Appendix L, Shasta Coldwater Pool Management

Attachment L.4 Sacramento River Redd Dewatering Analysis

L.4.1 Model Overview

Redd dewatering for salmon and steelhead occurs when the water level drops below the depth of an existing redd or drops low enough to cause lethal conditions for incubating eggs or alevins within the redd. Redd dewatering can occur at any time between the start of spawning to the final emergence of alevins from the redd. Fluctuations in flow during this period increase the probability of redd dewatering because higher flows could lead to redd placement in areas that subsequently may be dewatered when flows drop.

The redd dewatering analyses for the Sacramento River 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 three months for the four Sacramento River Chinook salmon races (fall-run, spring-run, winter-run, and late fall–run) and steelhead. The minimum flow during the egg cohort period is referred to herein as the *dewatering flow*. If flows during the three months after spawning are all greater than the spawning flow, no dewatering is assumed to occur. This analysis uses the flow results from Upper Sacramento River Daily Operations Model (USRDOM). The model has a daily time-step and the redd dewatering analysis assumes a new egg cohort begins each day of the spawning period. The redd dewatering period is assumed to end 90 days (three months) after the end of the spawning period. The results of the analysis are expressed as the percentage of redds dewatered. Therefore, the dewatering results provide relative rather than absolute estimates of numbers of redds dewatered, which can provide some comparison between alternatives.

L.4.2 Model Development

L.4.2.1 Methods

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- or race-specific spawning habitat weighted usable area (WUA). These tables are reproduced in Table L.4-1 through Table L.4-8. 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 because data on spring-run redds were insufficient to develop spring-run spawning WUA curves. Therefore, as was done for the WUA curves (see Attachment O.3, *Sacramento River Weighted Usable Area*), the fall-run salmon results were used to estimate spring-run redd dewatering, but flows for the spring-run spawning distribution (Table L.4-9) and spawning period (Table L.4-10) 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 Assumptions/Uncertainty. 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.

Table L.4-9 gives the spawning distributions of Chinook salmon in the Sacramento River as estimated from aerial redd surveys conducted by the California Department of Fish and Wildlife (CDFW) from 2006 through 2021 (CDFW unpublished data). The field studies used for the U.S. Fish and Wildlife Service (2006) study were conducted in the Sacramento River between Keswick Dam and Battle Creek at the same locations as the spawning WUA studies discussed in Attachment O.3, *Sacramento River Weighted Usable Area*. USRDOM flow data are available for three locations in the river section from Keswick Dam to Battle Creek: Keswick Dam (River Mile [RM] 302), the Sacramento River at Clear Creek (RM 289), and the Sacramento River at Battle Creek (RM 271). A single relationship between flows and redd dewatering 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 (Table L.4-9). The redd distributions of steelhead in the Sacramento River are poorly known but are expected to be similar to those of spring-run (U.S. Fish and Wildlife Service 2003). Therefore, Keswick Dam flows were used for the winter-run and late fall–run analyses, 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.

Table L.4-1. Percent Redd Dewatered Look-up Table for Winter-Run Chinook Salmon with ACID Dam Boards Out (the percent of redds dewatered are looked up at the intersection of the "Spawning Flow" columns and "Dewatering Flow" rows)

		Spawning Flow																												
		3,500	**3,750**	**4,000**	**4,250**	**4,500**	**4,750**	**5,000**	**5,250**	**5,500**	**6,000**	**6,500**	**7,000**	**7,500**	**8,000**	**9,000**	**10,000**	**11,000**	**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**	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	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	-	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	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	-	-	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	34.1	37.5	40.6	43.2	47.2	50	52.5	55.4	57.7	62.3	67.4	72
	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	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	-	-	-	-	0.1	0.3	0.5	0.8	1.2	2.2	3.4	5.9	7	9.1	14.3	20.3	25	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	-	-	-	-	-	0.2	0.3	0.6	0.8	1.7	2.6	3.9	5.5	7.6	12.2	17.8	22.3	26.3	29.6	32.6	35.3	39.6	42.5	45.1	48.2	51	56	61.7	66.9
	4,750	-	-	-	-	-	-	0.1	0.3	0.5	1.2	1.9	2.9	4.3	5.8	10.2	15.5	19.8	23.7	26.9	29.9	32.7	37	40	42.7	45.9	48.8	54	59.9	65.4
	5,000	-	-	-	-	-	-	-	0.2	0.4	0.9	1.5	2.4	3.5	4.8	8.7	13.8	17.9	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	-	-	-	-	-	-	-	-	0.2	0.6	1.1	1.8	2.7	3.8	7	11.8	15.7	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	-	-	-	-	-	-	-	-	-	0.3	0.8	1.4	2.1	3	5.8	10.3	14.1	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	-	-	-	-	-	-	-	-	-	-	0.2	0.6	1.1	1.7	3.7	7.7	10.9	14	16.7	19.4	22	26.4	29.6	32.6	35.9	39.6	45.4	52.2	58.5
	6,500	-	-	-	-	-	-	-	-	-	-	-	0.1	0.4	0.8	2.2	5.5	8.4	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	-	-	-	-	-	-	-	-	-	-	-	-	0.2	0.4	1.2	3.5	5.6	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	-	-	-	-	-	-	-	-	-	-	-	-	-	0.2	0.7	2.6	4.3	6.3	8.1	10.2	12.4	16.3	19.7	23	26.7	31	37.6	45.3	52.5
	8,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	1.9	3.2	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	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.2	1.8	3	4.4	6	7.8	11.4	14.7	18.3	22.1	26.6	33.6	41.9	49.5
	10,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.4	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 L.4-2. 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																												
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**	**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	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	43.4	46	48.4	50.3	53.5	56	58.9	62.4	65.4	69.5	73.7	77.2
	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	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	-	-	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	34.4	37.3	40	42.4	46.1	49	52.1	55.7	58.8	62.8	66.7	70.2
	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	32.2	35.3	38	40.4	44.2	47.2	50.3	53.9	57	61.1	65	68.5
	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	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	-	-	-	-	-	0.3	0.5	0.8	1.1	1.9	2.9	4.3	5.9	7.9	12.6	18.1	22.4	26.3	29.3	32	34.6	38.6	41.7	45	48.7	52	56	59.8	63.2
	4,750	-	-	-	-	-	-	0.2	0.4	0.7	1.3	2.1	3.1	4.5	6.1	10.5	15.7	20	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	-	-	-	-	-	-	-	0.3	0.5	1	1.6	2.5	3.7	5	9	14	18.1	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	-	-	-	-	-	-	-	-	0.3	0.7	1.2	1.9	2.9	3.9	7.3	11.9	15.9	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	-	-	-	-	-	-	-	-	-	0.4	0.9	1.5	2.3	3.2	6.1	10.5	14.3	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	-	-	-	-	-	-	-	-	-	-	0.3	0.7	1.3	1.9	4	8	11.3	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	-	-	-	-	-	-	-	-	-	-	-	0.2	0.5	1	2.4	5.8	8.8	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	-	-	-	-	-	-	-	-	-	-	-	-	0.3	0.5	1.4	3.8	6.1	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	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	0.9	2.9	4.8	7	9	11.2	13.5	17.7	21.4	25.2	29.3	33.2	37.2	40.7	44
	8,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.4	2.1	3.7	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	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.3	2.4	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	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.9	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 L.4-3. 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**	**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	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	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	-	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	60.1	61.1	63	64.2	64.9	63.8	66	69.5	73	79.1	86.2	91
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	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	-	-	-	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	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	-	-	-	-	0.8	1.6	2.7	4	5.4	8.9	13	17.2	21.6	25.8	34.9	42.8	48	51.8	53.6	56	58.1	59.6	58.8	61.3	65	68.5	75.7	83.1	87.8
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	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	-	-	-	-	-	-	0.8	1.6	2.5	4.8	7.6	10.8	14.2	17.6	25.8	33.2	38.8	43.3	45.6	48.6	51.4	54	53.7	56.6	60.4	64.5	71.7	80.3	85
5,000	-	-	-	-	-	-	-	0.7	1.3	3.2	5.6	8.6	11.6	14.7	22.6	30.2	36	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	-	-	-	-	-	-	-	-	0.7	2.1	4.2	6.8	9.4	12.3	19.8	27.2	33.1	37.7	40.2	43.5	46.5	50	50.2	53.5	57.4	60.7	68	78.2	83
5,500	-	-	-	-	-	-	-	-	-	1.4	3.2	5.4	7.7	10.3	17.6	24.9	31	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	-	-	-	-	-	-	-	-	-	-	1.2	2.8	4.6	6.4	12.9	19.7	25.8	30.9	33.8	37.3	40.6	45	45.8	49.5	53.2	57.2	65	75.4	80
6,500	-	-	-	-	-	-	-	-	-	-	-	1.3	2.6	4.2	9.8	15.6	21.1	26.5	29.2	32.7	36.1	41	42.4	46.5	50.4	54.8	63	73.3	77.7
7,000	-	-	-	-	-	-	-	-	-	-	-	-	0.9	2	6.6	11.8	17.3	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	-	-	-	-	-	-	-	-	-	-	-	-	-	0.8	4.4	9.1	14.1	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	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.6	6.6	11.5	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	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.2	5.5	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	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.9	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 L.4-4. Percent Redd Dewatered Look-up Table for Fall-Run Chinook Salmon (Also Used for the Spring-Run Chinook Salmon Analysis) with ACID Dam Boards In (the percent of redds dewatered are looked up at the intersection of the “Spawning Flow” columns and “Dewatering Flow” rows)

