 (0.1)	23 (0.6)	22 (0)	22 (-0.2)
November–February	Wet	5	5 (0)	5 (0)	5 (0)	5 (0)
	Above Normal	1	1 (0)	1 (0)	1 (0)	1 (0)
	Below Normal	2	2 (0.3)	2 (0.3)	2 (0.2)	2 (-0.1)
	Dry	1	2 (0.6)	1 (0.1)	2 (0.6)	1 (0.1)
	Critically Dry	2	4 (1.2)	4 (1.4)	4 (1.3)	4 (1.2)
	All	3	3 (0.4)	3 (0.3)	3 (0.4)	3 (0.2)
	Wet	20	21 (0.8)	21 (0.8)	20 (0.5)	21 (0.7)

Period	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
December–March	Above Normal	20	20 (-0.1)	20 (0)	20 (-0.2)	20 (-0.2)
	Below Normal	19	18 (-0.2)	18 (-0.2)	18 (-0.2)	18 (-0.2)
	Dry	26	25 (-0.6)	25 (-0.6)	25 (-0.6)	25 (-0.6)
	Critically Dry	21	21 (0)	21 (0)	21 (0)	20 (-0.8)
	All	21	21 (0.1)	21 (0.1)	21 (-0.1)	21 (-0.1)

[1] Water year type sorting is by hydrologic years.

Fall-run Chinook Salmon

The results for the Feather River fall-run spawning and incubation period (October through March) are quite different from those for spring-run despite the similarity in the spawning periods of the two runs (Table 11N-18). Most of the effects for spring-run are from spawning in September, which is a month earlier than the period analyzed for fall-run redd dewatering. The results show few differences in fall-run redd dewatering between Alternatives 1, 2, and 3 and the NAA. Most differences for all the alternatives are less than 1 percent. The one large difference, as noted above for spring-run, is a 5 percent increase in redd dewatering for spawning in October of Below Normal Water Years under Alternative 1B. In general, these results indicate that Alternatives 1–3 would have little effect on fall-run redd dewatering in the Feather River.

Steelhead

The results for the Feather River steelhead (Table 11N-19) show little effect of Alternatives 1, 2, and 3 on steelhead redd dewatering. Almost all differences from the NAA are less than 1 percent, except for a 6 percent reduction in redd dewatering under Alternative 3 for spawning in March of Above Normal Water Years. These results indicate that Alternatives 1, 2, and 3 would not affect steelhead redd dewatering in the Feather River.

Table 11N-19. Percent of Steelhead Redds Dewatered in the Feather River at Thermalito Afterbay Outlet and Differences in the Percentages for the NAA and Alternatives 1–3

Period	Water Year Type[a]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
December–March	Wet	11	12 (0.6)	12 (0.4)	12 (0.3)	12 (0.2)
	Above Normal	17	17 (-0.2)	17 (0)	17 (-0.2)	17 (0)
	Below Normal	14	13 (-0.4)	15 (1.1)	13 (-0.4)	13 (-1)
	Dry	21	20 (-0.4)	20 (-0.4)	20 (-0.4)	20 (-0.2)
	Critically Dry	14	14 (0)	14 (0)	14 (0)	14 (-0.4)
	All	15	15 (0)	15 (0.3)	15 (-0.1)	15 (-0.2)
January–April	Wet	29	29 (0)	29 (0)	29 (0)	29 (0)
	Above Normal	9	9 (0)	9 (0)	9 (0)	9 (0)
	Below Normal	0	0 (0)	0 (0)	0 (0)	0 (0.1)
	Dry	0	0 (0)	0 (0)	0 (0)	0 (0)

Period	Water Year Type[a]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
	Critically Dry	0	0 (0)	0 (0)	0 (0)	0 (0)
	All	11	11 (0)	11 (0)	11 (0)	11 (0)
February–May	Wet	57	57 (0.3)	57 (0.3)	57 (0.3)	58 (1)
	Above Normal	40	40 (-0.4)	40 (0)	40 (0)	40 (0)
	Below Normal	17	17 (0)	17 (0)	17 (0)	17 (0)
	Dry	7	7 (0)	7 (0.1)	7 (0)	7 (0.1)
	Critically Dry	7	7 (0)	7 (0)	7 (0)	7 (0)
	All	29	29 (0)	29 (0.1)	29 (0.1)	30 (0.3)
March–June	Wet	68	68 (0)	68 (0)	68 (0)	68 (0)
	Above Normal	63	63 (0)	62 (-1.2)	63 (0)	57 (-6)
	Below Normal	11	11 (0)	11 (0.3)	11 (0)	11 (0)
	Dry	6	6 (0.1)	6 (0.2)	6 (0.1)	6 (0.2)
	Critically Dry	13	13 (0)	13 (0)	13 (0)	13 (0)
	All	36	36 (0)	36 (-0.1)	36 (0)	35 (-0.8)

[a] Water year type sorting is by hydrologic years.

11N.3.1.3 American River

The redd dewatering analysis for the lower American River uses 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 and corresponding stage estimates below Nimbus Dam for each spawning month with the minimum flow and corresponding stage during 2 or 3 months following the spawning month to estimate the percentage of redds dewatered. The use of monthly time-step flow estimates like those obtained from CALSIM II modeling likely underestimates redd dewatering rates because they smooth out short-term flow fluctuations. This potential bias is expected to affect the Project and NAA scenarios equally.

The means of the redd dewatering estimates under the Project as compared to the NAA use 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. Spring-run, winter-run and late fall–run do not spawn in the American River.

Fall-run Chinook Salmon

The results of the redd dewatering analysis for American River fall-run (Table 11N-20) show notable increases in redd dewatering for spawning in November of Above Normal, Dry, and

Critically Dry Water Years under Alternative 3. The largest of these increases is 6 percent for Above Normal Water Years. The other alternatives show few differences of more than 1 percent. These results indicate that Alternative 3 would increase American River fall-run redd dewatering, but the other alternatives would have no appreciable effect.

Table 11N-20. Percent of Fall-run Redds Dewatered in the American River and Differences in the Percentages for the NAA and Alternatives 1–3

Period	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
October–January	Wet	0.3	0 (0)	0 (0)	0 (0)	0 (0)
	Above Normal	0.1	0 (0)	1 (0.8)	0 (0)	1 (0.6)
	Below Normal	3.3	3 (-0.4)	3 (-0.4)	2 (-1.7)	3 (0.1)
	Dry	0.1	0 (0)	0 (0)	0 (0)	0 (0)
	Critically Dry	11.0	11 (0)	11 (0)	11 (0)	10 (-1.3)
	All	2.3	2 (-0.1)	2 (0.1)	2 (-0.3)	2 (-0.1)
November–February	Wet	32.5	32 (0)	30 (-2.2)	32 (-0.2)	32 (-0.3)
	Above Normal	3.5	3 (-0.6)	5 (1.4)	3 (-0.2)	10 (6.2)
	Below Normal	7.7	7 (-0.3)	7 (-0.6)	7 (-0.6)	9 (1.7)
	Dry	2.2	2 (-0.4)	2 (0.1)	2 (-0.1)	5 (3)
	Critically Dry	5.2	5 (0)	6 (0.9)	6 (1.1)	8 (2.3)
	All	13.4	13 (-0.2)	13 (-0.5)	13 (-0.1)	15 (2.1)
December–March	Wet	22.4	22 (0)	23 (0.5)	22 (0)	23 (0.6)
	Above Normal	19.7	19 (-0.3)	20 (0.1)	20 (0)	19 (-0.9)
	Below Normal	26.3	26 (-0.1)	27 (0.8)	26 (-0.2)	28 (1.8)
	Dry	17.3	17 (-0.4)	16 (-0.9)	17 (0)	19 (1.7)
	Critically Dry	0.0	0 (0)	0 (0)	0 (0)	0 (0)
	All	18.3	18 (-0.2)	18 (0.1)	18 (0)	19 (0.7)

[1] Water year type sorting is by hydrologic years.

