2.5.1.2.2.3.2 American River

CCV steelhead eggs and alevins in the American River are vulnerable to dewatering from the time when spawning begins in December through the end of alevin emergence in May. The BA provided modeled results on the estimated percentage of steelhead redds dewatered by reductions in American River flow using CALSIM II estimates of mean monthly flows during the 3 months following each of the months that steelhead spawn. No model for predicting percentages of redds dewatered, such as that developed for the Sacramento River (USFWS 2006), has been developed for the American River. Therefore, the maximum reduction in American River flow for the three months following each of the months during which steelhead spawn was used as a proxy for percent of redds dewatered. CALSIM II flows at Nimbus were used for this analysis. Larger maximum reductions are assumed to increase the percent of redds dewatered and, therefore, to have a negative effect on steelhead. Further information on redd dewatering analysis methods is provided in Appendix 5.D, Section 5.D.2.2, Spawning Flows Methods.

Differences in maximum flow reductions under the PA and NAA were examined using exceedance plots of mean monthly maximum flow reductions, expressed as a percentage of the spawning flows, for the months that American River steelhead spawn (December through February) (BA Figures 5.4-254 through 5.4-259; Figure 2-80 through Figure 2-85).

Exceedance curves for all water year types combined (BA Figure 5.4-254; Figure 2-57) and those for wet, above normal, below normal, and dry water years (BA Tables 5.4-255 through 5.4-258; Figure 2-81 through 2-84) indicate that the PA would generally have slightly greater flow reductions than the NAA. These differences are typically minor, with a magnitude of approximately 5 to 15%. The exceedance curve for critical years appears to indicate a pronounced increase in flow reductions for the PA of up to approximately 40% (Figure 2-85).

However, further inspection, as referenced in the BA, reveals that increased reductions result from differences in only three months out of the 36 critical water year months of the CCV steelhead spawning period in the American River, with all of these months occurring in the same year (1933). The large magnitude of reduced flows in March 1933 under the PA appears to be due to CALSIM II attempting to balance storage levels among the CVP reservoirs, resulting in higher releases from Keswick Dam and lower releases from Folsom for this month.

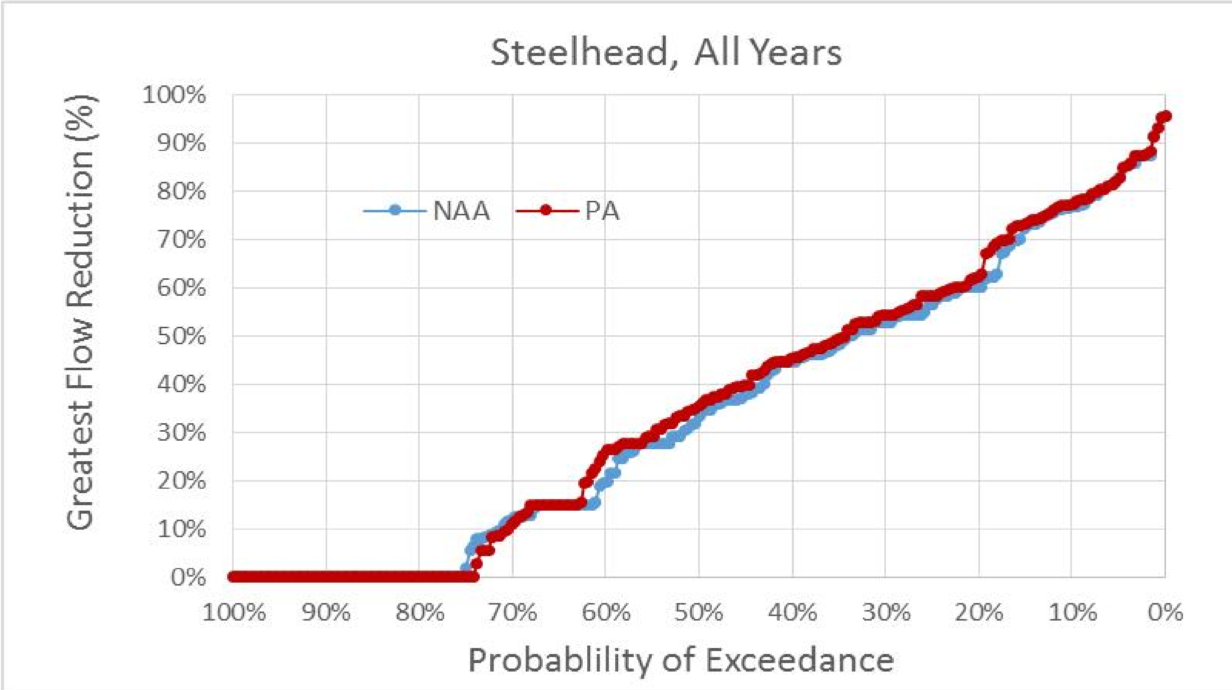

Figure 2-80. Exceedance Plot of Maximum Flow Reductions (Percent) for 3-Month Period After Central Valley Steelhead Spawning for NAA and PA Model Scenarios, All Water Years.