	Spawning Flow																												
Dewatering Flow		**3,500**	**3,750**	**4,000**	**4,250**	**4,500**	**4,750**	**5,000**	**5,250**	**5,500**	**6,000**	**6,500**	**7,000**	**7,500**	**8,000**	**9,000**	**10,000**	**11,000**	**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	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	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	-	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	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	-	-	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	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	-	-	-	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	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	-	-	-	-	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	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	-	-	-	-	-	0.8	1.6	2.6	3.7	6.0	8.9	11.9	15.0	17.8	24.4	29.9	33.6	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	-	-	-	-	-	-	0.8	1.6	2.4	4.3	6.6	9.1	11.8	14.3	20.3	25.7	29.5	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	-	-	-	-	-	-	-	0.7	1.3	2.9	4.9	7.2	9.6	11.9	17.7	23.1	26.9	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	-	-	-	-	-	-	-	-	0.6	1.9	3.5	5.6	7.7	9.7	15.3	20.4	24.1	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	-	-	-	-	-	-	-	-	-	1.2	2.7	4.4	6.2	8.1	13.5	18.5	22.3	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	-	-	-	-	-	-	-	-	-		1.0	2.3	3.7	5.1	9.8	14.5	18.3	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	-	-	-	-	-	-	-	-	-	-	-	1.1	2.1	3.3	7.4	11.5	15.0	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	-	-	-	-	-	-	-	-	-	-	-	-	0.7	1.6	5.0	8.6	12.1	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	-	-	-	-	-	-	-	-	-	-	-	-	-	0.6	3.4	6.7	9.9	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	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.0	4.9	8.1	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	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.6	3.8	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	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.2	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 L.4-5. 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**	**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	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	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	-	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	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	-	-	0.8	1.1	2	2.9	4.1	5.5	7	10.5	14.2	17.8	21.6	25	32	37.5	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	-	-	-	0.7	1.2	2	3	4.2	5.5	8.8	12.1	15.6	19.2	22.5	29.5	35.3	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	-	-	-	-	0.6	1.1	1.9	3	4.1	6.9	10	13.4	16.9	20.1	27.3	33.3	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	-	-	-	-	-	0.6	1.2	2.1	3.1	5.5	8.3	11.3	14.6	17.7	24.8	30.8	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	-	-	-	-	-	-	0.6	1.3	2	4	6.3	9	11.8	14.7	21.5	27.6	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	-	-	-	-	-	-	-	0.5	1	2.6	4.6	7	9.6	12.2	18.9	25.2	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	-	-	-	-	-	-	-	-	0.5	1.8	3.5	5.6	7.9	10.4	16.9	23.1	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	-	-	-	-	-	-	-	-	-	1.3	2.7	4.6	6.7	8.9	15.3	21.5	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	-	-	-	-	-	-	-	-	-	-	0.9	2.3	3.8	5.5	11.2	17.1	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	-	-	-	-	-	-	-	-	-	-	-	1	2.1	3.5	8.3	13.4	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	-	-	-	-	-	-	-	-	-	-	-	-	0.8	1.8	5.9	10.4	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	-	-	-	-	-	-	-	-	-	-	-	-	-	0.7	3.9	7.9	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	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.2	5.5	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	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.7	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 L.4-6. 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**	**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**	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	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	-	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	42.6	44	46	48.2	51.5	53.5	57.2	61.8	64.6	67.8	72.6	77.3
	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	40.5	42	44	46.3	49.6	51.5	55.1	59.7	62.6	65.6	70.4	75.1
	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	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	-	-	-	-	0.7	1.2	2	3	4.1	6.7	9.6	12.6	15.8	18.7	25.2	30.8	34.2	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	-	-	-	-	-	0.6	1.3	2.1	3.1	5.3	7.9	10.7	13.6	16.4	22.9	28.4	32	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	-	-	-	-	-	-	0.6	1.3	2.1	3.9	6	8.5	11.1	13.7	19.9	25.4	29.1	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	-	-	-	-	-	-	-	0.6	1.1	2.6	4.4	6.6	8.9	11.3	17.4	22.9	26.7	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	-	-	-	-	-	-	-	-	0.5	1.7	3.3	5.2	7.3	9.5	15.3	20.7	24.4	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	-	-	-	-	-	-	-	-	-	1.2	2.5	4.3	6.1	8.1	13.7	19.1	22.8	25.9	27.3	28.9	31.4	34.2	35.1	37.8	41	42.1	43.9	48	51.9
	6,000	-	-	-	-	-	-	-	-	-	-	0.9	2.1	3.4	5	10	15.1	19	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	-	-	-	-	-	-	-	-	-	-	-	0.9	1.9	3.1	7.4	11.8	15.4	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	-	-	-	-	-	-	-	-	-	-	-	-	0.8	1.6	5.2	9.1	12.5	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	-	-	-	-	-	-	-	-	-	-	-	-	-	0.7	3.5	6.9	9.9	13.7	15.5	17.6	20	23.1	23.8	26	28.3	28.4	29.2	32.2	35.2
	8,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	4.9	7.7	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	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.5	3.3	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	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		1	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 L.4-7. 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	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	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	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	-	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	52.9	60	67.1	73.6	81.4	84	86.4	87.4	89.9	90.5	92.3	94
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	49	55.9	63	69.7	77.8	80.9	84.3	85.9	88.9	89.7	91.7	93.8
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	46	52.9	60	66.8	74.9	78.2	82.1	84.1	88.1	89.4	91.6	93.7
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	43.6	50.3	57.3	64.1	72.3	75.6	79.8	82	86.8	88.3	91	93.3
4,500	-	-	-	-	-	1.1	1.9	3.3	4.5	7.1	9.6	12	14	16.3	22.4	28.5	34.2	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	-	-	-	-	-	-	0.8	2	2.8	5.1	7.4	9.7	11.6	13.8	19.8	25.8	31.4	37.3	43.7	50.2	57	66.1	70.1	74.6	77	83.1	85.5	89.2	91.9
5,000	-	-	-	-	-	-	-	1.1	1.8	3.7	5.8	8	9.7	11.8	17.7	23.8	26.6	35.4	41.7	48.2	55	64.1	68.2	72.8	75.2	82.1	85	88.8	91.6
5,250	-	-	-	-	-	-	-	-	0.8	2.4	4.2	6.2	7.7	9.4	14.9	21.1	26.8	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	-	-	-	-	-	-	-	-	-	1.5	3.2	5	6.1	7.8	13	19.1	24.6	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	-	-	-	-	-	-	-	-	-	-	1.3	2.7	3.8	5.3	10.2	15.9	21.2	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	-	-	-	-	-	-	-	-	-	-	-	2.8	1.3	2.6	6.9	12.1	17.2	22.9	28.7	34.5	40.4	48.6	52.6	58.2	61	69.2	74	79.2	81.4
7,000	-	-	-	-	-	-	-	-	-	-	-	-	0.5	1.3	4.8	9.4	14.3	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	-	-	-	-	-	-	-	-	-	-	-	-	-	0.7	3.8	8.1	12.7	18.2	24.1	30	35.8	44.4	48.2	54.1	57.3	66.2	71.1	76	78.2
8,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.8	6.7	10.9	16.3	22	27.7	33.4	42.1	46.4	52.7	55.9	64.6	69.5	75	77.2
9,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.6	5.3	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	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.9	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 L.4-8. 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**	**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**	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	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	-	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	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	-	-	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	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	-	-	-	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	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	-	-	-	-	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	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	-	-	-	-	-	1.4	2.7	4.2	5.5	8.2	10.8	13.3	15.4	17.6	23.6	28.4	32.7	36.6	39.8	42.6	44.6	44.5	41.5	40.1	36.5	34.2	34	34	35.8
	4,750	-	-	-	-	-	-	1.5	2.9	3.8	6.2	8.5	11	12.9	15.1	20.9	25.7	30	33.7	37	39.7	41.8	42.1	39.4	38.2	34.8	32.9	32.8	33	34.8
	5,000	-	-	-	-	-	-	-	1.7	2.4	4.4	6.5	8.8	10.6	12.6	18.3	23.1	27.5	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	-	-	-	-	-	-	-	-	1.1	2.6	4.6	6.5	8	9.6	15	19.7	24	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	-	-	-	-	-	-	-	-		1.5	3.2	4.8	6.2	7.7	12.8	17.5	21.6	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	-	-	-	-	-	-	-	-	-	-	1.3	2.7	3.8	5.1	9.9	14.3	18.3	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	-	-	-	-	-	-	-	-	-	-	-	2.7	1.4	2.5	6.9	10.8	14.8	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	-	-	-	-	-	-	-	-	-	-	-	-	0.5	1.3	4.9	8.4	12.2	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	-	-	-	-	-	-	-	-	-	-	-	-	-	0.7	4	7.3	10.8	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	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	5.9	9.2	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	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.2	4.4	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	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.6	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

Table L.4-9. Distributions of Spawning Redds among WUA River Segments as Percent of Total in the Sacramento River for Chinook Salmon Runs.

Segment No.	Description	River Miles	Winter-Run	Spring-Run	Fall-Run	Late Fall–Run
6	Keswick to ACID	302-298.5	35.6%	5.9%	17.4%	62.0%
5	ACID to Cow Creek	298.5-280	63.0%	72.1%	32.9%	19.8%
4	Cow Creek to Battle Creek	280-271	0.4%	6.7%	14.2%	8.7%
3	Battle Creek to RBDD	271-243	0.2%	3.6%	18.1%	3.7%
2	Downstream of RBDD	—	0.8%	11.7%	17.4%	5.8%

ACID = Anderson-Cottonwood Irrigation District
RBDD = Red Bluff Diversion Dam[1]

Estimated daily redd dewatering potential was calculated for the NAA and alternative model scenarios from USRDOM flow data for each day of the 100-year period of record. The percentage of redds dewatered was computed independently for each day of the period of record, which would potentially lead to overcounting of dewatered redds when the results are summarized. Therefore, the results are treated as estimates of daily redd dewatering potential rather than as estimates of total redd dewatering. Dewatering potential of the NAA and the BA and EIS modeled alternatives were compared using the monthly mean dewatering potential under each water year type. Composite estimates of redd dewatering for each race or species under each water year type and all water year types combined were computed by weighting mean monthly results by monthly weighting factors (Table L.4-10). For winter-run and late fall-run, these weighting factors were estimated from the mean proportions of redds counted each months in the aerial redd surveys conducted by California Department of Fish and Wildlife during 2006 through 2021 (CDFW unpublished data). Information from Williams (2006) was also used in estimating the late fall-run spawning months. For spring-run and steelhead the weighting factors were derived from information on life-history timings of listed anadromous salmonids of the Central Valley in Appendix C, and the weighting factors for fall-run were estimated from information in Moyle et al. 2017.

[1] For simplicity, this location is referred to as the Red Bluff Diversion Dam (RBDD) in this document despite dam decommissioning in 2013.

Table L.4-10. Monthly Weighting Factors for Sacramento River Winter-run, Spring-run, Fall-run, Late fall-run, and Steelhead Spawning Used for Computing Composite Redd Dewatering Results by Water Year Type.

Month	Winter-run	Spring-run	Fall-run	Late fall-run	Steelhead
January	0	0	0	0.4	0.15
February	0	0	0	0.1	0.35
March	0	0	0	0.1	0.35
April	0	0	0	0	0.15
May	0.1	0	0	0	0
June	0.4	0	0	0	0
July	0.4	0	0	0	0
August	0.1	0.1	0	0	0
September	0	0.6	0.1	0	0
October	0	0.3	0.3	0	0
November	0	0	0.4	0	0
December	0	0	0.2	0.4	0

L.4.2.2 Assumptions / Uncertainty

1. One assumption of the redd dewatering analysis is that dewatering of the redd results in 100% mortality of the eggs and alevins it contains. This assumption overestimates mortality. Several studies have demonstrated that the level of mortality is strongly related to the duration of dewatering, the temperature and humidity in the dewatered redd, and the life stages present when the redd is dewatered (Becker et al. 1982; Reiser and White 1983; McMichael et al. 2005). In general, eggs survive dewatering at a much higher rate than the alevins (Becker et al. 1982). Eggs may survive for weeks in a dewatered redd whereas alevins generally survive only a few hours (Becker et al. 1982; Reiser and White 1983). This observation suggests that dewatering of redds early in the spawning period of a population may have a less negative effect than later dewatering because the egg stage would be more prevalent early in the season than the alevin stage. Although the assumption of 100% mortality resulting from redd dewatering overestimates the effects of redd dewatering on the salmon and steelhead populations under the alternative scenarios, the level of overestimation is uncertain. Regardless, this assumption applies equally to all alternative scenarios.

2. The duration of egg and alevin incubation for steelhead and all runs of Chinook salmon is assumed to be the same regardless of the time of year. This ignores water temperature effects on egg and alevin development times and potential run and species differences, which increases uncertainty in the analysis. Water temperatures in the upper Sacramento River are not expected to differ greatly among the alternative scenarios, so any biases resulting from temperature effects are likely to be similar among scenarios.