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 changes in steelhead redd dewatering of 2 percent or more are a 2 percent reduction for February spawning in Above Normal Water Years under Alternative 3 and a 2 percent increase for February spawning in Critically Dry Water Years under Alternative 2. Overall, Alternatives 1–3 are expected to have little effect on American River steelhead redd dewatering.

Table 11N-21. Percent of Steelhead Redds Dewatered in the American River and Differences in the Percentages for the NAA and Alternatives 1–3

Period	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
December–February	Wet	9.3	9 (0)	10 (0.3)	9 (0)	10 (0.4)
	Above Normal	8.7	9 (-0.1)	9 (0.1)	9 (0)	8 (-0.5)
	Below Normal	17.2	17 (-0.1)	17 (-0.1)	17 (-0.1)	17 (-0.1)
	Dry	12.0	12 (0)	12 (0)	12 (0.1)	13 (0.9)
	Critically Dry	0.0	0 (0)	0 (0)	0 (0)	0 (0)
	All	9.8	10 (0)	10 (0.1)	10 (0)	10 (0.3)
January–March	Wet	40.1	40 (0)	40 (0)	40 (0)	40 (-0.4)
	Above Normal	26.6	27 (0)	27 (0)	27 (0)	27 (0)
	Below Normal	10.4	10 (0)	10 (0)	10 (0)	10 (0)
	Dry	1.8	2 (0)	2 (0)	2 (0)	2 (0)
	Critically Dry	0.9	1 (0)	1 (0)	1 (0)	1 (0)
	All	18.9	19 (0)	19 (0)	19 (0)	19 (-0.1)
February–April	Wet	59.8	60 (0)	60 (0)	60 (0)	60 (0)
	Above Normal	41.9	42 (0)	41 (-1.1)	42 (0)	40 (-2)
	Below Normal	40.3	40 (0)	40 (0)	40 (0)	40 (0)
	Dry	12.4	12 (-0.2)	12 (-0.7)	12 (-0.2)	12 (-0.7)
	Critically Dry	2.8	4 (1.6)	4 (1.6)	5 (2)	4 (0.8)
	All	35.1	35 (0.2)	35 (-0.1)	35 (0.2)	35 (-0.3)
March–May	Wet	16.5	17 (0)	17 (0)	17 (0)	17 (0)
	Above Normal	17.7	18 (0)	18 (0)	18 (0)	18 (0)
	Below Normal	0.9	1 (0)	1 (0)	1 (0)	1 (0)
	Dry	6.5	6 (0)	6 (0)	6 (0)	6 (0)
	Critically Dry	4.8	4 (-1.3)	5 (0.4)	3 (-1.4)	5 (0.1)
	All	10.1	10 (-0.2)	10 (0.1)	10 (-0.2)	10 (0)

[1] Water year type sorting is by hydrologic years.

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. However, Feather River flows during the high flow months (December through May), when scouring flows would be most likely to occur, are generally similar between the NAA and Alternatives 1, 2, and 3 (Chapter 5, *Surface Water Resources*). Therefore, no substantial differences on the frequency of scouring flows are expected between the NAA and Alternatives 1, 2, and 3.

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 RBPP 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, 6.3%, occurs for steelhead at the RBPP under the NAA and Alternative 3 (Table 11N-25).

Alternatives 1–3 have very little effect on the frequency of scouring/entombment flows (Table 11N-22 through Table 11N-25). The largest differences from the NAA are 0.2 percent (absolute value) increases in redd scour frequency for fall-run, late fall–run, and steelhead at Battle Creek (Table 11N-24). 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 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	1.1	1.2 (0)	1.2 (0)	1.2 (0)	1.2 (0.1)
Fall-run	September–January	2.4	2.4 (0)	2.4 (0)	2.4 (0)	2.5 (0.1)
Late fall–run	December–June	3.2	3.2 (0)	3.2 (0)	3.2 (0)	3.2 (0.1)
Steelhead	November–April	3.2	3.2 (0)	3.3 (0)	3.2 (0)	3.3 (0.1)

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 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	1.3	1.4 (0)	1.4 (0.1)	1.3 (0)	1.4 (0.1)
Fall-run	September–January	2.7	2.8 (0)	2.8 (0.1)	2.7 (0)	2.8 (0.1)
Late fall–run	December–June	3.5	3.6 (0)	3.6 (0)	3.5 (0)	3.6 (0)
Steelhead	November–April	3.6	3.6 (0)	3.6 (0.1)	3.6 (0)	3.6 (0.1)

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 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	2.7	2.7 (0)	2.7 (0)	2.7 (0)	2.7 (0.1)
Fall-run	September–January	4.8	4.9 (0.1)	4.9 (0.1)	4.9 (0.1)	5 (0.2)
Late fall–run	December–June	6.0	6.1 (0.1)	6.1 (0.1)	6.1 (0.1)	6.1 (0.2)
Steelhead	November–April	6.1	6.2 (0.1)	6.2 (0.1)	6.2 (0.1)	6.2 (0.2)

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 RBPP under the 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	2.8	2.7 (0)	2.7 (0)	2.7 (-0.1)	2.8 (0)
Fall-run	September–January	5.1	5 (-0.1)	5 (-0.1)	5 (-0.1)	5 (0)
Late fall–run	December–June	6.2	6.1 (-0.1)	6.1 (-0.1)	6.1 (-0.1)	6.2 (-0.1)
Steelhead	November–April	6.3	6.2 (-0.1)	6.2 (-0.1)	6.2 (-0.1)	6.3 (-0.1)

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 described in Section 11N.2, 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, 2, and 3. These results indicate that Alternatives 1–3 would have no effect on redd scour/entombment for fall-run and steelhead in the American River.

Table 11N-26. Percentages and Differences (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 NAA and Alternatives 1–3

Species	Total Months of Active Redds	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
Fall-run	492	0.4 (0)	0.4 (0)	0.4 (0)	0.4 (0)	0.4 (0)
Steelhead	492	0.4 (0)	0.4 (0)	0.4 (0)	0.4 (0)	0.4 (0)

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 (U.S. Fish and Wildlife Service 2006). The minimum flow over 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).

Estimated levels of juvenile stranding under 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 11N-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. The information on fry occurrence is included in Table 11N-27 through Table 11N-29 under the months in which the fry occur. All of the estimates of juvenile stranding may be biased high because the analysis methodology assumes no movement of juveniles out of rearing habitat as the water level drops (U.S. Fish and Wildlife Service 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.

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

Note: Only the fry stage is included in the stranding analysis.

The results for the three river locations are generally similar (Table 11N-28 through Table 11N-30). All three show high increases and reductions in stranding during certain months and water year types. The two upstream locations, Keswick and Clear Creek, show the largest and most frequent differences from the NAA under Alternative 3 and the least difference under Alternatives 1A and 2, with Alternative 1B showing an intermediate level of difference. In contrast, the downstream location, Battle Creek, shows similar degrees of difference under Alternatives 1A, 1B, and 2, and greater difference under Alternative 3. The largest percent increases and reductions in stranding by reach and alternative are as follows:

1. Keswick Reach—Under Alternatives 1A and 2, the largest increases are about 11% in May of Below Normal Water Years and the largest reductions are -18% in June of Critically Dry Water Years; under Alternative 1B the largest increase is 18% in March of Critically Dry Water Years and the largest reduction is -29% in April of Dry Water Years; and under Alternative 3, the largest increase is 39% in May of Below Normal Water Years and the largest reduction is -38% in June of Above Normal Water Years.