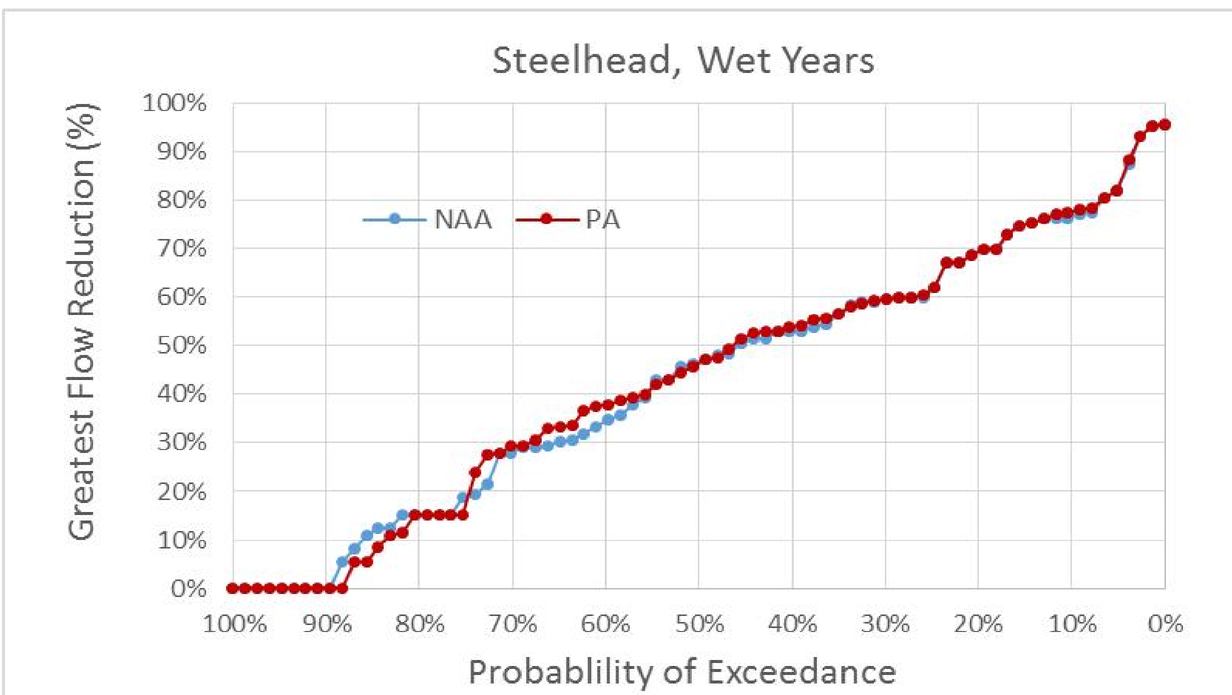

Figure 2-81. Exceedance Plot of Maximum Flow Reductions (Percent) for 3-Month Period After Central Valley Steelhead Spawning for NAA and PA Model Scenarios, Wet Water Years.

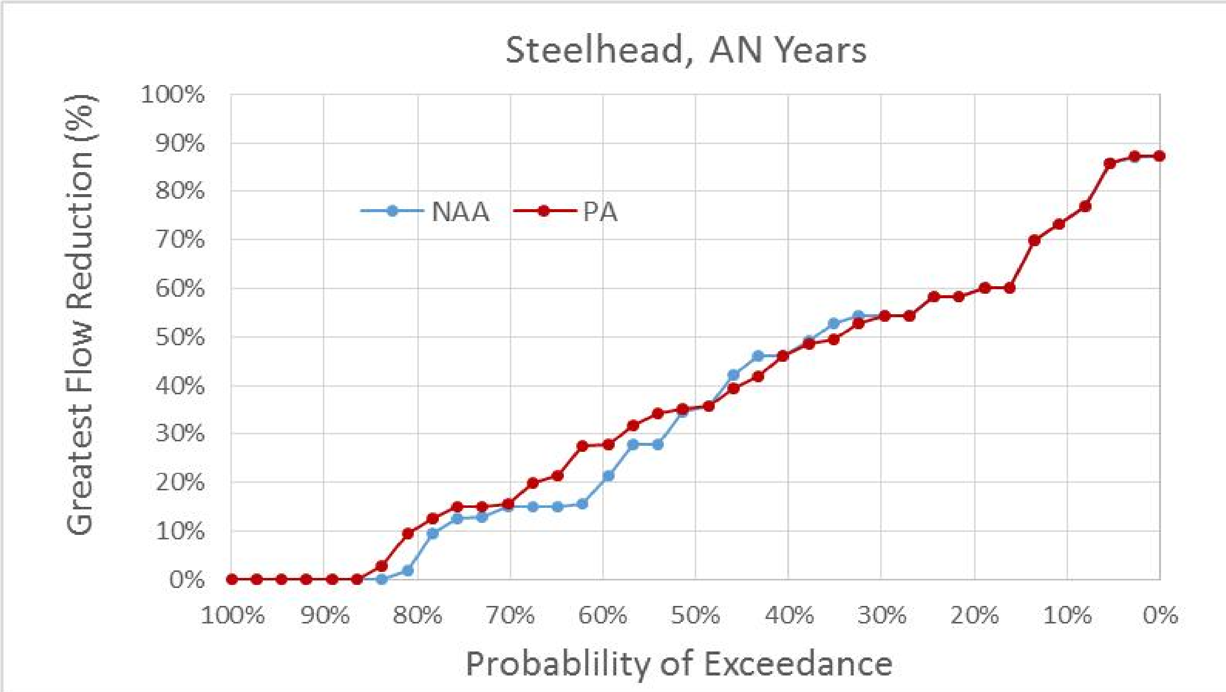

Figure 2-82. Exceedance Plot of Maximum Flow Reductions (Percent) for 3-Month Period After Central Valley Steelhead Spawning for NAA and PA Model Scenarios, Above Normal Water Years.