3. As noted in Section L.4.2.1, *Methods*, the percentage of redds dewatered was computed independently for each day of the period of record, which would potentially lead to overcounting of dewatered redds when the results are summarized. Therefore, the results are treated as estimates of daily redd dewatering potential rather than as estimates of total redd dewatering.
4. As noted previously, Sacramento River fall-run Chinook salmon redd dewatering tables were used to model spring-run dewatering in the analysis because data on spring-run redds were insufficient to develop spring-run spawning WUA curves. Spawning WUA data are needed because spawning WUA results were used to develop redd dewatering tables (USFWS 2006). Substitution of fall-run WUA results for spring-run follows previous practice for WUA analyses. For instance, two models that currently produce spawning WUA outputs for spring-run Chinook salmon, SALMOD and Sacramento River Ecological Flows Tool (SacEFT), derive the spring-run WUA results using fall-run Chinook salmon spawning WUA curves as surrogates (Bartholow 2004; ESSA Technologies 2011). Mark Gard, who led the U.S. Fish and Wildlife Service studies that produced the Sacramento River WUA curves and dewatering tables, has endorsed this practice (Gard pers. comm.). However, this practice introduces additional uncertainty to spring-run Chinook salmon redd dewatering results.
5. USRDOM incorporates tributary inflow and flow variability not caused solely by reservoir releases. There is uncertainty in the source of potential redd dewatering since it is not solely caused by releases and instead incorporates variable hydrometeorology. This is likely more the case during wetter water years than drier water years.
6. Estimates of redd dewatering are an order of magnitude greater than observed in recent years for all species. This bias likely results from the multiple counting of redd dewatering events discussed in Assumption #3 listed above. Results are likely still useful for comparison between alternatives, but should not be considered as absolute values.
7. The redd dewatering analyses assume that channel characteristics of the river, such as proportions of mesohabitat types, during the years of field data collection, 1995–1999, by U.S. Fish and Wildlife Service have remained in dynamic equilibrium to the present time and will continue to do so through the life of the Project (USFWS 2010). If the channel characteristics substantially changed, the shape of the curves might no longer be applicable.

L.4.2.3 Code and Data Repository

Data for this analysis are available upon request.

L.4.3 Results

The following results provide the estimates of redd dewatering potential for winter-run, spring-run, fall-run, and late fall-run Chinook salmon, and steelhead. The results are provided separately for each race and species, with tables and figures for the BA and EIS modeled scenarios included in each section. As noted in Section L.4.2.1, *Methods*, the composite redd dewatering potential results by water year type in the tables were computed from mean monthly results weighted by the factors in Table L.4-10.

L.4.3.1 Winter-run Chinook

Table L.4-11 and Table L.4-12 provide the redd dewatering results for Sacramento River winter-run Chinook salmon under the BA modeled scenarios and EIS modeled scenarios, respectively. As noted above, these results are composite means computed by weighting mean monthly results by the monthly weighting factors (Table L.4-10). Months with weighting factors of zero are excluded from computation of the composite means. The results are the means for all years analyzed, weighted by the factors month (Table L.4-10). The table for the EIS modeled scenarios includes the percent differences between the results of the NAA and the alternatives (Table L.4-12).

The results for both the BA and EIS modeled scenarios show modest and inconsistent variation in percentage of winter-run redds dewatered with water year type for the EXP 1 and EXP 3, but under the NAA and all BA and EIS modeled scenarios for the alternatives, the variation among water year types is consistent, with the lowest percentages of redds dewatered under wet water years and highest in below normal and dry water years. During winter and spring, redd dewatering is generally higher during wet water years because periodic storms and high runoff, which increase flow fluctuations, tend to be more frequent in such water years. However, winter-run spawning and incubation occur during late spring through early fall, when flows tend to be less variable. The minimum rates of redd dewatering for winter-run during wet years (Table L.4-11 and Table L.4-12) may result from increased stability in project operations related to greater reservoir storage levels. For the EIS modeled scenarios, the largest difference between the NAA and the scenarios is a 33.3% increase in redd dewatering for Alt 4 in above normal years (Table L.4-12). The largest reduction is 26.2% for Alt 2 With TUCP Without VA in critical water years. Note that these large percentages may be misleading as they represent, respectively, 4.9% and 4.4% absolute differences in percentages of redds dewatered.

Table L.4-11. Expected Percentage of Redds Dewatered for Winter-run Chinook Egg Incubation in the Sacramento River from Keswick Dam to the Battle Creek Confluence for EXP1, EXP3, NAA, and Four Phases of Alternative 2

Water Year Type	EXP1	EXP3	NAA	Alt2wTUCP woVA	Alt2woTUCP woVA	Alt2woTUCP DeltaVA	Alt2woTUCP AllVA
Wet	9.2	7.7	7.0	6.7	6.8	6.8	6.8
AN	6.6	9.1	11.9	10.9	10.8	10.8	10.5
BN	4.6	9.9	19.6	18.1	17.7	17.6	15.4
Dry	3.8	9.5	19.0	17.7	17.8	18.4	17.6
Critical	2.2	6.2	13.9	9.6	14.9	14.1	14.2
All	5.6	8.5	13.9	12.5	13.3	13.2	12.6

Table L.4-12. Estimated percent of redd dewatering potential for Winter-run Chinook Egg Incubation in the Sacramento River from Keswick Dam to the Battle Creek Confluence for the NAA and Alternatives 1-4. The Lower Panel Gives the Percent Differences of the Alternatives and the NAA

WYT	NAA	Alt 1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt 3	Alt 4
W	7.0	8.0	6.8	6.8	6.7	6.7	8.0	8.1
AN	11.9	15.1	10.7	10.7	10.7	10.2	10.5	15.9
BN	19.6	17.2	17.4	17.1	17.4	15.8	17.9	19.0
D	19.0	18.4	18.1	18.2	18.4	17.6	20.1	18.2
C	13.9	18.4	10.3	15.6	14.9	15.2	13.0	10.5
All	13.9	14.8	12.5	13.3	13.3	12.8	13.8	14.0
WYT	**NAA**	**Alt 1**	**Alt2 wTUCP woVA**	**Alt2 woTUCP woVA**	**Alt2 woTUCP DeltaVA**	**Alt2 woTUCP AllVA**	**Alt 3**	**Alt 4**
W	7.0	14.8	-3.1	-3.1	-3.7	-4.0	14.1	15.7
AN	11.9	26.8	-10.2	-10.1	-10.0	-14.2	-11.9	33.3
BN	19.6	-12.2	-11.4	-12.6	-11.2	-19.1	-8.8	-2.9
D	19.0	-3.4	-4.6	-4.2	-3.0	-7.2	5.7	-4.2
C	13.9	31.9	-26.2	11.8	6.9	9.3	-6.5	-24.4
All	13.9	6.2	-10.2	-4.3	-4.4	-8.0	-0.9	0.2

The results for winter-run redd dewatering grouped by incubation period indicate that the BA modeled scenarios generally have peak redd dewatering in the July – October period and August – November period, except for EXP1, which has peak dewatering expected in May (

Figure L.4-1). For the EIS modeled scenarios, redd dewatering peaks in the July – October period and has the largest range of values in the May – August period (Figure L.4-2).

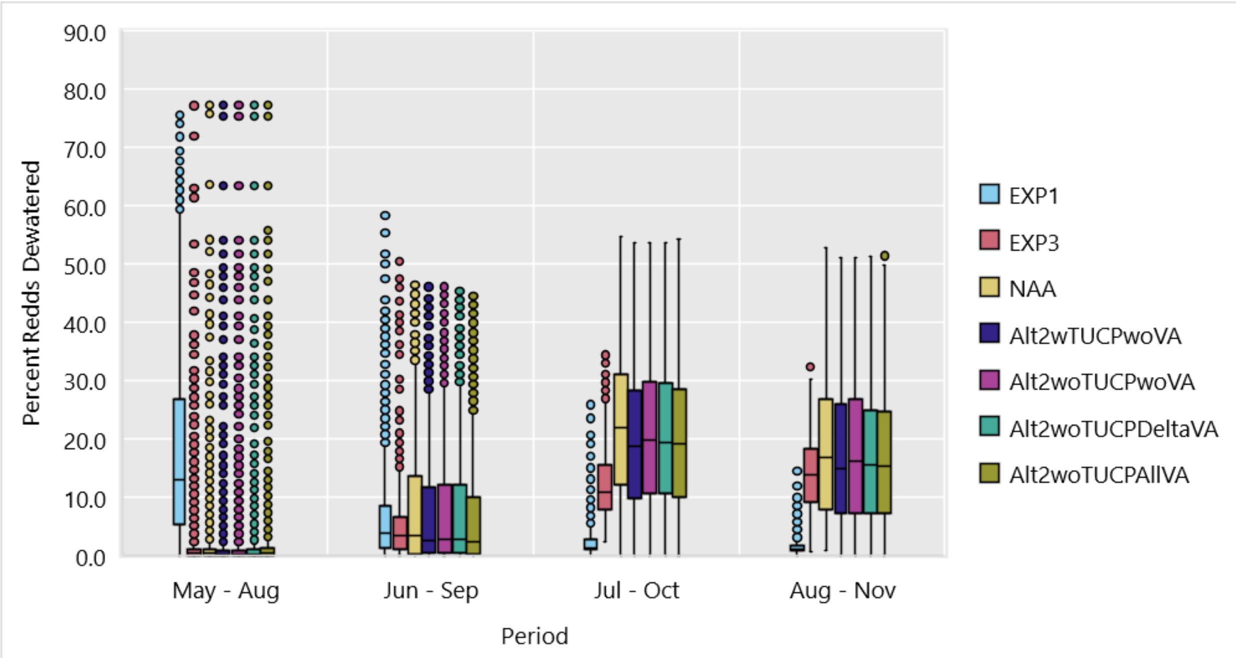

Figure L.4-1. Estimated percent of redd dewatering potential for Winter-run Chinook Salmon in the Sacramento River from Keswick Dam to the Battle Creek Confluence for EXP1, EXP3, NAA, and four phases of Alternative 2, by Incubation Period

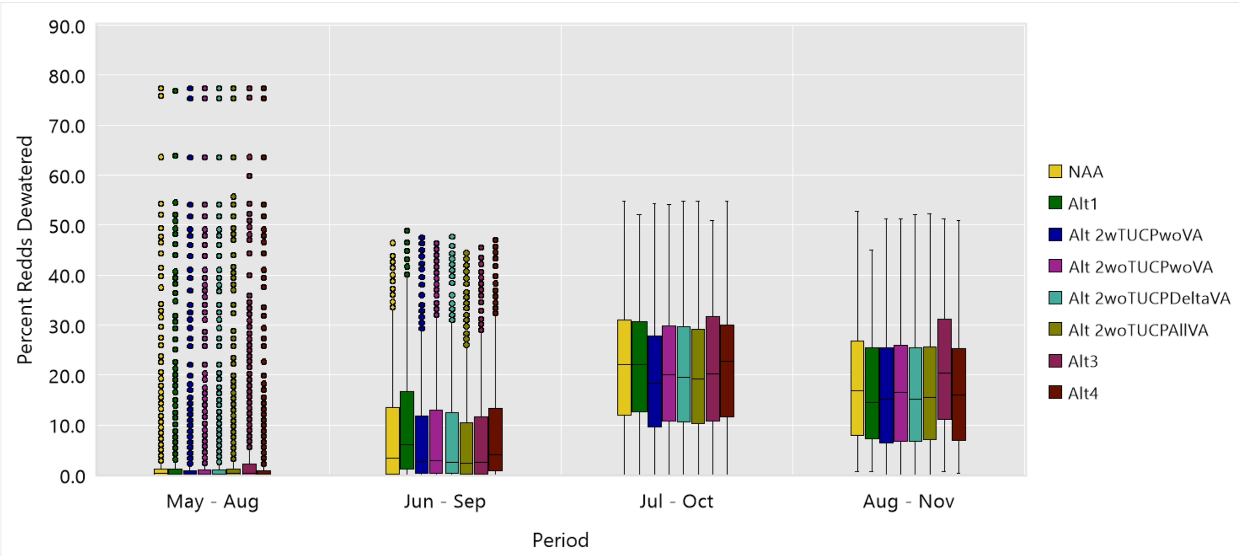

Figure L.4-2. Estimated percent of redd dewatering potential for Winter-run Chinook Salmon in the Sacramento River from Keswick Dam to the Battle Creek Confluence for the NAA and Alternatives 1-4, by Incubation Period.

Figure L.4-3 and Figure L.4-4 give the results for winter-run redd dewatering grouped by water year type. The results are the same as those provided in Table L.4-11 and Table L.4-12, but additionally show the variation and range in the results.