2. Clear Creek Reach—Under Alternatives 1A and 2, the largest increase are 11% in June of Above Normal Water Years and the largest reductions are about -17% in June of Critically Dry Water Years; under Alternative 1B the largest increase is 14% in June of Wet Water Years and the largest reduction is -19% in April of Dry Water Years; and under Alternative 3, the largest increase is 25% in May of Below Normal Water Years and the largest reduction is -38% in June of Above Normal Water Years.

3. Battle Creek Reach—Under Alternatives 1A and 2, the largest increases are 18% and 19% in June of Above Normal Water Years and the largest reductions are -24% and -27% in May of Critically Dry Water Years; under Alternative 1B the largest increase is 14% in May of Above Normal Water Years and the largest reduction is -23% in May of Critically Dry Water Years; and under Alternative 3, the largest increase is 37% in May of Below Normal Water Years and the largest reduction is -32% in June of Above Normal Water Years.

Most of the largest differences noted above occur in April, May, and June, when late fall–run fry are expected to be present (Table 11N-27). However, reductions in stranding during these months are generally greater than increases, so no net negative effect is expected on late fall–run fry.

Winter-run fry are present in the upper Sacramento River primarily from about July through October (Table 11N-27). During this period, juvenile stranding under Alternatives 1, 2, and 3 is generally similar to or lower than stranding under the NAA in the Keswick and Clear Creek reaches of the river (Table 11N-28 and Table 11N-29). The largest reductions for both reaches are 35% and occur for both reaches in July of Above Normal Water Years under Alternative 3. In the Battle Creek reach, winter-run stranding in individual months and water year types is mostly similar or slightly higher under Alternatives 1A, 1B, and 2 to stranding under the NAA, but it is mostly lower under Alternative 3 (Table 11N-30).

To summarize the overall effects of all differences between Alternatives 1, 2, and 3 and the NAA on juvenile stranding, the mean number of juveniles stranded over all months and water year types were computed for the fry period for each of the salmon runs and steelhead (Table 11N-27) at each of the river location (Table 11N-31 and Table 11N-32). For winter-run, these results indicate that Alternatives 1, 2, and 3 would have little effect on in the Keswick and Clear Creek reaches under Alternatives 1A, 1B, and 2, and would reduce stranding about 2% under Alternative 3 (Table 11N-31 and Table 11N-32). At the Battle Creek location, winter-run stranding would be about 3% higher under Alternatives 1A and 2 (Table 11N-33). For all reaches combined, Alternatives 1A and 2 are expected result in a 2% increase in stranding of winter-run of fry juveniles, Alternative 3 is expected to result in a 1% reduction, while Alternative 1B is expected to have almost no effect. The summary results for the other salmon runs and steelhead are more variable, with increases and reductions in stranding evident in the tables (Table 11N-31 and Table 11N-33). Notable difference between Alternatives 1, 2, and 3 and the NAA include increases in stranding in the Keswick and Clear Creek reaches under Alternative 3, especially for spring-run, fall-run, and steelhead. The largest of these increases is about 6% increase for fall-run in the Keswick reach. In the Battle Creek reach, juvenile stranding for all the salmonids other than winter-run is lower under Alternatives 1, 2, and 3, including 3% lower for spring-run under Alternatives 1A, 1B, and 2 (Table 11N-33). Overall, the results show that Alternatives 1, 2, and 3 would produce increases and reductions in juvenile stranding for the salmon runs and steelhead in the three upper reaches of the Sacramento River, but most changes are relatively small and tend to balance out.

The results of the stranding analysis show large increases and reductions in juvenile stranding under Alternatives 1, 2, and 3 relative to the NAA, especially during late spring and early summer, but these differences generally balance out and the alternatives are not expected to substantially affect juvenile stranding in the upper Sacramento River.

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 NAA and Alternatives 1–3

Month	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
January *spring-run fall-run*	Wet	14.8	14.9 (0.7%)	15.3 (3.7%)	14.9 (0.7%)	16.4 (10.6%)
	Above Normal	10.5	10.7 (2.1%)	10.7 (2%)	10.6 (1.9%)	12.4 (18.2%)
	Below Normal	7.6	7.3 (-3.3%)	7.4 (-2.6%)	7.3 (-3.3%)	7.4 (-1.7%)
	Dry	4.1	3.4 (-16.3%)	3.4 (-16.7%)	3.4 (-16.3%)	3.6 (-11.9%)

Month	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
	Critically Dry	2.9	2.8 (-4.1%)	2.8 (-3.4%)	2.9 (-2.2%)	2.8 (-3.3%)
	All	8.8	8.7 (-1.6%)	8.8 (0%)	8.7 (-1.6%)	9.5 (7.2%)
February *spring-run fall-run steelhead*	Wet	18.5	18.5 (-0.2%)	19.3 (4.6%)	18.5 (-0.2%)	20 (8.2%)
	Above Normal	14.5	14.6 (0.9%)	14.6 (0.9%)	14.6 (0.9%)	15.2 (5.1%)
	Below Normal	11.6	11.6 (-0.2%)	12 (3%)	12 (2.8%)	11.6 (0%)
	Dry	4.2	3.6 (-13.6%)	4.1 (-1.1%)	3.6 (-13.6%)	4.2 (-0.6%)
	Critically Dry	3.7	3.6 (-0.8%)	3.7 (0.8%)	3.7 (-0.5%)	3.7 (1.9%)
	All	11.4	11.3 (-1.1%)	11.8 (3%)	11.4 (-0.5%)	12 (5.2%)
March *fall-run late fall–run steelhead*	Wet	16.0	16.1 (0.3%)	16.4 (2.5%)	16 (0.2%)	17.2 (7.8%)
	Above Normal	13.7	13.8 (0.6%)	13.8 (0.4%)	13.8 (0.5%)	13.8 (1%)
	Below Normal	7.0	6.8 (-3.7%)	6.8 (-3.7%)	6.7 (-4.1%)	6.8 (-3.8%)
	Dry	3.5	3.7 (5.7%)	3.6 (4.1%)	3.7 (5.2%)	3.8 (9.6%)
	Critically Dry	3.1	3.2 (4%)	3.7 (17.7%)	3.2 (3.9%)	3.7 (18.9%)
	All	9.5	9.5 (0.4%)	9.7 (2.1%)	9.5 (0.3%)	10 (5.6%)
April *late fall–run steelhead*	Wet	9.3	9.3 (0.2%)	9.3 (0.8%)	9.3 (0.2%)	9.4 (1.1%)
	Above Normal	5.5	5.4 (-1.4%)	5.5 (0.2%)	5.4 (-0.3%)	4.6 (-16.4%)
	Below Normal	3.1	3.1 (-0.2%)	3.2 (1.3%)	3.1 (0%)	3.2 (2.4%)
	Dry	2.2	2.2 (0.5%)	1.6 (-28.8%)	2.2 (0.5%)	1.6 (-28.8%)
	Critically Dry	1.9	2.1 (7.6%)	2.2 (13.5%)	2.1 (8.5%)	2.3 (19.6%)
	All	5.0	5.1 (0.3%)	5 (-1.4%)	5.1 (0.6%)	4.9 (-3.4%)
May *late fall–run steelhead*	Wet	1.6	1.6 (1.1%)	1.6 (0.1%)	1.6 (1.1%)	1.6 (1.2%)
	Above Normal	0.9	0.9 (-1.2%)	0.8 (-6.8%)	0.9 (-1.2%)	0.6 (-28.7%)
	Below Normal	0.3	0.3 (10.6%)	0.3 (6.3%)	0.3 (10.4%)	0.3 (39.4%)
	Dry	0.4	0.4 (0.7%)	0.3 (-10.7%)	0.4 (0.2%)	0.4 (-2.5%)
	Critically Dry	2.2	2.1 (-5.6%)	2.1 (-4.7%)	2.1 (-6.3%)	2 (-8.3%)
	All	1.1	1.1 (-0.8%)	1.1 (-2.7%)	1.1 (-1.1%)	1 (-4%)
June *late fall–run*	Wet	0.5	0.5 (7.7%)	0.6 (13.2%)	0.5 (7.7%)	0.5 (8.4%)
	Above Normal	0.7	0.8 (9.6%)	0.6 (-15.3%)	0.8 (10.5%)	0.5 (-38.2%)
	Below Normal	4.0	4.3 (7.7%)	4 (0%)	4.3 (7.6%)	4.2 (5.1%)
	Dry	6.7	6.8 (2.6%)	6.8 (1.8%)	6.8 (2.6%)	6.9 (3%)
	Critically Dry	7.4	6 (-18.1%)	6.1 (-17.8%)	6 (-17.9%)	6.4 (-13.1%)
	All	3.5	3.4 (-2.3%)	3.3 (-4.6%)	3.4 (-2.3%)	3.4 (-2.6%)
July *winter-run*	Wet	2.4	2.6 (4.7%)	2.5 (0.8%)	2.6 (4.7%)	2.5 (4%)
	Above Normal	4.5	4.1 (-9.4%)	3.8 (-16.9%)	4.1 (-9.8%)	2.9 (-35.4%)
	Below Normal	7.5	8 (5.9%)	7.7 (1.8%)	8 (6.2%)	7.5 (-0.5%)
	Dry	10.4	11.2 (7.1%)	11 (5.7%)	11.1 (6.3%)	10.7 (2.8%)