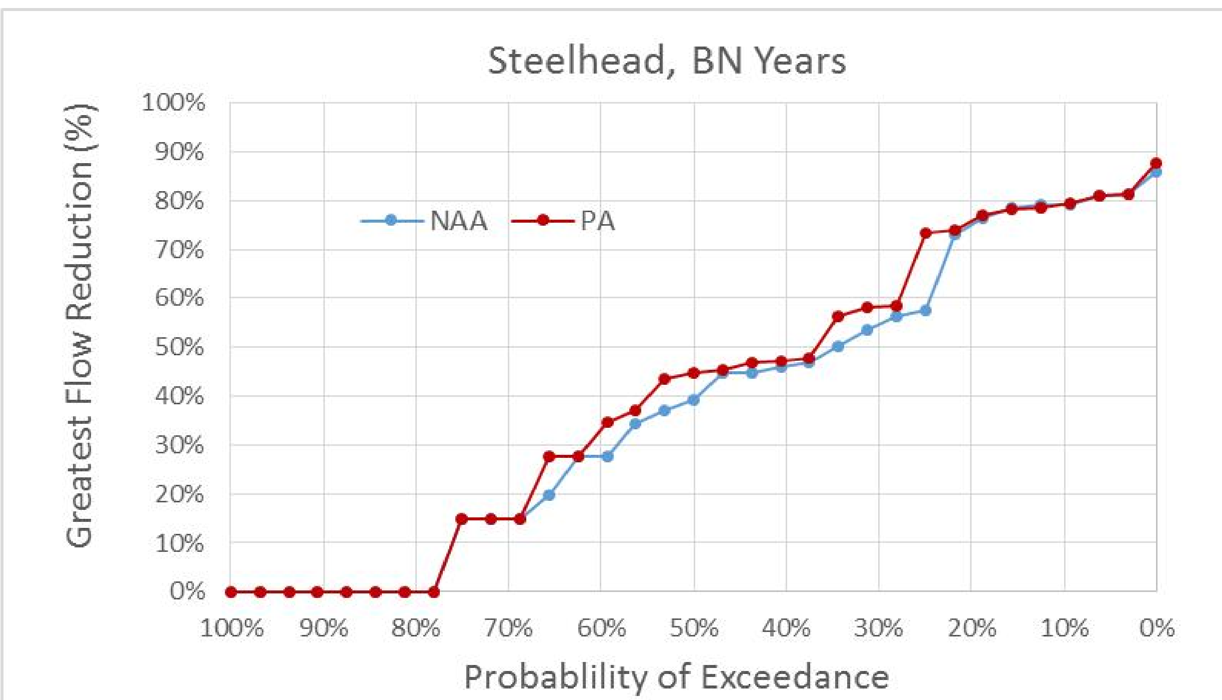

Figure 2-83. Exceedance Plot of Maximum Flow Reductions (Percent) for 3-Month Period After Central Valley Steelhead Spawning for NAA and PA Model Scenarios, Below Normal Water Years.

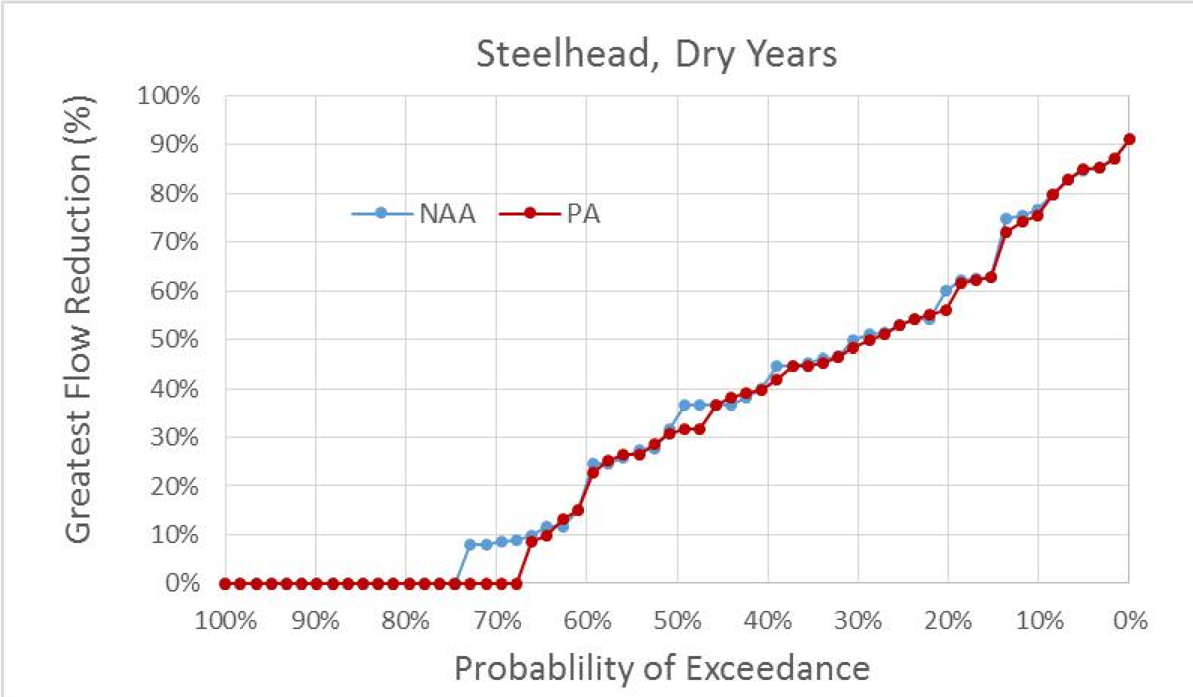

Figure 2-84. Exceedance Plot of Maximum Flow Reductions for 3-Month Period After Central Valley Steelhead Spawning for NAA and PA Model Scenarios, Dry Water Years.