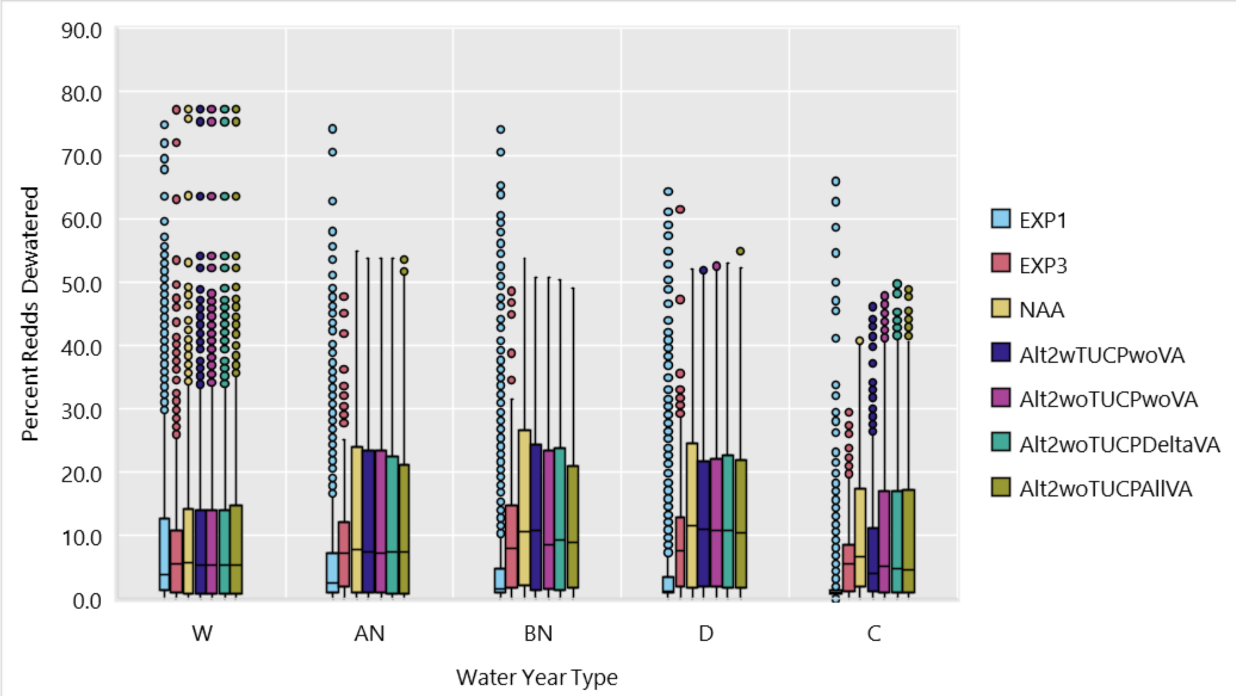

Figure L.4-3. Estimated percent of redd dewatering potential for Winter-run Chinook Salmon in the Sacramento River from Keswick Dam to the Battle Creek Confluence for EXP1, EXP3, NAA, and four phases of Alternative 2, by Water Year Type.

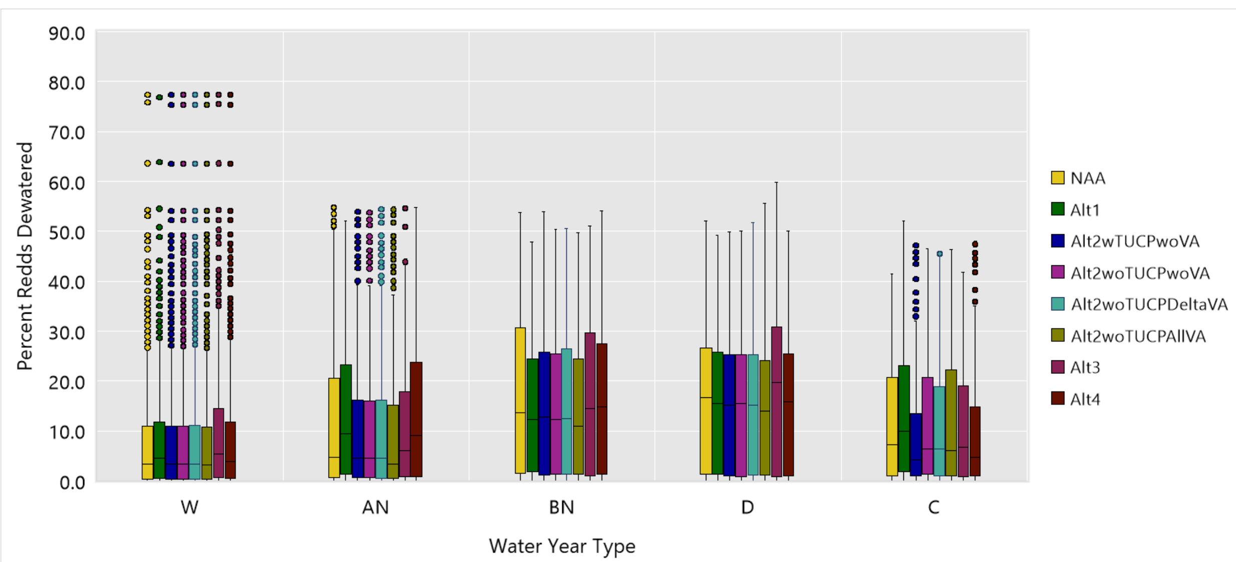

Figure L.4-4. Estimated percent of redd dewatering potential for Winter-run Chinook Salmon in the Sacramento River from Keswick Dam to the Battle Creek Confluence for the NAA and Alternatives 1-4, by Water Year Type.

L.4.3.2 Spring-run Chinook

Table L.4-13 and Table L.4-14 provide the redd dewatering results for Sacramento River spring-run Chinook salmon under the BA modeled scenarios and EIS modeled scenarios, respectively. The results are the means for all years analyzed, weighted by their expected spawning distribution among months (Table L.4-10). The table for the EIS modeled scenarios includes the percent differences between the results of the NAA and the alternatives (Table L.4-14).

The results for both the BA and EIS modeled scenarios show modest and inconsistent variation in estimates of spring-run redd dewatering potential with water year type for EXP 1 and EXP 3. However, under the NAA and all BA and EIS modeled scenarios for the alternatives, the variation among water year types is consistent, with the lowest estimates of redd dewatered potential in critical water years and highest estimates in wet and above normal water years (Table L.4-13 and Table L.4-14). This pattern of variation is expected for spring-run Chinook because their spawning occurs in the fall, with incubation extending into early winter. During wet winters, periodic storms and high runoff increase flow fluctuations, which tends to result in greater estimates of redd dewatering potential. In drier winters, flow fluctuations are reduced and fewer redds are potentially dewatered. For the EIS modeled scenarios, reductions in the estimates of redd dewatering potential from the NAA tend to be larger and more frequent than increases (Table L.4-14). The largest reduction is 40.6% for Alt 4 in above normal years. The largest increase is 11.3% for Alt 1 in dry water years.

Table L.4-13. Estimated percent of redd dewatering potential for Spring-run Chinook Egg Incubation in the Sacramento River from Keswick Dam to the Battle Creek Confluence for EXP1, EXP3, NAA, and Four Phases of Alternative 2

Water Year Type	EXP1	EXP3	NAA	Alt2wTUCP woVA	Alt2woTUCP woVA	Alt2woTUCP DeltaVA	Alt2woTUCP AllVA
Wet	3.3	8.6	25.7	24.6	24.7	24.8	25.0
AN	3.0	8.9	27.4	28.8	28.8	28.8	28.7
BN	2.8	10.6	14.4	13.2	12.6	12.8	14.4
Dry	2.5	11.5	12.7	13.1	12.8	12.1	12.5
Critical	1.4	11.2	9.5	8.2	8.1	7.9	7.9
All	2.7	10.1	18.2	17.8	17.6	17.5	17.9

Table L.4-14. Estimated percent of redds dewatering potential for Spring-run Chinook Egg Incubation in the Sacramento River from Keswick Dam to the Battle Creek Confluence for the NAA and Alternatives 1-4. The Lower Panel Gives the Percent Differences of the Alternatives and the NAA

WYT	NAA	Alt 1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt 3	Alt 4
W	25.7	22.3	25.1	25.2	25.4	25.5	22.9	19.8
AN	27.4	16.7	29.1	29.2	29.4	29.7	22.5	16.3
BN	14.4	15.6	13.9	13.3	14.1	14.1	14.2	13.8
D	12.7	14.2	12.8	12.7	12.1	12.3	13.9	13.0
C	9.5	8.5	7.8	7.8	7.4	8.0	9.1	8.5
All	18.2	16.2	18.0	17.9	17.9	18.1	16.9	14.8
WYT	**NAA**	**Alt 1**	**Alt2 wTUCP woVA**	**Alt2 woTUCP woVA**	**Alt2 woTUCP DeltaVA**	**Alt2 woTUCP AllVA**	**Alt 3**	**Alt 4**
W	25.7	-13.4	-2.3	-2.1	-1.3	-1.0	-10.8	-23.0
AN	27.4	-39.2	6.1	6.4	7.3	8.3	-17.9	-40.6
BN	14.4	8.4	-3.8	-7.4	-2.3	-2.1	-1.4	-3.9
D	12.7	11.3	0.4	-0.1	-5.1	-3.1	9.2	2.3
C	9.5	-9.8	-18.1	-17.3	-22.0	-15.7	-4.4	-10.2
All	18.2	-11.4	-1.6	-1.9	-2.0	-0.7	-7.1	-18.8

The results for spring-run redd dewatering potential grouped by incubation period indicate that for both BA and EIS modeled scenarios redd dewatering peaks in the September – December period and is generally similar under the NAA and four phases of Alternative 2 (Figure L.4-5 and Figure L.4-6).

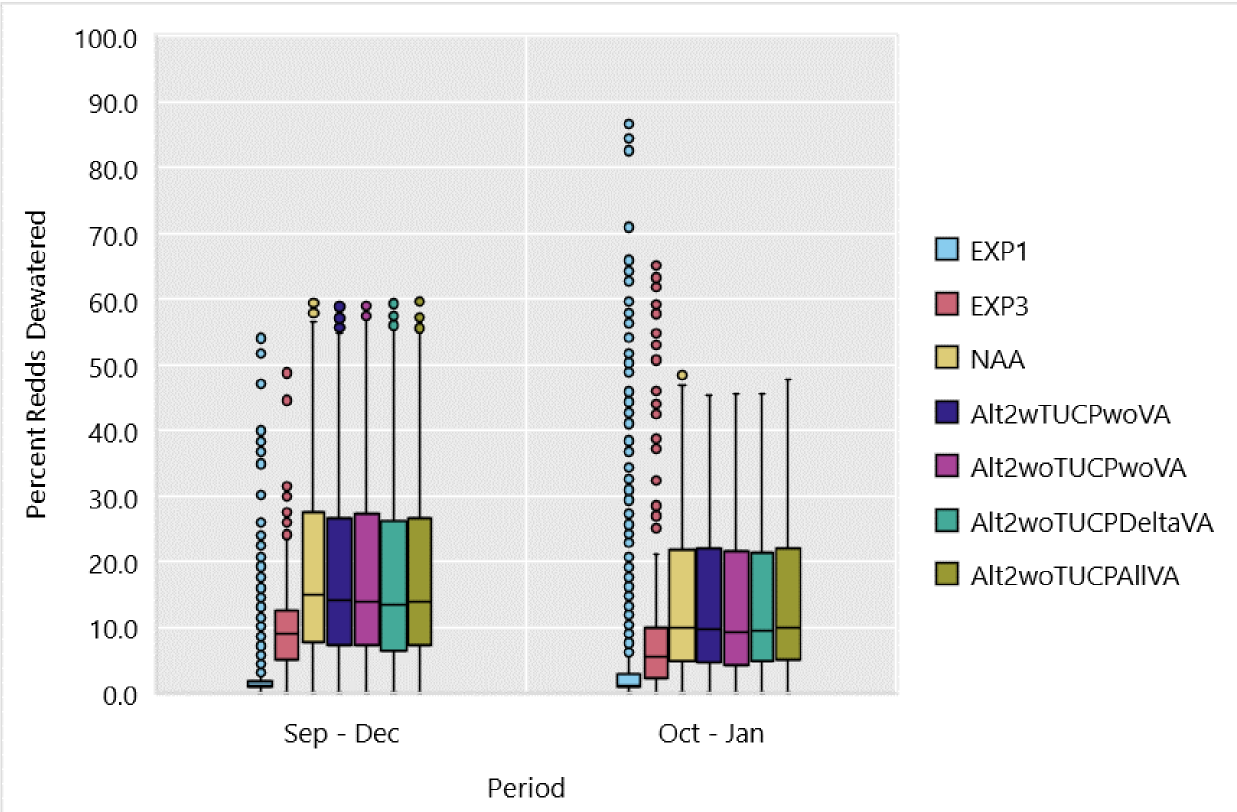

Figure L.4-5. Estimated percent of redd dewatering potential for Spring-run Chinook Salmon in the Sacramento River from Keswick Dam to the Battle Creek Confluence for EXP1, EXP3, NAA, and four phases of Alternative 2, by Incubation Period