Month	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
	Critically Dry	10.3	8.8 (-14.4%)	8.9 (-14%)	8.9 (-13.8%)	9.7 (-5.9%)
	All	6.5	6.5 (-0.1%)	6.4 (-2.5%)	6.5 (-0.2%)	6.3 (-3.6%)
August *winter-run*	Wet	6.4	6.6 (2%)	6.5 (0.2%)	6.6 (2.1%)	6.6 (2.1%)
	Above Normal	6.8	6.9 (1.2%)	6.4 (-6.2%)	6.9 (1.4%)	5.6 (-18.4%)
	Below Normal	10.4	10.8 (3.9%)	10.9 (4.4%)	10.8 (4%)	9.1 (-12.8%)
	Dry	13.3	14.6 (9.7%)	13.9 (4.7%)	14.6 (9.9%)	13.7 (3.4%)
	Critically Dry	13.3	13.5 (1.7%)	13.5 (1.7%)	13.5 (2.2%)	13.6 (3%)
	All	9.7	10.1 (4.5%)	9.9 (2%)	10.1 (4.7%)	9.5 (-2.2%)
September *winter-run*	Wet	10.9	11 (1.3%)	10.9 (-0.1%)	11 (1.3%)	11 (1.1%)
	Above Normal	11.5	11.2 (-2.9%)	10.3 (-10.5%)	11.2 (-3.3%)	10.8 (-6.5%)
	Below Normal	10.8	10 (-7.4%)	10.4 (-4.2%)	10 (-7.3%)	8 (-26.4%)
	Dry	10.7	11 (3.4%)	10.7 (0.6%)	11.1 (3.7%)	10.8 (1.4%)
	Critically Dry	14.3	15.5 (8.6%)	15.4 (7.7%)	15.5 (8.6%)	15 (5.5%)
	All	11.4	11.5 (1%)	11.3 (-0.7%)	11.5 (1.1%)	11 (-3.6%)
October *winter-run*	Wet	12.9	12.6 (-2.2%)	12.3 (-4.8%)	12.6 (-2.1%)	12.2 (-5.2%)
	Above Normal	13.1	12.8 (-2.3%)	13.3 (1.9%)	12.9 (-1.7%)	12.8 (-1.9%)
	Below Normal	14.3	13.7 (-4.1%)	13.8 (-3%)	13.7 (-4.2%)	14.7 (3%)
	Dry	18.2	17.8 (-1.8%)	17.9 (-1.5%)	17.8 (-1.9%)	18.2 (0.2%)
	Critically Dry	15.7	15.8 (0.4%)	15.7 (0.2%)	15.6 (-0.4%)	15.9 (1.4%)
	All	14.7	14.4 (-2%)	14.4 (-2%)	14.4 (-2.1%)	14.6 (-0.9%)
November *spring-run*	Wet	10.0	9.2 (-8.8%)	9 (-10.8%)	9.2 (-8.8%)	8.6 (-14.3%)
	Above Normal	11.0	10.4 (-5.5%)	10.5 (-5.1%)	10.4 (-5.3%)	10.6 (-3.9%)
	Below Normal	13.1	12.3 (-6.3%)	12.3 (-5.8%)	12.3 (-6.2%)	13.2 (0.9%)
	Dry	15.9	15.4 (-3%)	16 (0.9%)	15.4 (-3%)	15.7 (-1.3%)
	Critically Dry	16.1	15.3 (-4.9%)	15.3 (-4.9%)	15.1 (-6%)	16.4 (2.1%)
	All	12.9	12.2 (-5.7%)	12.2 (-5%)	12.1 (-5.8%)	12.4 (-3.8%)
December *spring-run* *fall-run*	Wet	10.4	10.7 (2.6%)	10.8 (4.1%)	10.7 (2.9%)	11.3 (8.9%)
	Above Normal	9.9	10.1 (2.4%)	10.1 (2%)	10.1 (2.2%)	10.2 (3.6%)
	Below Normal	12.3	12.4 (1.4%)	12.5 (1.9%)	12.4 (1.4%)	12.6 (2.3%)
	Dry	10.4	10.9 (4.4%)	11 (5.9%)	10.9 (4.3%)	11.6 (11.4%)
	Critically Dry	10.2	10 (-2.8%)	9.4 (-8.6%)	9.9 (-2.9%)	9.1 (-11.1%)
	All	10.6	10.8 (2%)	10.8 (2%)	10.8 (2%)	11.1 (4.6%)

[1] Water year type sorting is by hydrologic years.