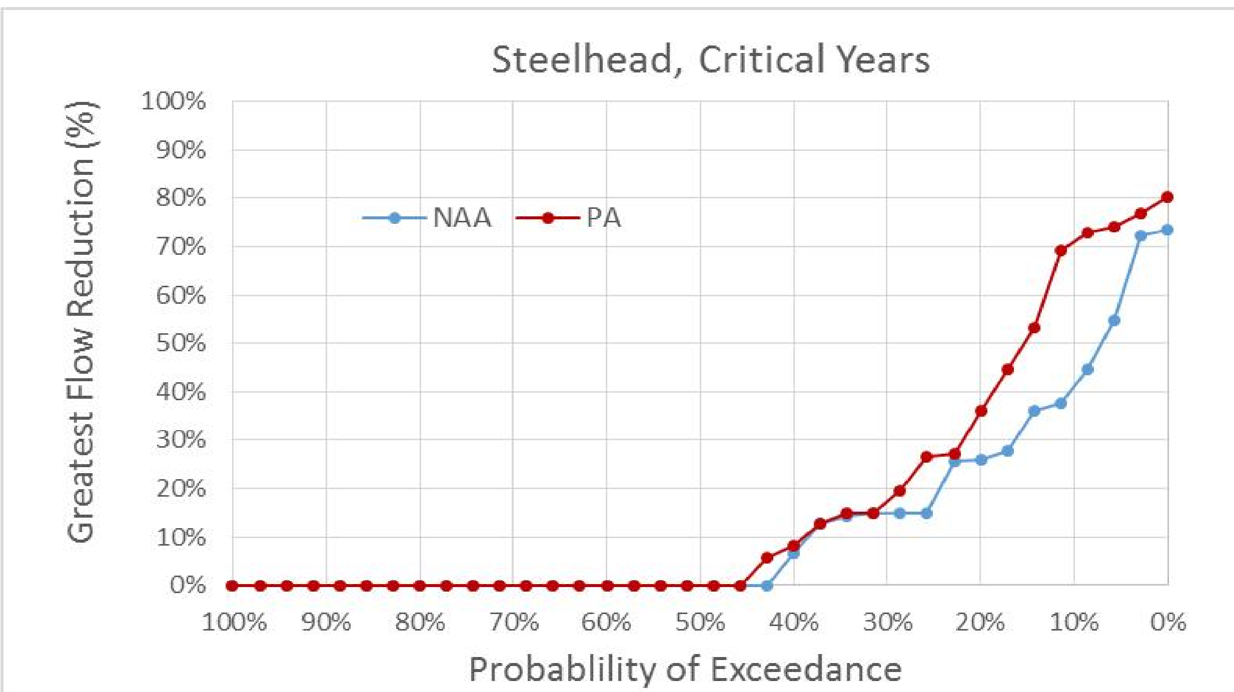

Figure 2-85. Exceedance Plot of Maximum Flow Reductions for 3-Month Period After Central Valley Steelhead Spawning for NAA and PA Model Scenarios, Critical Water Years.

Differences in the mean maximum flow reduction, expressed as a percentage of the spawning flow, for each month of spawning under each water year type and all water year types combined indicate that steelhead redd dewatering would generally be little affected by the PA (less than 5% raw difference), except for a 5% increase in the maximum flow reduction for January of critical years and 6 and 7% increases for February of below normal and critical years, respectively. As previously noted, increases in flow reduction are assumed to increase redd dewatering, negatively affecting steelhead (Table 2-141).

Table 2-141. Maximum Flow Reductions (cfs) for 3-Month Period after Central Valley Steelhead Spawning, and Differences in the Maximums (Percent Differences) Between Model Scenarios. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher[1].)

Month	WYT	Mean Greatest Flow Reduction, as Percent		Raw Difference	Relative (Percent) Difference
		NAA	PA	PA vs. NAA	PA vs. NAA
December	Wet	33.3%	33.5%	0.2%	0.7%
	Above Normal	29.1%	29.0%	-0.1%	-0.2%
	Below Normal	24.3%	24.3%	0.0%	-0.2%
	Dry	35.8%	32.9%	-2.9%	-8.2%
	Critical	15.8%	17.1%	1.3%	8.2%
	All	29.5%	29.0%	-0.5%	-1.6%
January	Wet	42.4%	42.3%	0.0%	-0.1%
	Above Normal	27.0%	26.9%	-0.2%	-0.6%
	Below Normal	40.2%	40.3%	0.1%	0.2%
	Dry	35.8%	36.1%	0.2%	0.6%
	Critical	8.1%	13.2%	5.0%	61.8%
	All	33.0%	33.8%	0.8%	2.3%
February	Wet	53.5%	54.3%	0.8%	1.4%
	Above Normal	50.7%	54.6%	3.9%	7.7%
	Below Normal	50.5%	56.5%	6.0%	11.9%
	Dry	28.1%	27.7%	-0.4%	-1.3%
	Critical	15.8%	22.8%	7.0%	44.5%
	All	41.0%	43.6%	2.6%	6.4%

[1] Increased flow reduction is assumed to increase redd dewatering, negatively affecting steelhead.

2.5.1.2.2.4 Green Sturgeon Exposure and Risk

As previously described, green sturgeon spawning primarily occurs in deep pools containing small to medium sized gravel, cobble or boulder substrate in cool sections of the upper mainstem Sacramento River. Because green sturgeon spawn in deep pools, they are not vulnerable to redd dewatering as a result of flow management in the upper Sacramento River (Benson et al. 2007, Erickson and Webb 2007, Heublein et al. 2008, Poytress et al. 2015).

2.5.1.2.2.5 Fall/Late Fall-run Species Exposure and Risk

2.5.1.2.2.5.1 Sacramento River

2.5.1.2.2.5.1.1 Fall-run Chinook Salmon

Fall-run Chinook salmon eggs and alevins in the Sacramento River are vulnerable to dewatering from the time when spawning begins in September through fry emergence in January (Vogel and Marine 1991). Nearly all fall-run Chinook salmon redds are constructed upstream of Woodson Bridge, with 61% of redds occurring upstream of the Battle Creek confluence (Table 2-3). The redd dewatering analysis presented in the BA and below relies upon the relationships between flow fluctuations and redd dewatering for Chinook salmon in the Sacramento River between Keswick Dam and Battle Creek (USFWS 2006). The flow fluctuation-redd dewatering relationship downstream of Battle Creek is not available, and as such, the analysis covers the Sacramento River upstream of the Battle Creek confluence. Based on the spatial distribution of redds from 2003-2014 (Table 2-102), therefore, 60% of the habitat used for Sacramento River fall-run Chinook salmon spawning and egg incubation was analyzed for potential risks from dewatering, while the remaining 40% spawning habitat downstream of the Battle Creek confluence was not. As described below, the results for redd dewatering for areas of the Sacramento River upstream of the Battle Creek under the PA are in most cases similar to redd dewatering under the NAA. NMFS expects that a similar result would be seen for redds occurring downstream of the Battle Creek.