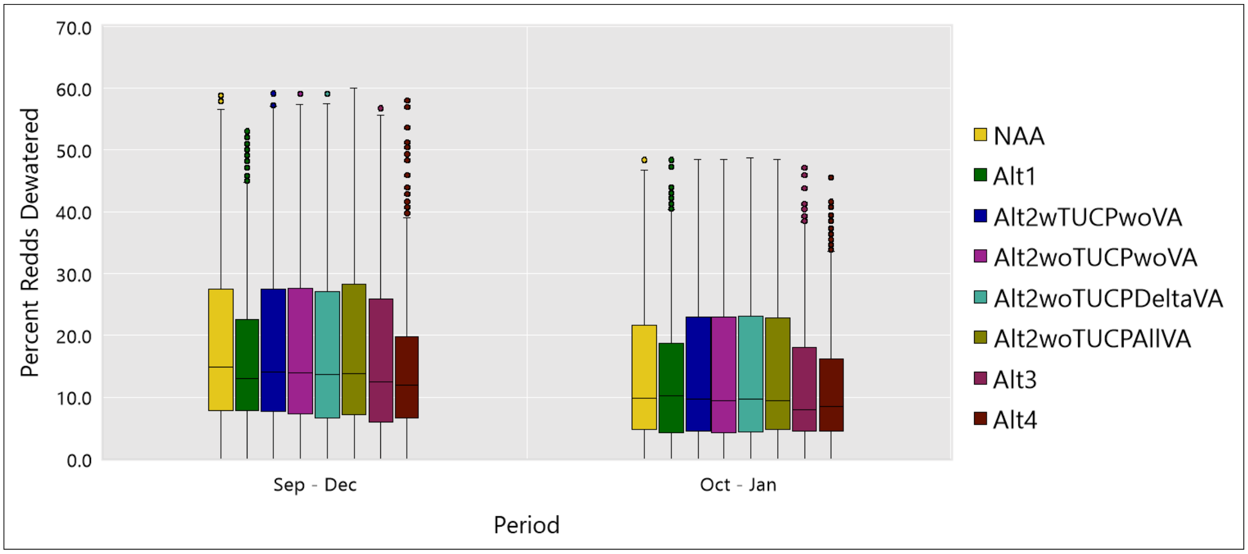

Figure L.4-6. Estimated percent of redd dewatering potential for Spring-run Chinook Salmon in the Sacramento River from Keswick Dam to the Battle Creek Confluence for the NAA and Alternatives 1-4, by Incubation Period.

Figure L.4-7 and Figure L.4-8 give the results for spring-run estimated redd dewatering potential grouped by water year type. The results are the same as those provided in Table L.4-13 and Table L.4-14, but additionally show the variation and range in the results. As described above for Table L.4-13 and Table L.4-14, redd dewatering potential is highest in Wet and Above Normal years, reflecting the greater flow fluctuations in those years during the spring-run egg incubation period.

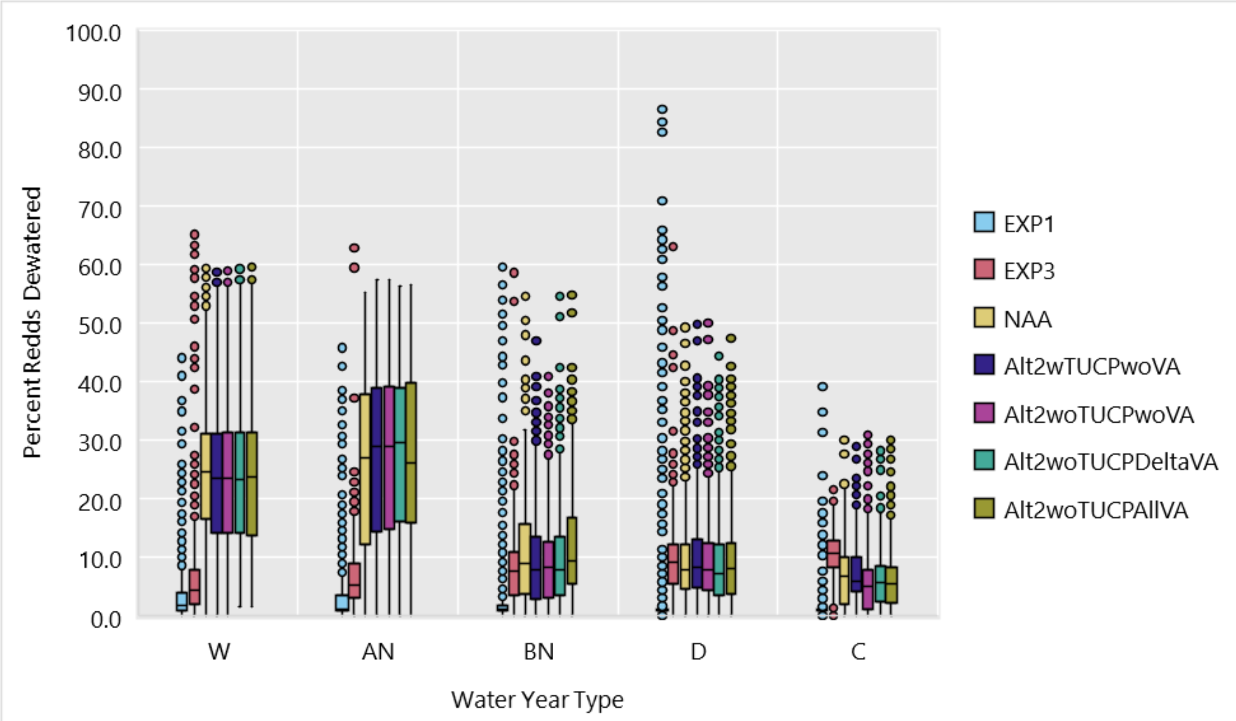

Figure L.4-7. Estimated percent of redd dewatering potential for Spring-run Chinook Salmon in the Sacramento River from Keswick Dam to the Battle Creek Confluence for EXP1, EXP3, the NAA, and four phases of Alternative 2, by Water Year Type.

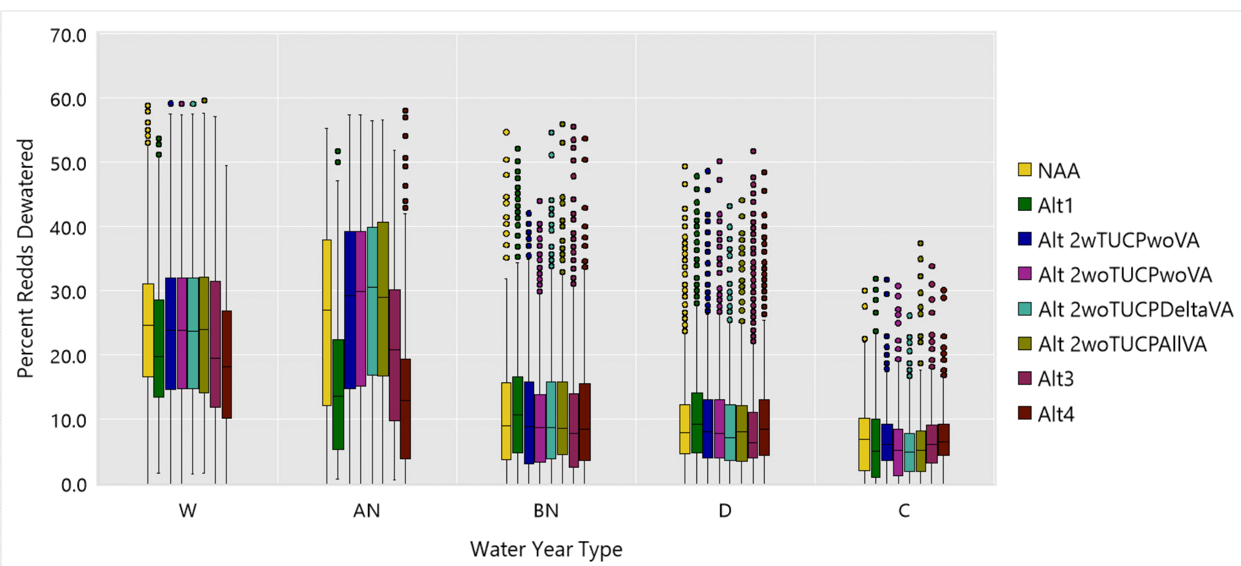

Figure L.4-8. Estimated percent of redd dewatering potential for Spring-run Chinook Salmon in the Sacramento River from Keswick Dam to the Battle Creek Confluence for the NAA and Alternatives 1-4, by Water Year Type.

L.4.3.3 Steelhead

Table L.4-15 and Table L.4-16 provide the estimated redd dewatering potential results for Sacramento River steelhead under the BA modeled scenarios and EIS modeled scenarios, respectively. The results are the means for all years analyzed, weighted by their expected spawning distributions among months (Table L.4-10). The table for the EIS modeled scenarios includes the percent differences between the results of the NAA and the alternatives (Table L.4-16).

The results for both the BA and EIS modeled scenarios show large and consistent variation in percentage of steelhead redds dewatered with water year type under the BA and EIS modeled scenarios, although the variation for EXP1 is somewhat reduced in comparison to that for the other scenarios (Table L.4-15 and Table L.4-16). For EXP3, the NAA, and all BA and EIS modeled scenarios, the mean redd dewatering is much higher in wet water years than in the other water year types and steadily declines with drier water year types. This pattern of variation reflects flow conditions for the winter and early spring months when steelhead spawning and incubation occurs. During wet winters and springs, periodic storms and high runoff increase flow fluctuations, which tends to result in greater redd dewatering. In drier years, flow fluctuations are reduced and fewer redds are dewatered. For the EIS modeled scenarios, reductions in redd dewatering from the NAA tend to be larger and more frequent than increases (Table L.4-16). The largest reduction is 30.3% for Alt 2 Without TUCP With Delta VA in critical water years. The largest increase is 13.0% for Alt 3 in below normal years.