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 NAA and Alternatives 1–3

Month	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
January *spring-run fall-run*	Wet	11.0	11.1 (0.6%)	11.3 (2.4%)	11.1 (0.6%)	12 (9.4%)
	Above Normal	11.3	11.4 (1.1%)	11.4 (1.1%)	11.4 (1.1%)	12.6 (11.3%)
	Below Normal	11.7	11.3 (-3.1%)	11.4 (-2.9%)	11.3 (-3.1%)	11.4 (-2.7%)
	Dry	8.5	8.2 (-3.5%)	8.2 (-3.2%)	8.2 (-3.5%)	8.3 (-1.9%)
	Critically Dry	8.4	8.5 (0.9%)	8.5 (1.1%)	8.5 (1.3%)	8.2 (-2.1%)
	All	10.2	10.2 (-0.7%)	10.2 (0%)	10.2 (-0.7%)	10.6 (3.9%)
February *spring-run fall-run steelhead*	Wet	17.1	17.1 (-0.1%)	17.5 (2.5%)	17.1 (-0.1%)	18.2 (6.2%)
	Above Normal	16.2	16.2 (0.1%)	16.1 (-0.5%)	16.2 (0.1%)	16.9 (4.4%)
	Below Normal	16.1	16.1 (-0.1%)	16.3 (1.1%)	16.2 (0.9%)	16.1 (0.3%)
	Dry	10.8	10.6 (-2.1%)	10.6 (-1.6%)	10.6 (-2.1%)	10.6 (-2.3%)
	Critically Dry	8.6	8.5 (-0.3%)	8.5 (-0.2%)	8.5 (-0.1%)	8.6 (0%)
	All	14.2	14.1 (-0.4%)	14.3 (0.8%)	14.1 (-0.2%)	14.5 (2.8%)
March *fall-run late fall–run steelhead*	Wet	15.8	15.8 (0.1%)	16.1 (1.7%)	15.8 (0%)	16.8 (6.4%)
	Above Normal	14.2	14.2 (0%)	14.1 (-0.9%)	14.2 (0%)	14.4 (0.9%)
	Below Normal	11.9	11.6 (-2.3%)	11.6 (-2.3%)	11.6 (-2.4%)	11.6 (-2.2%)
	Dry	8.8	8.9 (1.2%)	8.7 (-1.2%)	8.9 (1%)	8.7 (-0.7%)
	Critically Dry	6.9	6.7 (-1.7%)	7.2 (4.7%)	6.7 (-2%)	7.2 (4.9%)
	All	12.1	12 (-0.3%)	12.1 (0.4%)	12 (-0.4%)	12.4 (2.7%)
April *late fall–run steelhead*	Wet	10.4	10.4 (0.1%)	10.5 (0.6%)	10.4 (0.1%)	10.4 (0%)
	Above Normal	6.5	6.4 (-1.6%)	6.3 (-3%)	6.4 (-1.3%)	5.1 (-21.4%)
	Below Normal	5.0	4.9 (-1.8%)	4.9 (-1.6%)	4.9 (-1.8%)	4.9 (-0.2%)
	Dry	3.1	3.1 (-0.9%)	2.5 (-18.7%)	3.1 (-0.9%)	2.5 (-20.2%)
	Critically Dry	2.3	2.3 (0.8%)	2.4 (6.7%)	2.3 (1.4%)	2.6 (11.7%)
	All	6.1	6.1 (-0.5%)	6 (-2.1%)	6.1 (-0.4%)	5.8 (-5%)
May *late fall–run steelhead*	Wet	1.7	1.8 (0.7%)	1.7 (-0.2%)	1.8 (0.7%)	1.7 (0%)
	Above Normal	0.9	0.9 (-2.5%)	0.9 (-2.3%)	0.9 (-2.4%)	0.7 (-18.7%)
	Below Normal	0.3	0.3 (6.9%)	0.3 (5.3%)	0.3 (6.9%)	0.4 (24.9%)
	Dry	0.4	0.4 (-2.5%)	0.3 (-16.6%)	0.4 (-3.2%)	0.4 (-13.4%)
	Critically Dry	2.3	2.1 (-6.1%)	2.2 (-5.2%)	2.1 (-7.1%)	2.1 (-8.8%)
	All	1.2	1.1 (-1.6%)	1.1 (-2.9%)	1.1 (-1.9%)	1.1 (-4.5%)
June *late fall–run*	Wet	0.5	0.5 (8.1%)	0.6 (14.5%)	0.5 (8.1%)	0.5 (9%)
	Above Normal	0.8	0.9 (10.5%)	0.7 (-14.1%)	0.9 (11.4%)	0.5 (-38.4%)
	Below Normal	4.2	4.5 (7%)	4.2 (-1.2%)	4.5 (6.9%)	4.4 (4.1%)

Month	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
	Dry	6.7	6.9 (3.2%)	6.9 (2.4%)	6.9 (3.2%)	7 (3.6%)
	Critically Dry	7.5	6.2 (-17.4%)	6.2 (-17.5%)	6.2 (-17.7%)	6.4 (-15%)
	All	3.6	3.5 (-1.9%)	3.4 (-4.4%)	3.5 (-2%)	3.5 (-3.1%)
July *winter-run*	Wet	2.1	2.3 (6.3%)	2.1 (0.4%)	2.3 (6.3%)	2.3 (5.7%)
	Above Normal	4.0	3.7 (-7.8%)	3.4 (-13.9%)	3.7 (-8.1%)	2.6 (-35.3%)
	Below Normal	7.1	7.4 (4.6%)	7.1 (0.3%)	7.4 (4.9%)	7.2 (1.5%)
	Dry	9.8	10.1 (2.4%)	10 (1.1%)	10.1 (2.4%)	10 (1.8%)
	Critically Dry	10.1	8.5 (-16.3%)	8.5 (-16%)	8.5 (-16.2%)	8.9 (-12.4%)
	All	6.1	6 (-2.2%)	5.8 (-4.7%)	6 (-2.2%)	5.8 (-4.8%)
August *winter-run*	Wet	5.0	5.2 (3.2%)	5 (0.1%)	5.2 (3.3%)	5.2 (3.5%)
	Above Normal	5.7	5.8 (3%)	5.4 (-3.7%)	5.9 (4.3%)	4.5 (-20.8%)
	Below Normal	8.5	8.5 (0.1%)	8.5 (-0.1%)	8.6 (0.3%)	7.5 (-11.9%)
	Dry	11.0	11.6 (5.6%)	11.1 (0.9%)	11.6 (5.8%)	11.1 (1.7%)
	Critically Dry	11.4	11 (-3.6%)	10.9 (-3.7%)	11 (-3.3%)	11 (-3.1%)
	All	7.9	8.1 (1.9%)	7.9 (-0.9%)	8.1 (2.2%)	7.6 (-3.8%)
September *winter-run*	Wet	7.8	7.9 (1.7%)	7.7 (-1%)	7.9 (1.7%)	7.9 (1.4%)
	Above Normal	8.1	8 (-1.2%)	7.8 (-4.5%)	7.9 (-2.1%)	7.9 (-2.6%)
	Below Normal	6.3	5.8 (-7.7%)	6.1 (-3.1%)	5.8 (-7.6%)	4.3 (-30.8%)
	Dry	6.1	6.2 (1.5%)	5.7 (-5.5%)	6.2 (2.3%)	6.1 (1.2%)
	Critically Dry	11.8	12.6 (7.2%)	12.5 (6.3%)	12.6 (7%)	12.5 (6.5%)
	All	7.8	7.9 (1.1%)	7.7 (-1%)	7.9 (1.1%)	7.6 (-2.5%)
October *winter-run*	Wet	8.3	8.4 (0.4%)	8.3 (0.3%)	8.3 (0.1%)	8.1 (-2.3%)
	Above Normal	11.1	11 (-1.3%)	11.1 (0.3%)	11 (-0.6%)	11.2 (0.8%)
	Below Normal	10.3	10.2 (-0.7%)	10.3 (0.2%)	10.2 (-0.6%)	10.8 (4.9%)
	Dry	13.4	13.5 (0.9%)	13.5 (0.4%)	13.5 (0.8%)	13.7 (1.9%)
	Critically Dry	10.8	11.3 (5.2%)	11.2 (4.6%)	11.2 (4%)	11.3 (5%)
	All	10.5	10.6 (0.8%)	10.6 (1%)	10.6 (0.7%)	10.7 (1.7%)
November *spring-run*	Wet	6.6	6.2 (-6.3%)	6.2 (-6.6%)	6.2 (-6.5%)	5.6 (-15.6%)
	Above Normal	10.0	9.5 (-5.1%)	9.5 (-4.9%)	9.5 (-4.9%)	9.6 (-4.1%)
	Below Normal	10.1	9.8 (-2.6%)	9.9 (-2.1%)	9.8 (-2.3%)	10.1 (0.4%)
	Dry	13.8	13.9 (0.6%)	14 (1.7%)	13.9 (0.6%)	14.2 (3.2%)
	Critically Dry	12.8	12.6 (-1.1%)	12.7 (-0.7%)	12.5 (-2.5%)	13.3 (3.7%)
	All	10.2	9.9 (-2.5%)	10 (-2.1%)	9.9 (-2.7%)	10 (-2.1%)
December *spring-run* *fall-run*	Wet	7.4	7.6 (2.1%)	7.6 (1.9%)	7.6 (2.5%)	7.5 (1.1%)
	Above Normal	8.5	8.4 (-0.6%)	8.4 (-0.5%)	8.4 (-0.4%)	8.5 (0.2%)
	Below Normal	11.3	11.4 (1.6%)	11.4 (1.7%)	11.4 (1.6%)	11.4 (1%)