The percentage of fall-run Chinook salmon redds dewatered by reductions in Sacramento River flow was estimated using CALSIM II estimates of monthly mean flows during the three months following each month of spawning combined with the functional relationships developed in field studies by U.S. Fish and Wildlife Service (2006) that predicted percentages of redds dewatered from an array of paired spawning and dewatering flows (BA Appendix 5D.2.2, Spawning Flows Methods). The analysis estimated fall-run Chinook salmon redd dewatering under the PA and NAA for the three upstream river segments (Segments 4, 5 and 6). River Segment 4 stretches 8 miles from Battle Creek to the confluence with Cow Creek; Segment 5 reaches 16 miles from Cow Creek to the A.C.I.D. Dam; and Segment 6 covers 2 miles from A.C.I.D. Dam to Keswick Dam. Detailed information on redd dewatering analysis methods is provided in the BA in Appendix 5D.2.2, Spawning Flows Methods.

Differences in fall-run Chinook salmon redd dewatering under the PA and NAA were examined using exceedance plots of mean monthly percent of redds dewatered for the September through November months of spawning. Because river Segment 5 is the longest segment and includes the bulk of the analyzed fall-run Chinook salmon spawning area, those results are described in more detail here. The exceedance curves for the PA generally show consistently similar or lower redd dewatering percentages than those for the NAA for all water year types combined, and for wet and above normal water year types (Figure 2-92 through Figure 2-94). The biggest differences in the dewatering curves are predicted for wet water years, with about 61% of all months having greater than 20% of redds dewatered under the NAA, but only 40% of all months having greater than 20% of redds dewatered under the PA (Figure 2-93). Results for Segment 6 (Figure 2-86) through (Figure 2-91) and Segment 4 (Figure 2-97 through Figure 2-103) are similar to those for Segment 5 (BA) in that the PA generally shows consistently similar or lower redd dewatering percentages than for the NAA for all water year types combined, and for wet and above normal water year types.

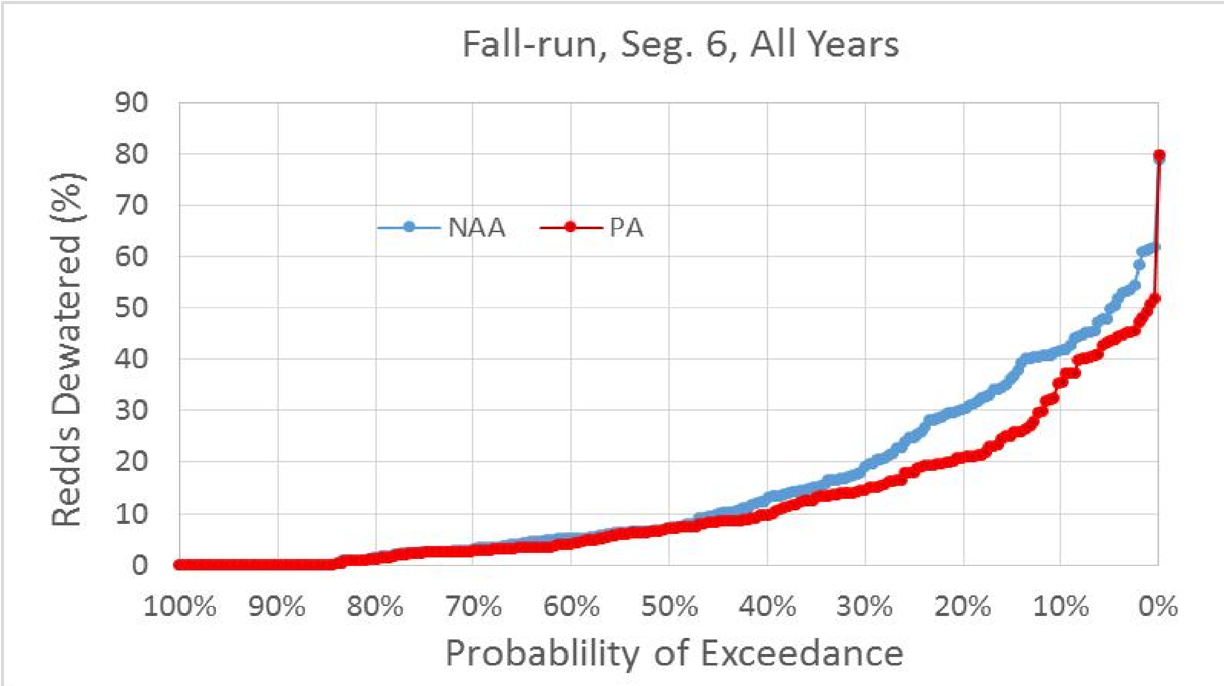

Figure 2-86. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 6, All Water Years.