Table L.4-15. Expected Percentage of Redds Dewatered for Steelhead Egg Incubation in the Sacramento River from Keswick Dam to the Battle Creek Confluence for EXP1, EXP3, the NAA, and four phases of Alternative 2

Water Year Type	EXP1	EXP3	NAA	Alt2wTUCP woVA	Alt2woTUCP woVA	Alt2woTUCP DeltaVA	Alt2woTUCP AllVA
Wet	50.3	44.9	45.4	45.3	45.4	45.3	45.0
AN	49.3	28.7	26.8	26.0	25.8	25.6	25.1
BN	34.5	11.1	10.5	10.8	10.4	10.6	9.3
Dry	32.8	8.9	7.1	6.4	6.5	6.2	6.5
Critical	20.9	2.9	4.8	4.8	5.2	5.1	4.9
All	38.4	21.2	20.8	20.6	20.6	20.5	20.1

Table L.4-16. Expected Percentage of Redds Dewatered for Steelhead Egg Incubation in the Sacramento River from Keswick Dam to the Battle Creek Confluence for the NAA and Alternatives 1-4. The Lower Panel Gives the Percent Differences of the Alternatives and the NAA

WYT	NAA	Alt 1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt 3	Alt 4
W	45.4	46.6	45.3	45.3	45.3	45.0	46.1	45.3
AN	26.8	27.4	26.4	25.7	26.0	24.7	28.5	26.2
BN	10.5	11.1	10.5	10.2	10.6	9.1	11.9	10.4
D	7.1	6.5	6.4	6.4	6.1	6.1	6.7	5.7
C	4.8	3.7	4.3	4.5	3.4	5.2	4.0	4.8
All	20.8	21.0	20.5	20.3	20.2	20.0	21.3	20.4
WYT	**NAA**	**Alt 1**	**Alt2 wTUCP woVA**	**Alt2 woTUCP woVA**	**Alt2 woTUCP DeltaVA**	**Alt2 woTUCP AllVA**	**Alt 3**	**Alt 4**
W	45.4	2.6	-0.2	-0.3	-0.2	-0.8	1.6	-0.2
AN	26.8	2.4	-1.5	-4.2	-3.0	-7.8	6.3	-2.0
BN	10.5	5.5	0.3	-3.2	0.5	-13.7	13.0	-0.9
D	7.1	-8.6	-10.0	-9.8	-14.4	-14.1	-6.5	-19.2
C	4.8	-22.6	-11.1	-7.5	-30.3	7.7	-17.4	-0.1
All	20.8	1.0	-1.6	-2.3	-3.0	-4.0	2.1	-2.2

The results for steelhead redd dewatering grouped by months indicate that for both the BA and EIS modeled scenarios redd dewatering is consistently variable throughout the egg incubation period (Figure L.4-9 and Figure L.4-10). For the BA modeled scenarios, EXP1 has the highest median percent of redds dewatered in March - June. The lowest median percent of redds dewatered occurs in April – July for EXP3, the NAA, and four Alternative 2 scenarios. For the EIS modeled scenarios, Alternative 1 and Alternative 3 have the highest median percent of redds dewatered in February - May. The lowest median percent of redds dewatered occurs in April – July under the EIS scenarios.

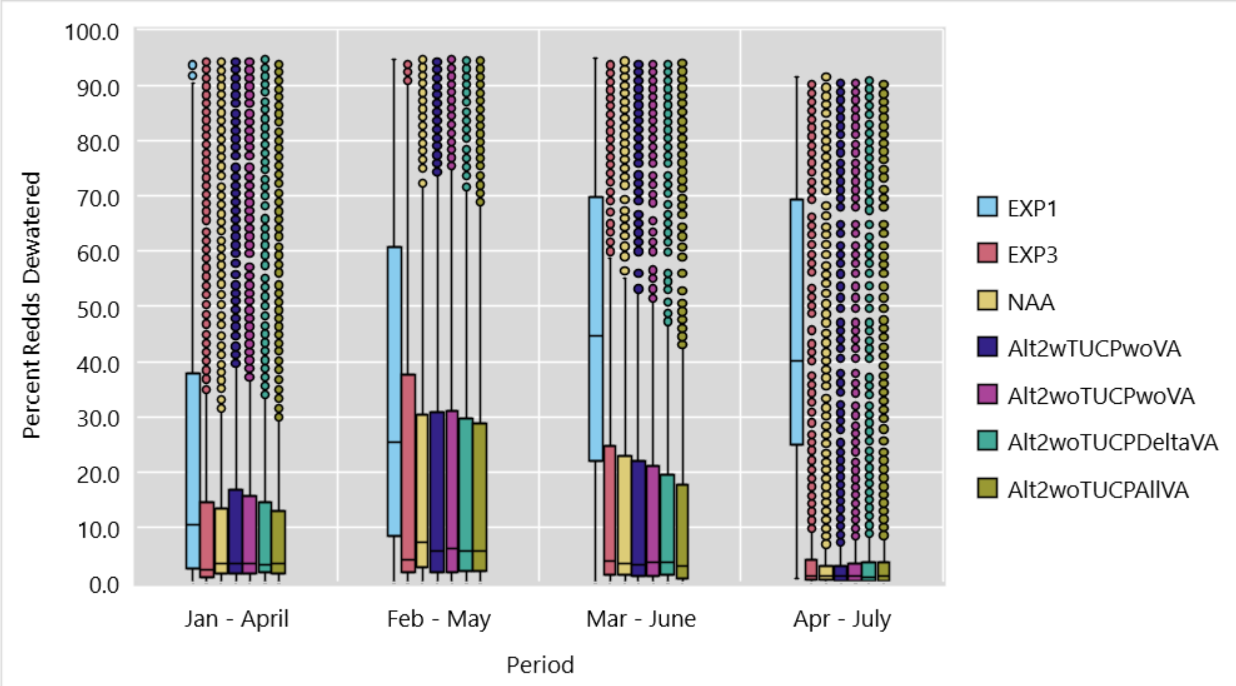

Figure L.4-9. Expected Mean Percent Redds Dewatered for Steelhead in the Sacramento River from Keswick Dam to the Battle Creek Confluence for EXP1, EXP3, the NAA, and four phases of Alternative 2, by Incubation Period.

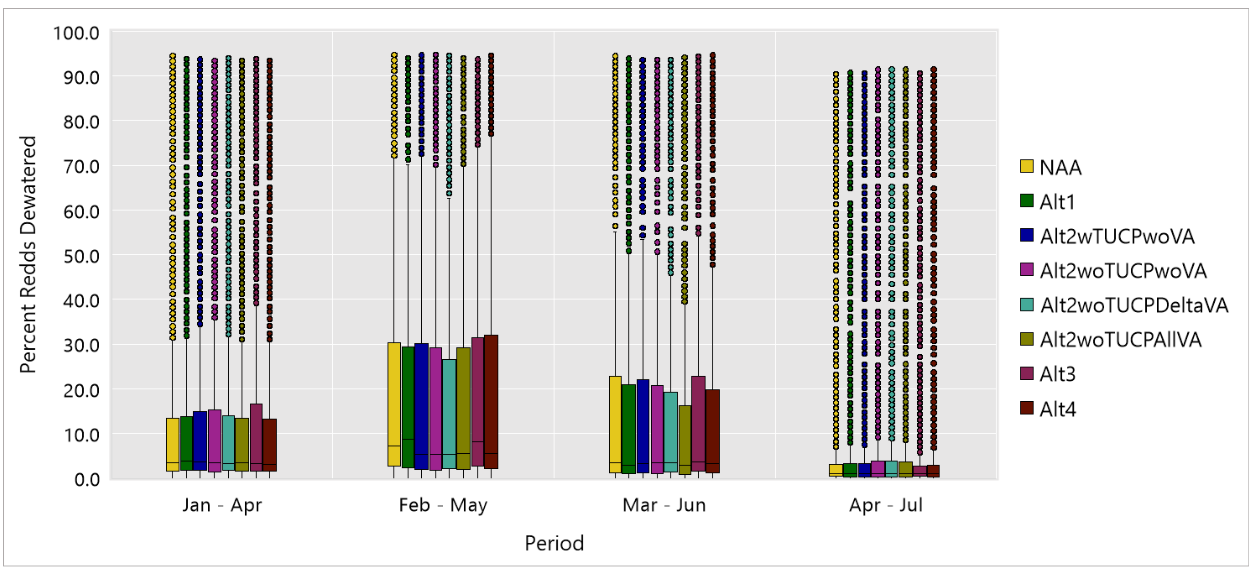

Figure L.4-10. Expected Mean Percent Redds Dewatered for Steelhead in the Sacramento River for the NAA and Alternatives 1-4, by Incubation Period.

Figure L.4-11 and Figure L.4-12 give the results for steelhead redd dewatering grouped by water year type. The results are the same as those provided in Table L.4-15 and Table L.4-16, but additionally show the variation in the results. In the BA modeled scenarios, EXP1 has the most variation in the median percent redds dewatered across water year types and consistently has the highest values (Figure L.4-11). The four phases of Alternative 2 and the NAA are relatively consistent within each water year type. In the EIS modeled scenarios, Alternative 3 has the highest percent of redds dewatered across most water year types, but differences are relatively small (Figure L.4-12). Wet years have the highest median redd dewatering rates because, as discussed for Table L.4-15 and Table L.4-16, flow fluctuations are greatest in wet years during much of the steelhead spawning and incubation period.

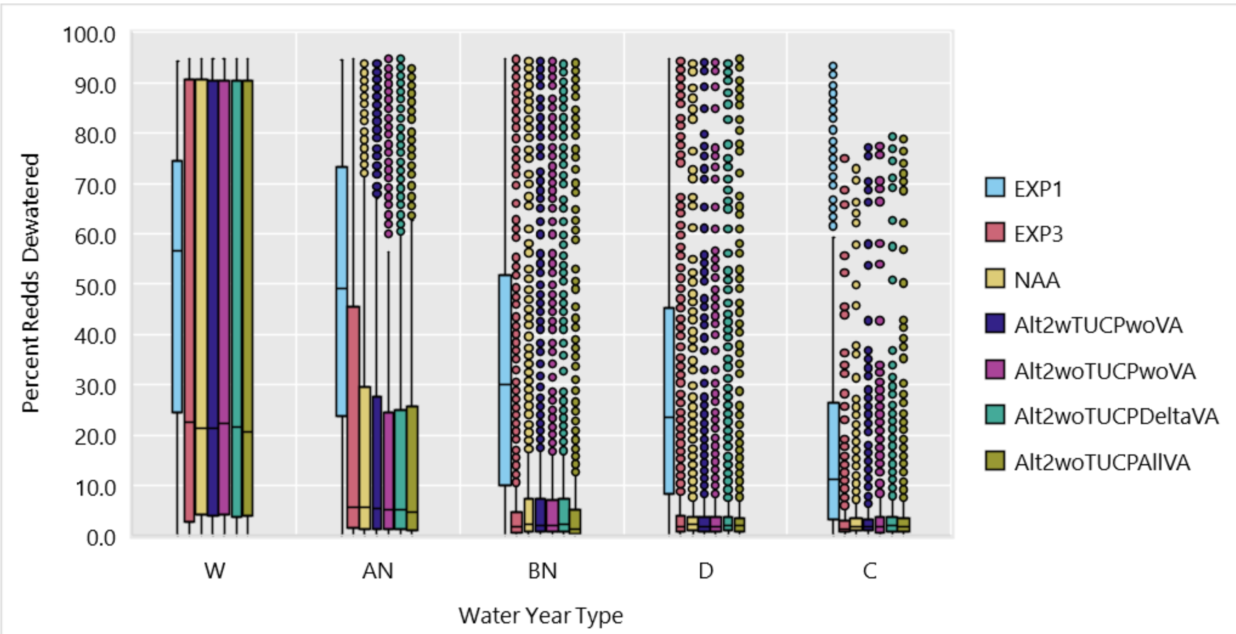

Figure L.4-11. Expected Mean Percent Redds Dewatered for Steelhead in the Sacramento River from Keswick Dam to the Battle Creek Confluence for EXP1, EXP3, the NAA, and four phases of Alternative 2, by Water Year Type.