Month	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
	Dry	12.1	12.5 (3.3%)	12.3 (2.1%)	12.4 (3.2%)	12.6 (4.9%)
	Critically Dry	11.4	11.7 (2.6%)	11.5 (1.2%)	11.7 (2.4%)	10.6 (-6.9%)
	All	9.8	10 (2.1%)	10 (1.5%)	10 (2.1%)	9.9 (0.6%)

[1] Water year type sorting is by hydrologic years.

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 NAA and Alternatives 1–3

Month	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
January *spring-run fall-run*	Wet	2.4	2.4 (0.8%)	2.5 (4.2%)	2.4 (1%)	2.7 (13.8%)
	Above Normal	4.5	4.1 (-8.9%)	4.1 (-8.9%)	4.1 (-8.9%)	4.4 (-2.5%)
	Below Normal	4.2	4.1 (-0.6%)	4.2 (0.4%)	4.1 (-0.6%)	4.2 (0.8%)
	Dry	3.8	3.7 (-2.5%)	3.7 (-3.1%)	3.7 (-2.5%)	3.5 (-9.3%)
	Critically Dry	4.3	4.3 (0.2%)	4.2 (-0.5%)	4.3 (0.3%)	4.2 (-1.2%)
	All	3.6	3.5 (-2.1%)	3.5 (-1.5%)	3.5 (-2.1%)	3.6 (0.2%)
February *spring-run fall-run steelhead*	Wet	3.5	3.5 (-0.4%)	3.6 (0.9%)	3.5 (-0.4%)	3.7 (5.8%)
	Above Normal	4.7	4.7 (-1.2%)	4.7 (-1.7%)	4.7 (-1.2%)	4.8 (1.2%)
	Below Normal	5.5	5.5 (0.2%)	5.6 (1.5%)	5.5 (0.7%)	5.5 (0.5%)
	Dry	4.9	4.9 (-0.3%)	4.9 (-0.3%)	4.9 (-0.3%)	4.8 (-2.8%)
	Critically Dry	4.8	4.8 (-0.6%)	4.8 (-0.1%)	4.8 (-0.4%)	4.8 (0%)
	All	4.5	4.5 (-0.4%)	4.5 (0.2%)	4.5 (-0.3%)	4.6 (1.1%)
March *fall-run late fall–run steelhead*	Wet	3.2	3.2 (-0.3%)	3.2 (-0.7%)	3.2 (-0.3%)	3.4 (4.8%)
	Above Normal	4.5	4.4 (-1.5%)	4.4 (-2.3%)	4.4 (-1.5%)	4.4 (-1.4%)
	Below Normal	4.3	4.2 (-2%)	4.2 (-0.9%)	4.2 (-1.9%)	4.2 (-1%)
	Dry	4.8	4.9 (0.5%)	4.8 (-1.3%)	4.9 (0.6%)	4.7 (-2.3%)
	Critically Dry	4.2	4.2 (0.2%)	4.3 (4.5%)	4.2 (0.2%)	4.4 (6.3%)
	All	4.1	4.1 (-0.5%)	4.1 (-0.4%)	4.1 (-0.5%)	4.1 (1.1%)
April *late fall–run steelhead*	Wet	2.0	2 (-0.4%)	1.9 (-5.8%)	2 (-0.4%)	1.9 (-4.8%)
	Above Normal	2.6	2.6 (-2.8%)	2.5 (-4.1%)	2.6 (-2.8%)	2.2 (-18.1%)
	Below Normal	2.3	2.2 (-1.3%)	2.3 (-0.8%)	2.2 (-1.3%)	2.3 (1.6%)
	Dry	2.2	2.2 (-2.8%)	2.1 (-7.5%)	2.2 (-2.8%)	2 (-11.4%)
	Critically Dry	1.5	1.4 (-7.4%)	1.4 (-5.3%)	1.4 (-7.4%)	1.5 (1.4%)
	All	2.1	2.1 (-2.3%)	2 (-4.9%)	2.1 (-2.3%)	2 (-6.9%)
May	Wet	0.5	0.5 (-0.1%)	0.5 (-6.2%)	0.5 (0%)	0.5 (-6.2%)
	Above Normal	0.3	0.3 (-4.6%)	0.4 (14.1%)	0.3 (-4.6%)	0.4 (12.2%)