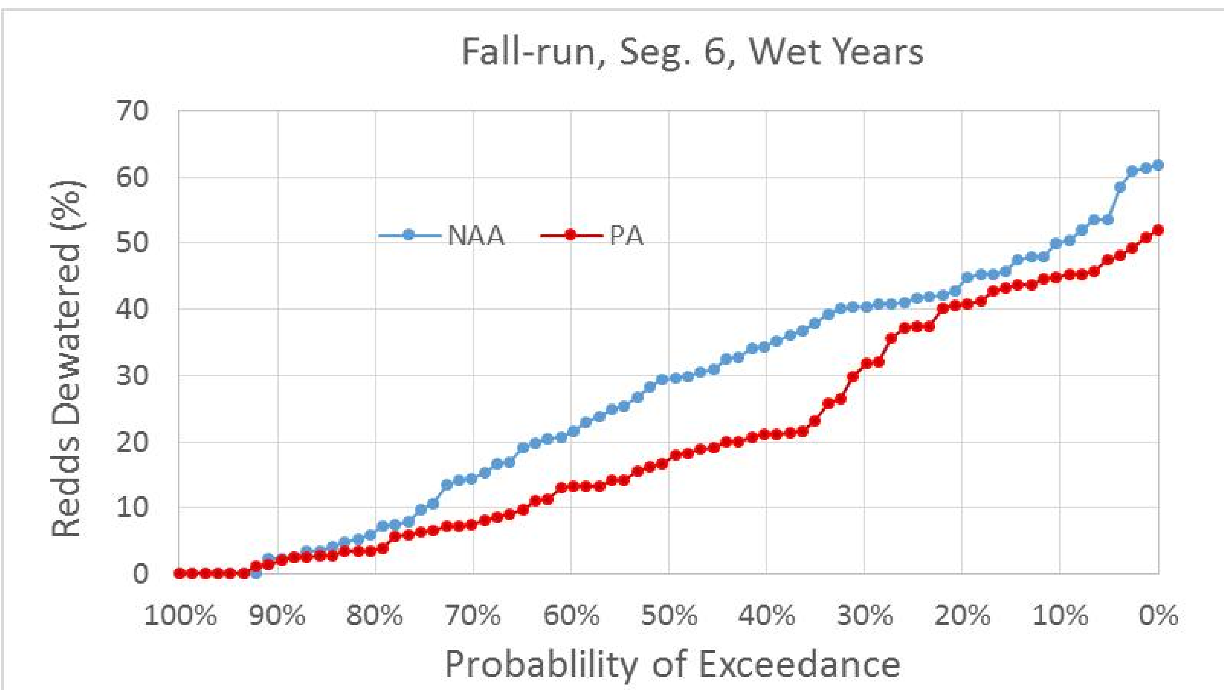

Figure 2-87. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 6, Wet Water Years.

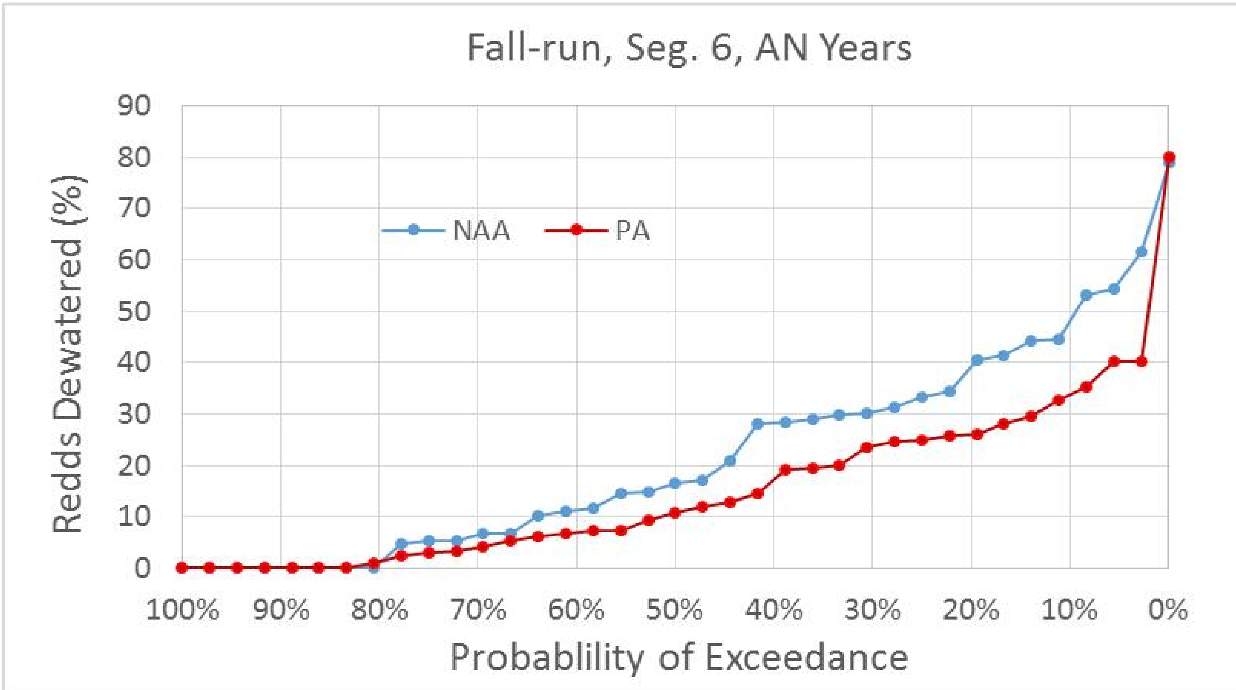

Figure 2-88. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 6, Above Normal Water Years.