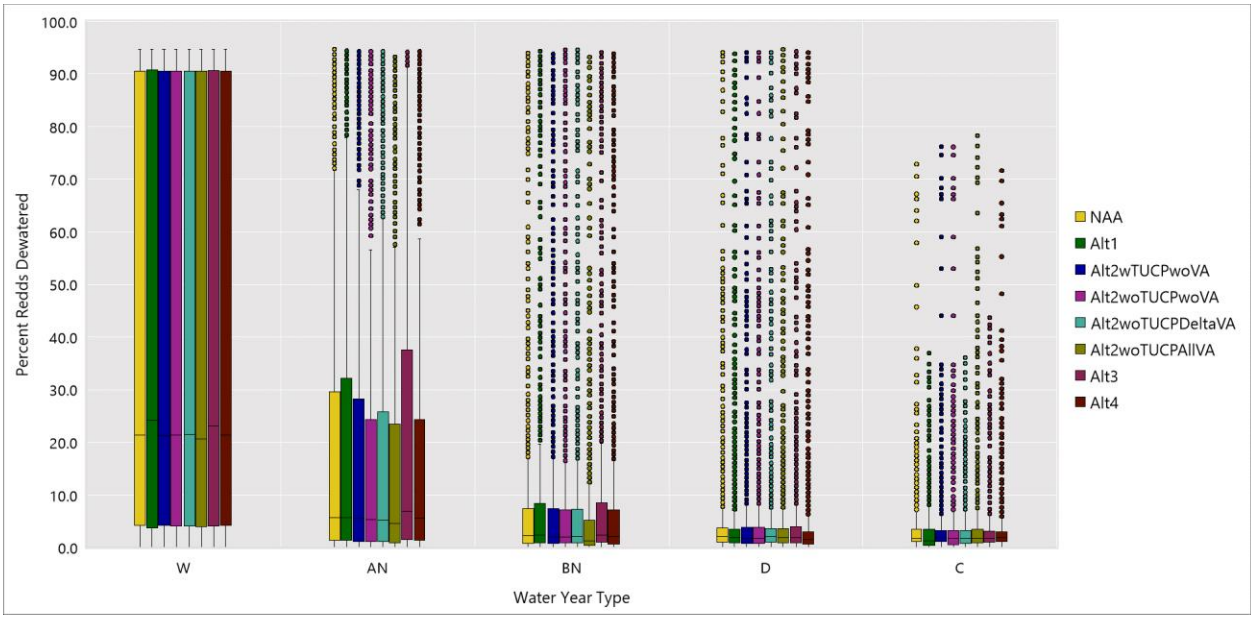

Figure L.4-12. Expected Mean Percent Redds Dewatered for Steelhead in the Sacramento River from Keswick Dam to the Battle Creek Confluence for the NAA and Alternatives 1-4, by Water Year Type

L.4.3.4 Fall-run Chinook

Table L.4-17 provides the redd dewatering results for Sacramento River fall-run Chinook salmon under the EIS modeled scenarios. The results are the means for all years analyzed, weighted by their expected spawning distributions among months (Table L.4-10). The table includes the percent differences between the results of the NAA and the EIS modeled scenarios alternatives (Table L.4-17).

The results show modest and generally consistent variation in percentage of fall-run redds dewatered with water year type (Table L.4-17). Under NAA and all EIS modeled scenarios for the alternatives, the percent of redds dewatered is lowest in critical water years and, is highest in either wet water years or above normal years. As discussed for spring-run, this pattern of variation is expected for fall-run Chinook because their spawning occurs in the fall and early winter, with incubation extending through winter. During wet winters, periodic storms and high runoff increase flow fluctuations, which tends to result in greater redd dewatering. In drier winters, flow fluctuations are reduced and fewer redds are dewatered. For the EIS modeled scenarios, increases and reductions in redd dewatering from the NAA are similar in number (Table L.4-17). The largest difference is a reduction of 26.6% for Alt 1 in above normal years and the largest increase is 15.6% for Alt 2 Without TUCP Without VA in critical water years.

As noted above, the pattern of variation for fall-run Chinook resembles that reported for spring-run Chinook (see Table L.4-14 and Table L.4-17). This similarity is expected given that the two races have similar spawning periods (Table L.4-10) and redd dewatering for spring-run was determined using the fall-run redd dewatering tables, as discussed in Section L.4.2.1, *Methods*. The main difference in redd dewatering between the two races is that redd dewatering percentages are somewhat higher for spring-run than for fall-run.

Table L.4-17. Expected Percentage of Redds Dewatered for Fall-run Chinook Egg Incubation in the Sacramento River from Keswick Dam to the Battle Creek Confluence for the NAA and Alternatives 1-4. The Lower Panel Gives the Percent Differences of the Alternatives and the NAA

WYT	NAA	Alt 1	Alt2 wTUCP woVA	Alt2 woTUCP woVA	Alt2 woTUCP DeltaVA	Alt2 woTUCP AllVA	Alt 3	Alt 4
W	14.7	13.6	14.4	14.4	14.7	14.8	13.3	13.6
AN	14.5	10.6	15.1	14.9	15.3	15.4	12.8	11.5
BN	9.2	9.5	8.7	8.6	9.3	10.0	8.6	9.6
D	9.0	8.7	8.6	8.5	9.2	9.5	9.3	8.7
C	6.3	5.9	6.4	7.3	6.2	6.7	7.1	6.7
All	11.0	10.1	10.9	10.9	11.2	11.5	10.5	10.3
WYT	**NAA**	**Alt 1**	**Alt2 wTUCP woVA**	**Alt2 woTUCP woVA**	**Alt2 woTUCP DeltaVA**	**Alt2 woTUCP AllVA**	**Alt 3**	**Alt 4**
W	14.7	-7.6	-2.1	-2.0	0.1	0.8	-9.6	-7.3
AN	14.5	-26.6	4.1	3.3	5.4	6.3	-11.2	-20.7
BN	9.2	2.9	-6.3	-7.2	0.5	8.3	-7.3	3.7
D	9.0	-2.5	-4.1	-5.2	2.8	6.1	3.9	-3.2
C	6.3	-6.8	2.0	15.6	-0.5	6.4	12.7	6.8
All	11.0	-8.6	-1.6	-0.9	1.7	4.5	-5.0	-6.2

The results for fall-run redd dewatering grouped by months indicate that for EIS modeled scenarios redd dewatering has a large range throughout the egg incubation period (Figure L.4-13). The lowest median percent of redds dewatered are similar October through March, during peak egg incubation. The highest median value for redd dewatering occurs September – December under Alternative 2 without TUCP with Systemwide VA and the No Action Alternative. The lowest median value for redd dewatering occurs under Alternative 1 November – February.

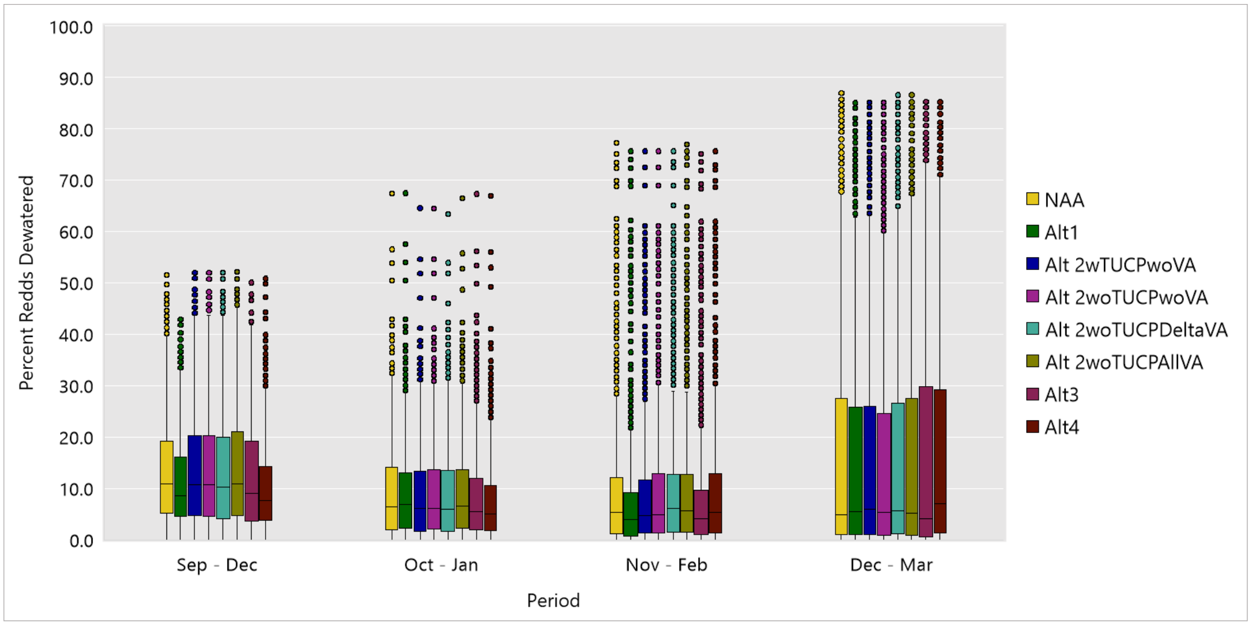

Figure L.4-13. Expected Mean Percent Redds Dewatered for Fall-run Chinook Salmon in the Sacramento River from Keswick Dam to the Battle Creek Confluence for the NAA and Alternatives 1-4, by Incubation Period.

Figure L.4-14 gives the results for fall-run redd dewatering grouped by water year type. The results are the same as those provided in Table L.4-17, but additionally show the variation and range in the results. The four Alternative 2 phases and the NAA are relatively consistent within each water year type. Alternatives 1, 3, and 4 have the lowest median value in Wet and Above Normal years and are relatively similar to the other scenarios in Below Normal, Dry, and Critically Dry years (Figure L.4-14). As noted previously, the higher redd dewatering rates in the wetter years result from greater fluctuations in flow during such years.

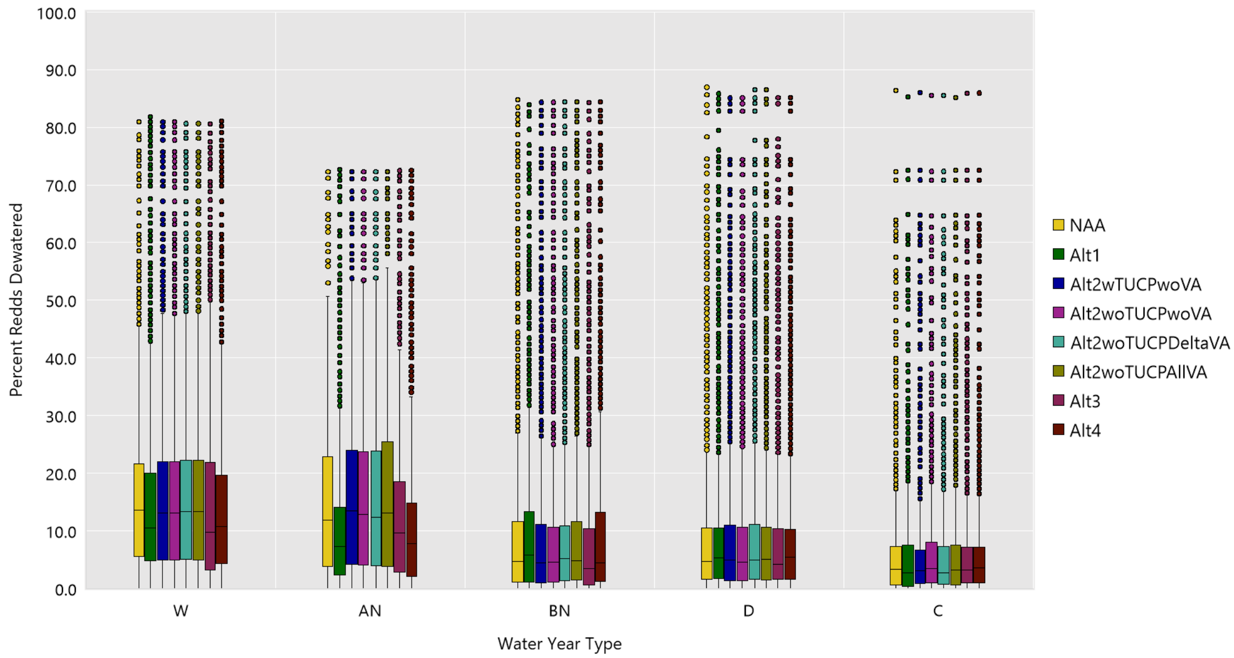

Figure L.4-14. Expected Mean Percent Redds Dewatered for Fall-run Chinook Salmon in the Sacramento River from Keswick Dam to the Battle Creek Confluence for the NAA and Alternatives 1-4, by Water Year Type.