Month	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
late fall–run steelhead	Below Normal	0.2	0.2 (11.7%)	0.2 (7.7%)	0.2 (11.7%)	0.3 (37.3%)
	Dry	0.3	0.3 (2.1%)	0.3 (5.4%)	0.3 (1.9%)	0.3 (13%)
	Critically Dry	0.7	0.5 (-24.3%)	0.5 (-23.4%)	0.5 (-27.2%)	0.5 (-29.7%)
	All	0.4	0.4 (-5.1%)	0.4 (-4.7%)	0.4 (-5.8%)	0.4 (-2.8%)
June *late fall–run*	Wet	0.3	0.3 (5.6%)	0.4 (13%)	0.3 (5.6%)	0.4 (7.9%)
	Above Normal	0.5	0.6 (18%)	0.5 (-8.2%)	0.6 (19.1%)	0.4 (-32.2%)
	Below Normal	3.3	3.6 (7.4%)	3.3 (-0.3%)	3.6 (7.4%)	3.5 (4.4%)
	Dry	4.8	4.9 (3%)	4.9 (2.5%)	4.9 (3%)	5 (4%)
	Critically Dry	5.9	5.2 (-12.6%)	5.1 (-13.3%)	5.1 (-13.1%)	5.3 (-10.5%)
	All	2.7	2.7 (-0.6%)	2.6 (-3.1%)	2.6 (-0.7%)	2.6 (-1.5%)
July *winter-run*	Wet	1.3	1.4 (8.4%)	1.3 (3.1%)	1.4 (8.4%)	1.4 (8.5%)
	Above Normal	2.5	2.4 (-4.4%)	2.3 (-8%)	2.4 (-4.9%)	1.9 (-25.3%)
	Below Normal	5.2	5.6 (6.4%)	5.3 (1.7%)	5.6 (7%)	5.5 (4.2%)
	Dry	6.7	7 (3.7%)	7 (3.2%)	7 (4%)	6.9 (2.6%)
	Critically Dry	7.7	7.1 (-8.5%)	7 (-9.8%)	7 (-9.5%)	7.2 (-6.6%)
	All	4.3	4.3 (0.8%)	4.2 (-1.5%)	4.3 (0.7%)	4.2 (-1.3%)
August *winter-run*	Wet	2.6	2.8 (5.5%)	2.6 (1.2%)	2.8 (5.5%)	2.7 (4.9%)
	Above Normal	3.4	3.5 (4.1%)	3.3 (-1.3%)	3.5 (4.8%)	3 (-11.7%)
	Below Normal	5.5	5.9 (6.4%)	5.6 (2%)	5.9 (6.8%)	5.5 (0.3%)
	Dry	6.9	7.3 (5.2%)	7.2 (3.1%)	7.4 (6%)	7.1 (2.5%)
	Critically Dry	7.3	7.3 (0.3%)	7.3 (0.2%)	7.3 (0.5%)	7.3 (-0.1%)
	All	4.9	5.1 (4.3%)	4.9 (1.5%)	5.1 (4.7%)	4.9 (0.5%)
September *winter-run*	Wet	3.5	3.6 (2.8%)	3.4 (-0.7%)	3.6 (2.8%)	3.5 (2.1%)
	Above Normal	4.1	4.1 (0.2%)	4.1 (-1%)	4.1 (-1.1%)	4.3 (5.2%)
	Below Normal	2.8	2.9 (6.8%)	2.9 (5.8%)	3 (7.2%)	2.4 (-12.1%)
	Dry	2.8	2.9 (4.2%)	2.8 (-1.2%)	3 (5.6%)	2.8 (-1.2%)
	Critically Dry	5.0	5.6 (12.9%)	5.6 (11.7%)	5.6 (12.3%)	5.4 (7.6%)
	All	3.5	3.7 (5.2%)	3.6 (2.6%)	3.7 (5.2%)	3.6 (1.3%)
October *winter-run*	Wet	3.1	3.2 (2.6%)	3.2 (2.7%)	3.1 (1.8%)	3.3 (7.4%)
	Above Normal	4.4	4.3 (-2.2%)	4.3 (-2.4%)	4.3 (-1.3%)	4.2 (-3.5%)
	Below Normal	4.0	4 (-1.3%)	4 (-0.9%)	4 (-1.1%)	4.2 (5.4%)
	Dry	6.3	6.2 (-2.4%)	6.3 (-0.8%)	6.1 (-2.8%)	6.3 (-0.1%)
	Critically Dry	4.8	5.1 (5.9%)	5.1 (5%)	5.1 (5.9%)	5.1 (5.7%)
	All	4.4	4.4 (0.3%)	4.4 (0.7%)	4.4 (0.1%)	4.5 (2.9%)
November *spring-run*	Wet	2.6	2.4 (-9.2%)	2.5 (-7%)	2.4 (-9.9%)	2.4 (-7.8%)
	Above Normal	5.8	5 (-14%)	5 (-14%)	5 (-14%)	5 (-14.1%)

Month	Water Year Type[1]	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
	Below Normal	4.2	4.1 (-2.1%)	4.1 (-1.7%)	4.1 (-1.8%)	4.1 (-0.7%)
	Dry	6.4	6.2 (-3.1%)	6.3 (-0.1%)	6.2 (-3.1%)	6.2 (-2.9%)
	Critically Dry	4.7	4.2 (-11.2%)	4.1 (-13%)	4.1 (-13.6%)	4.5 (-4.5%)
	All	4.5	4.2 (-7.4%)	4.2 (-6.3%)	4.1 (-7.9%)	4.2 (-5.8%)
December *spring-run fall-run*	Wet	2.9	2.9 (-2%)	2.8 (-2.7%)	2.9 (-2.1%)	2.8 (-3.7%)
	Above Normal	5.1	4.4 (-12.3%)	4.4 (-13.2%)	4.4 (-13.1%)	4.4 (-13.7%)
	Below Normal	4.2	4.5 (5.6%)	4.5 (5.2%)	4.5 (5.5%)	4.4 (3%)
	Dry	5.2	5.3 (2%)	5.2 (-0.7%)	5.3 (1.9%)	5.3 (2.4%)
	Critically Dry	4.1	3.9 (-5.1%)	3.9 (-4.1%)	3.9 (-4.9%)	3.7 (-8%)
	All	4.1	4.1 (-1.9%)	4 (-2.8%)	4 (-2%)	4 (-3.3%)

[1] Water year type sorting is by hydrologic years.

Table 11N-31. Estimated Number of Juvenile Chinook Salmon or Steelhead Stranded by Flow Reductions at Keswick for All Months Combined Under the NAA and Alternatives 1–3, and Percent Difference (in parentheses) between the NAA and each of the Alternatives.

Species/Run	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
Winter-run	10.6	10.6 (0.6%)	10.5 (-0.8%)	10.6 (0.6%)	10.3 (-2.4%)
Spring-run	10.9	10.7 (-1.8%)	10.9 (-0.2%)	10.8 (-1.7%)	11.2 (2.8%)
Fall-run	10.1	10.1 (0%)	10.3 (1.9%)	10.1 (0.1%)	10.7 (5.5%)
Late fall–run	4.8	4.8 (-0.2%)	4.8 (-0.3%)	4.8 (-0.2%)	4.8 (1.2%)
Steelhead	6.8	6.7 (-0.3%)	6.9 (1.6%)	6.8 (-0.1%)	7 (3.3%)

Table 11N-32. Estimated Number of Juvenile Chinook Salmon or Steelhead Stranded by Flow Reductions at the Clear Creek Confluence for All Months Combined Under the NAA and Alternatives 1–3, and Percent Difference (in parentheses) between the NAA and each of the Alternatives.

Species/Run	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
Winter-run	8.1	8.1 (0.6%)	8 (-1%)	8.1 (0.6%)	7.9 (-1.9%)
Spring-run	11.1	11.1 (-0.4%)	11.1 (0.1%)	11.1 (-0.4%)	11.3 (1.4%)
Fall-run	11.6	11.6 (0.1%)	11.6 (0.7%)	11.6 (0.1%)	11.9 (2.6%)
Late fall–run	5.7	5.7 (-0.7%)	5.7 (-1.2%)	5.7 (-0.7%)	5.7 (-0.6%)
Steelhead	8.4	8.3 (-0.4%)	8.4 (0%)	8.3 (-0.4%)	8.5 (1.1%)

Table 11N-33. Estimated Number of Juvenile Chinook Salmon or Steelhead Stranded by Flow Reductions at the Battle Creek Confluence for All Months Combined Under the NAA and Alternatives 1–3, and Percent Difference (in parentheses) between the NAA and each of the Alternatives.

Species/Run	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
Winter-run	4.3	4.4 (2.6%)	4.3 (0.8%)	4.4 (2.6%)	4.3 (0.8%)
Spring-run	4.2	4.1 (-3%)	4.1 (-2.6%)	4.1 (-3.1%)	4.1 (-2%)
Fall-run	4.1	4 (-1.2%)	4 (-1.1%)	4 (-1.2%)	4.1 (-0.2%)
Late fall–run	2.3	2.3 (-1.1%)	2.3 (-2.4%)	2.3 (-1.2%)	2.3 (-1.7%)
Steelhead	2.8	2.8 (-1%)	2.8 (-1.2%)	2.8 (-0.9%)	2.8 (-0.6%)

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

The low-flow thresholds used for determination of potential interference with upstream passage are 3,250 cfs for migrating salmonid adults and 5,300 cfs for migrating 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 (see Section 11N.2). The frequency of flows below these thresholds was examined for the immigration periods of the four Chinook salmon runs, steelhead, and green and white 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 for salmonids in the Sacramento River was determined for daily flows using USRDOM model outputs near Keswick Dam, Battle Creek, and RBPP 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.The frequency of flows below the 5,300 cfs threshold for sturgeon in the Sacramento River was determined for daily flows using USRDOM model outputs near Colusa.