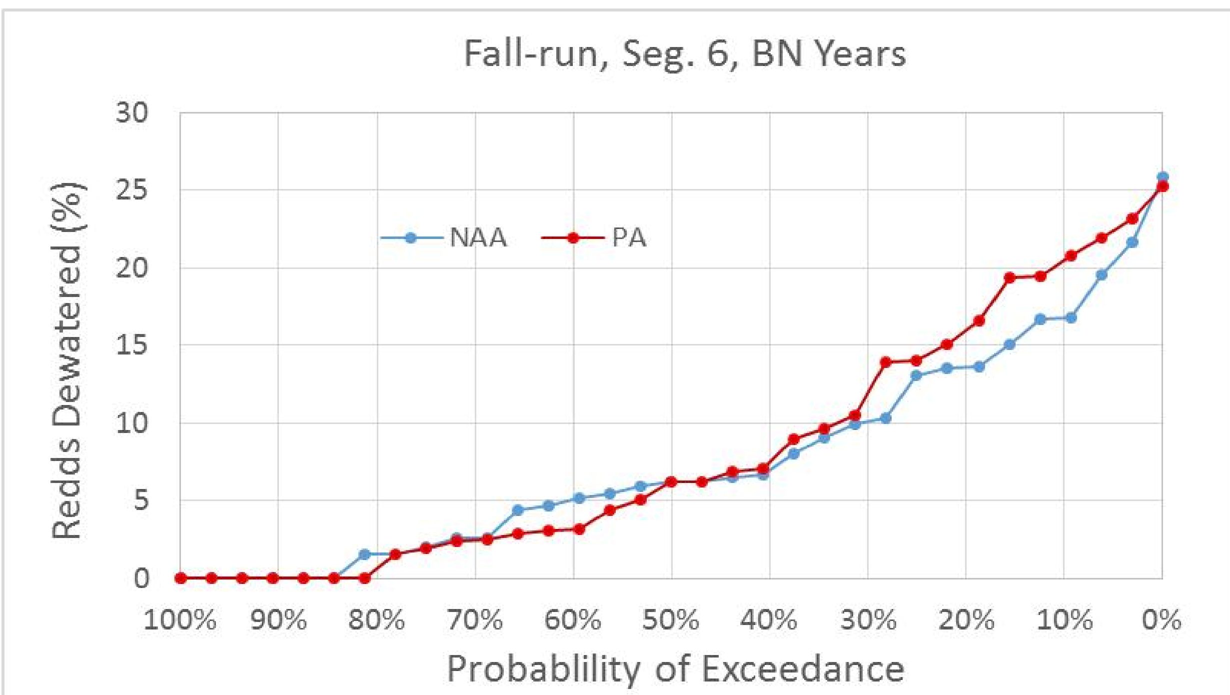

Figure 2-89. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 6, Below Normal Water Years.

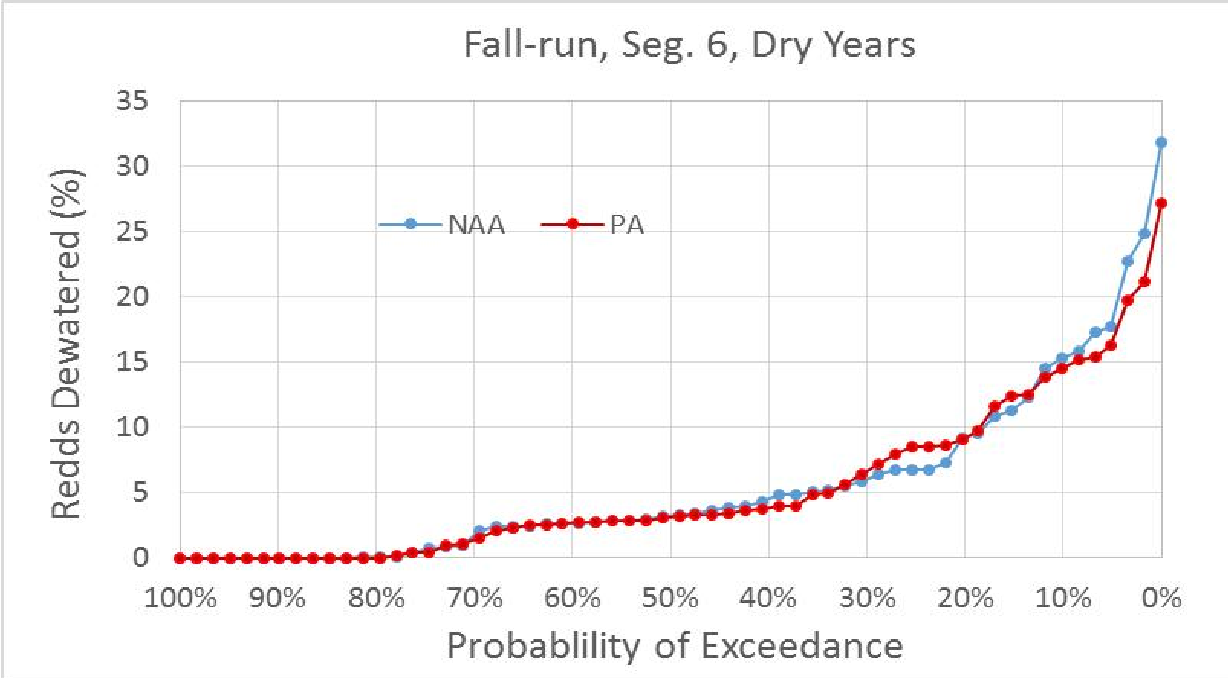

Figure 2-90. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 6, Dry Water Years.

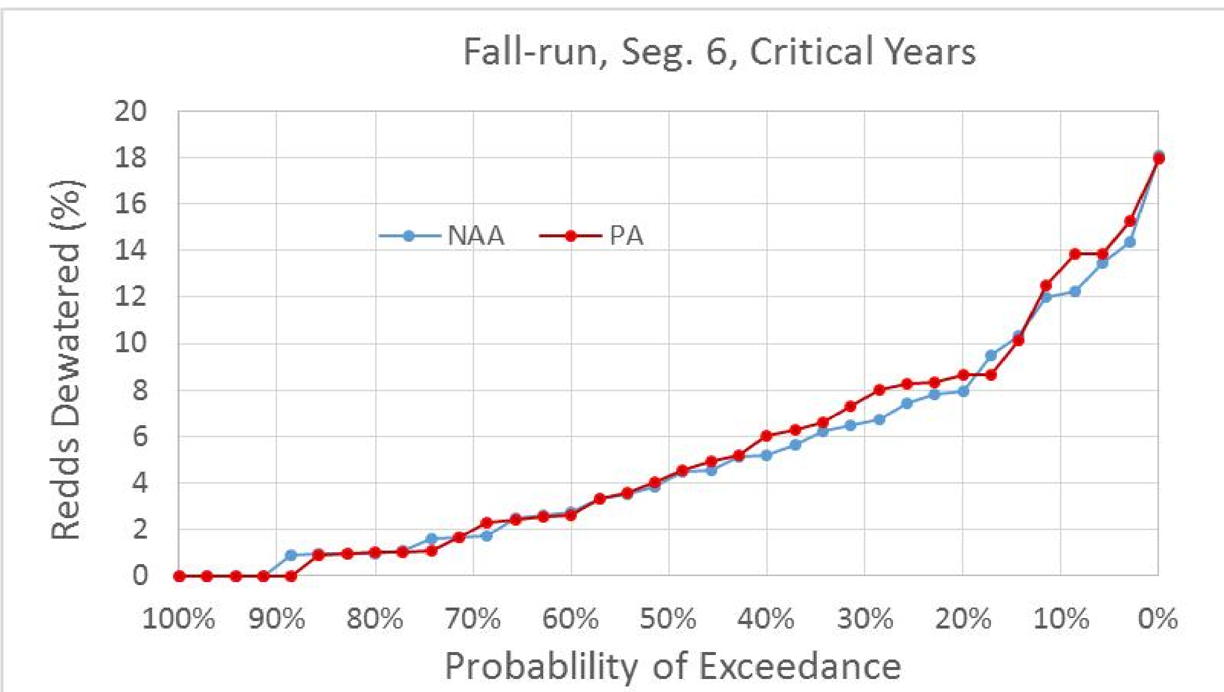

Figure 2-91. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 6, Critical Water Years.