L.4.3.5 Late Fall-run Chinook

Table L.4-18 provides the redd dewatering results for Sacramento River late fall-run Chinook salmon under the EIS modeled scenarios. The results are the means for all years analyzed, weighted by their expected spawning distributions among months (Table L.4-10). The table includes the percent differences between the results of the NAA and for the EIS modeled scenarios alternatives (Table L.4-18).

The results show large and consistent variation in percentage of late fall-run redds dewatered with water year type under the NAA and the EIS and alternatives (Table L.4-18). For the NAA and EIS modeled scenarios, the mean redd dewatering is higher in wet water years than in the other water year types and steadily declines with drier water year types. This pattern of variation reflects flow conditions for the winter and early spring months when late fall-run spawning and incubation occurs. During wet winters and springs, periodic storms and high runoff increase flow fluctuations, which tends to result in greater redd dewatering. In drier years, flow fluctuations are reduced and fewer redds are dewatered. For the EIS modeled scenarios, increases in redd dewatering from the NAA tend to be larger and more frequent than reductions (Table L.4-18). The largest increase is 35.5% for Alt 3 in critical water years and the largest reduction in 39.2% for Alt 2 Without TUCP Delta VA in critical water years. For all alternatives scenarios except Alt

1, the largest differences in redd dewatering from the NAA occur for critical or dry water years (Table L.4-18).

The pattern of variation for late fall-run Chinook redd dewatering resembles that previously reported for steelhead (Table L.4-15 and Table L.4-16). This similarity is expected given that the two races have similar spawning periods (Table L.4-10). The main difference between late fall-run and steelhead redd dewatering is that redd dewatering percentages are higher for steelhead in wet and above normal water years (see Table L.4-16 and Table L.4-18). Such a difference suggests that steelhead redds are more vulnerable than late fall-run redds to dewatering at high, fluctuating flows, as might be true if they tended to spawn at shallower depths, but there no evidence of such a difference has been shown (Gard 2023).

Table L.4-18. Expected Percentage of Redds Dewatered for Late Fall-run Chinook Egg Incubation in the Sacramento River from Keswick Dam to the Battle Creek Confluence for the NAA and Alternatives 1-4. The Lower Panel Gives the Percent Differences of the Alternatives and the NAA

WYT	**NAA**	**Alt 1**	**Alt2 wTUCP woVA**	**Alt2 woTUCP woVA**	**Alt2 woTUCP DeltaVA**	**Alt2 woTUCP AllVA**	**Alt 3**	**Alt 4**
W	29.9	30.5	30.2	30.2	30.1	30.0	30.6	31.3
AN	17.8	20.1	17.7	17.0	17.3	17.1	20.2	18.3
BN	10.1	10.2	10.3	10.2	10.7	10.7	11.2	10.2
D	7.8	7.8	8.2	8.0	8.6	9.2	7.9	7.5
C	2.3	2.3	2.3	2.1	1.4	2.8	3.2	2.7
All	15.0	15.5	15.2	15.0	15.1	15.4	15.8	15.4
WYT	**NAA**	**Alt 1**	**Alt2 wTUCP woVA**	**Alt2 woTUCP woVA**	**Alt2 woTUCP DeltaVA**	**Alt2 woTUCP AllVA**	**Alt 3**	**Alt 4**
W	29.9	1.8	1.0	1.0	0.5	0.3	2.1	4.5
AN	17.8	12.6	-0.8	-4.4	-3.2	-4.2	13.1	2.7
BN	10.1	0.6	1.9	1.2	6.2	5.5	10.2	0.5
D	7.8	0.7	5.4	2.8	10.2	18.7	2.0	-3.1
C	2.3	-0.2	-0.5	-9.9	-39.2	20.2	35.5	15.6
All	15.0	3.4	1.3	0.1	0.8	2.9	5.8	3.1

The results for late fall-run redd dewatering grouped by months indicate that for EIS modeled scenarios redd dewatering has a large range throughout the egg incubation period (Figure L.4-15). The lowest median percent of redds dewatered occurs in March – June across all scenarios. These reduced redd dewatering rates may result from the installation of the ACID Dam beginning in April, which results in reduced flow fluctuation in the reach below Keswick, where most late fall-run Chinook spawn (Table L.4-9). The Keswick reach redd dewatering table for April through October (Table L.4-2) reflects this change. The highest median value for redd dewatering occurs in February – May period under Alternative 1.

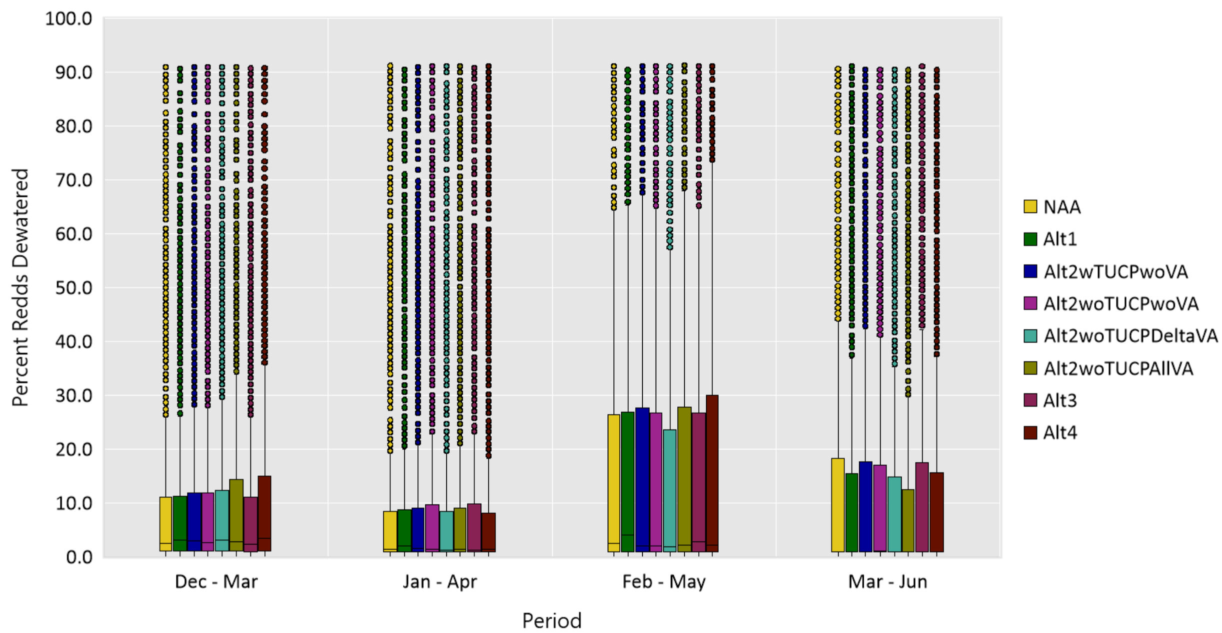

Figure L.4-15. Expected Mean Percent Redds Dewatered for Late Fall-run Chinook Salmon in the Sacramento River from Keswick Dam to the Battle Creek Confluence for the NAA and Alternatives 1-4, by Incubation Period.

Figure L.4-16 gives the results for late fall-run redd dewatering grouped by water year type. The results are the same as those provided in Table L.4-18, but additionally show the variation and range in the results. Critically dry years have the least amount of variation in redd dewatering and below normal, dry, and critical water year types have very low median values. The four Alternative 2 phases and the NAA are relatively consistent within each water year type.

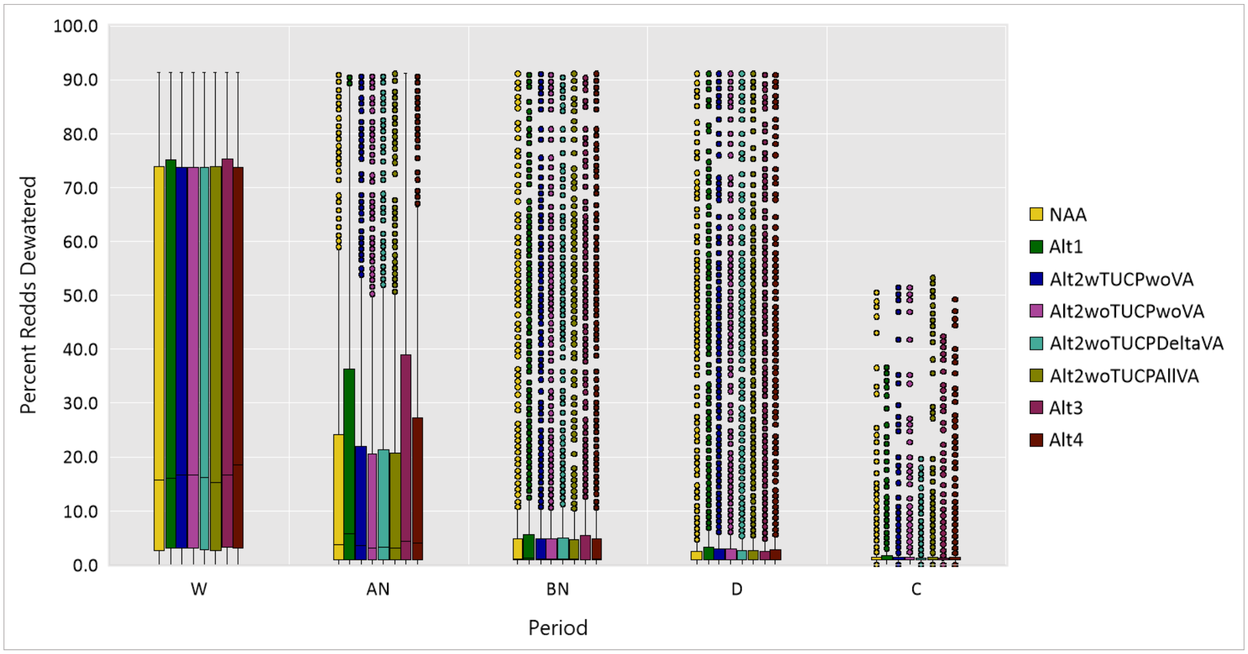

Figure L.4-16. Expected Mean Percent Redds Dewatered for Late Fall-run Chinook Salmon in the Sacramento River from Keswick Dam to the Battle Creek Confluence for the NAA and Alternatives 1-4, by Water Year Type.

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Gard, M. Fish and Wildlife Biologist. U.S. Fish and Wildlife Service. July 5, 2015—Email to Sophie Unger, Senior Fish Biologist, ICF, Sacramento, CA.