The Keswick Dam location has a much greater frequency of flows less than 3,250 cfs under all scenarios than the Battle Creek, RBPP, or Wilkins Slough locations (Tables 11N-34 through Table 11N-37). The maximum frequency for Keswick Dam is 11% of days with flows less than 3,250 cfs during the late fall–run upstream migration period under the NAA and Alternatives 1, 2, and 3 (Table 11N-34). Differences at Keswick Dam between the percent of days with low flows under the NAA and Alternatives 1–3 are small (less than or equal to 0.2%), indicating little difference in the frequency of low flows under Alternatives 1, 2, and 3 as compared to the NAA. At Battle Creek, RBPP and Wilkins Slough, frequencies of flow below 3,250 cfs and differences between Alternatives 1–3 and the NAA are very low (Table 11N-35 through Table 11N-37). These results indicate that Alternatives 1–3 would not appreciably affect low-flow passage conditions for upstream migrating adult salmonids in the Sacramento River.

Table 11N-34. Percent of Days with Flows below the Low-Flow Threshold (3,250 cfs) for Passage of Migrating Adult Salmonids in the Sacramento River at Keswick Dam and Differences in Percentages (in parentheses) for the NAA and Alternatives 1–3

Species/Run	Immigration Period	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
Winter-run	December–August	7.2	7.3 (0.12)	7.2 (0.06)	7.2 (0.05)	7.2 (-0.02)
Spring-run	March–September	4.7	4.7 (0.05)	4.7 (0.05)	4.7 (0.01)	4.8 (0.13)
Fall-run	August–March	1.6	1.6 (0.01)	1.5 (-0.05)	1.6 (-0.03)	1.4 (-0.18)
Late fall–run	July–December	11.0	11.1 (0.16)	11 (0.07)	11 (0.06)	10.9 (-0.09)
Steelhead	November–April	6.2	6.4 (0.15)	6.3 (0.04)	6.3 (0.07)	6.1 (-0.18)

Table 11N-35. Percent of Days with Flows below the Low-Flow Threshold (3,250 cfs) for Passage of Migrating Adult Salmonids in the Sacramento River at Battle Creek and Differences in Percentages (in parentheses) for the NAA and Alternatives 1–3

Species/Run	Immigration Period	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
Winter-run	December–August	0.05	0.05 (0)	0.05 (0)	0.05 (0)	0.03 (-0.03)
Spring-run	March–September	0.00	0 (0)	0 (0)	0 (0)	0 (0)
Fall-run	August–March	0.02	0.02 (0)	0.02 (0)	0.02 (0)	0.01 (-0.01)
Late fall–run	July–December	0.08	0.08 (0)	0.08 (0)	0.08 (0)	0.04 (-0.04)
Steelhead	November–April	0.06	0.06 (0)	0.06 (0)	0.06 (0)	0.03 (-0.03)

Table 11N-36. Percent of Days with Flows below the Low-Flow Threshold (3,250 cfs) for Passage of Migrating Adult Salmonids in the Sacramento River at RBPP and Differences in Percentages (in parentheses) for the NAA and Alternatives 1–3

Species/Run	Immigration Period	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
Winter-run	December–August	0.04	0.11 (0.07)	0.13 (0.09)	0.13 (0.08)	0.09 (0.04)
Spring-run	March–September	0.00	0 (0)	0 (0)	0 (0)	0 (0)
Fall-run	August–March	0.01	0.03 (0.02)	0.07 (0.05)	0.06 (0.05)	0.03 (0.01)
Late fall–run	July–December	0.07	0.17 (0.1)	0.2 (0.13)	0.2 (0.13)	0.13 (0.07)
Steelhead	November–April	0.05	0.13 (0.08)	0.15 (0.1)	0.15 (0.1)	0.1 (0.05)

Table 11N-37. Percent of Months with Mean Flows below the Low-Flow Threshold (3,250 cfs) for Passage of Migrating Adult Salmonids in the Sacramento River at Wilkins Slough and Differences in Percentages (in parentheses) for the 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 (0)	0 (0)	0 (0)	0.14 (0.14)
Spring-run	March–September	0.0	0 (0)	0 (0)	0 (0)	0 (0)
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)

Species/Run	Immigration Period	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
Steelhead	November–April	0.0	0 (0)	0 (0)	0 (0)	0 (0)

The frequency of flows at Colusa lower than the 5,300 cfs low-flow threshold for sturgeon under all scenarios range from 9.3% for white sturgeon to 11.4% for green sturgeon (Table 11N-38). All the frequencies are lower under Alternatives 1, 2, and 3 than the NAA for both sturgeon species, except green sturgeon under Alternative 2, for which the frequency is equal to that under the NAA. These results indicate that Alternatives 1, 2, and 3 would not appreciably affect low-flow passage conditions for upstream migrating adult sturgeon in the Sacramento River.

Table 11N-38. Percent of Days with Mean Flows below the Low-Flow Threshold (5,300 cfs) for Passage of Migrating Adult Green and White Sturgeon in the Sacramento River Downstream of Colusa Weir and Differences in Percentages (in parentheses) for the NAA and Alternatives 1–3

Species/Run	Immigration Period	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
Green Sturgeon	February–June	11.4	11.3 (-0.02)	11.2 (-0.19)	11.4 (0)	10.9 (-0.45)
White Sturgeon	March–April	9.9	9.3 (-0.64)	9.3 (-0.62)	9.3 (-0.62)	9.5 (-0.4)

11N.3.4.2 Feather River

The frequencies of flows below the 1,500 cfs threshold during the immigration periods for spring-run, fall-run, and steelhead 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-39). For spring-run, fall-run, and steelhead, the frequencies of months with flows less than 1,500 cfs under Alternatives 1–3 are similar to or smaller than those under the NAA. For green sturgeon, the frequency of months with flows less than 6,000 cfs is 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 potentially benefit low-flow passage conditions for immigrating adult green sturgeon.

Table 11N-39. 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 NAA and Alternatives 1–3

Species/Run	Immigration Period	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
Spring-run^	March–June	37.2	36.9 (-0.3)	37.5 (0.3)	33.5 (-0.3)	37.8 (0.61)
Fall-run^	August–December	29.0	26.1 (-2.93)	25.9 (-3.17)	24.4 (-4.15)	26.1 (-2.93)
Steelhead^	August–March	29.1	27.6 (-1.42)	27.4 (-1.63)	26.8 (-2.44)	27.8 (-1.22)

Species/Run	Immigration Period	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
Green Sturgeon*	February–June	77.6	62.4 (-15.1)	62.2 (-15.4)	62.4 (-15.4)	62.2 (-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-40). However, there is little difference in the results between Alternatives 1–3 and the NAA (all differences are 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-40. Percent of Months with Mean Flows below the Low-Flow Threshold (1,000 cfs) for Passage of Migrating Adult Fall-run Chinook Salmond and Steelhead in the American River at Nimbus Dam and Differences in Percentages (in parentheses) for the NAA and Alternatives 1–3

Species/Run	Immigration Period	NAA	Alt 1A	Alt 1B	Alt 2	Alt 3
Fall-run	August–December	18.8	19 (0.24)	18.5 (-0.24)	19 (0.24)	18.8 (0)
Steelhead	October–April	17.9	17.9 (0)	17.8 (-0.17)	18.1 (0.17)	17.8 (-0.17)

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 redd dewatering results for Sacramento River steelhead and late fall–run Chinook salmon, negative effects were more numerous and on average larger than positive ones. For other results, such as the redd dewatering and juvenile stranding results for winter-run, increases in positive effects were greater than reductions.

11N.5 References Cited

11N.5.1 Printed References

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