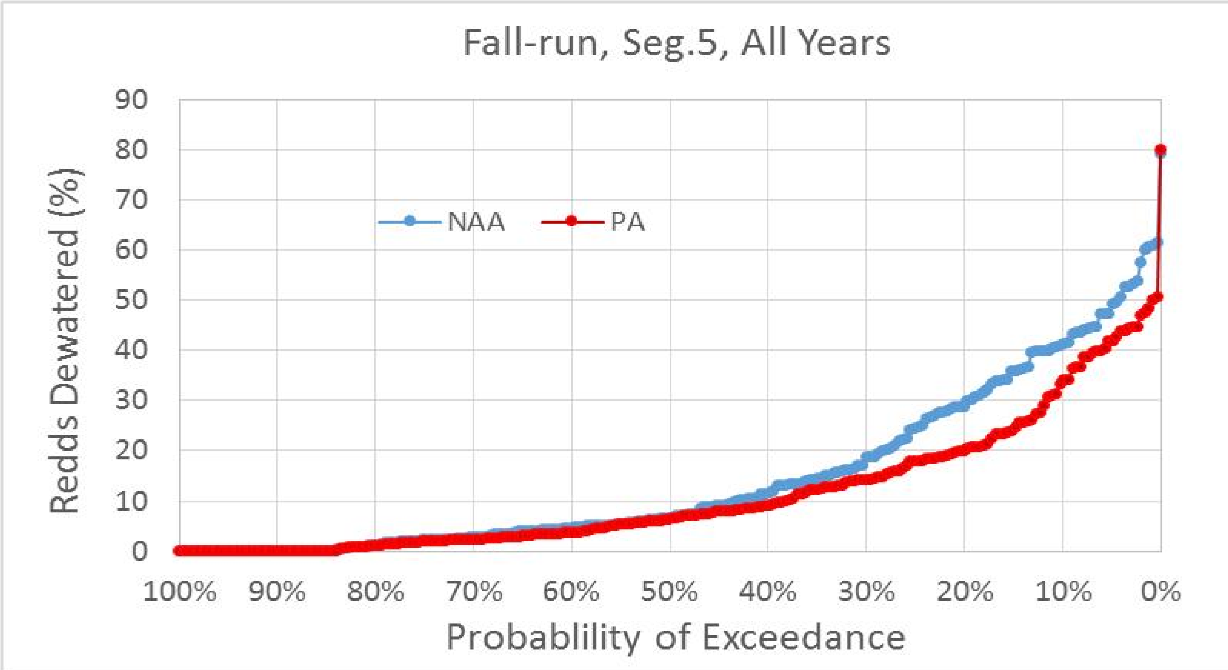

Figure 2-92. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 5, All Water Years.

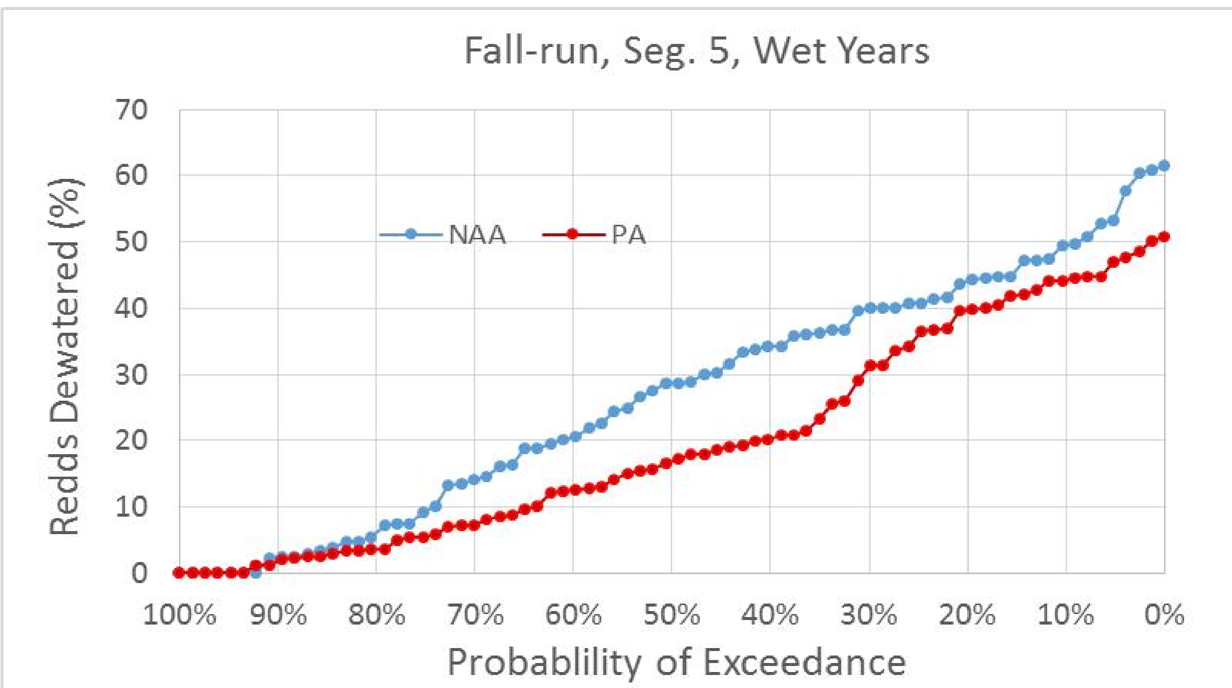

Figure 2-93. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 5, Wet Water Years.

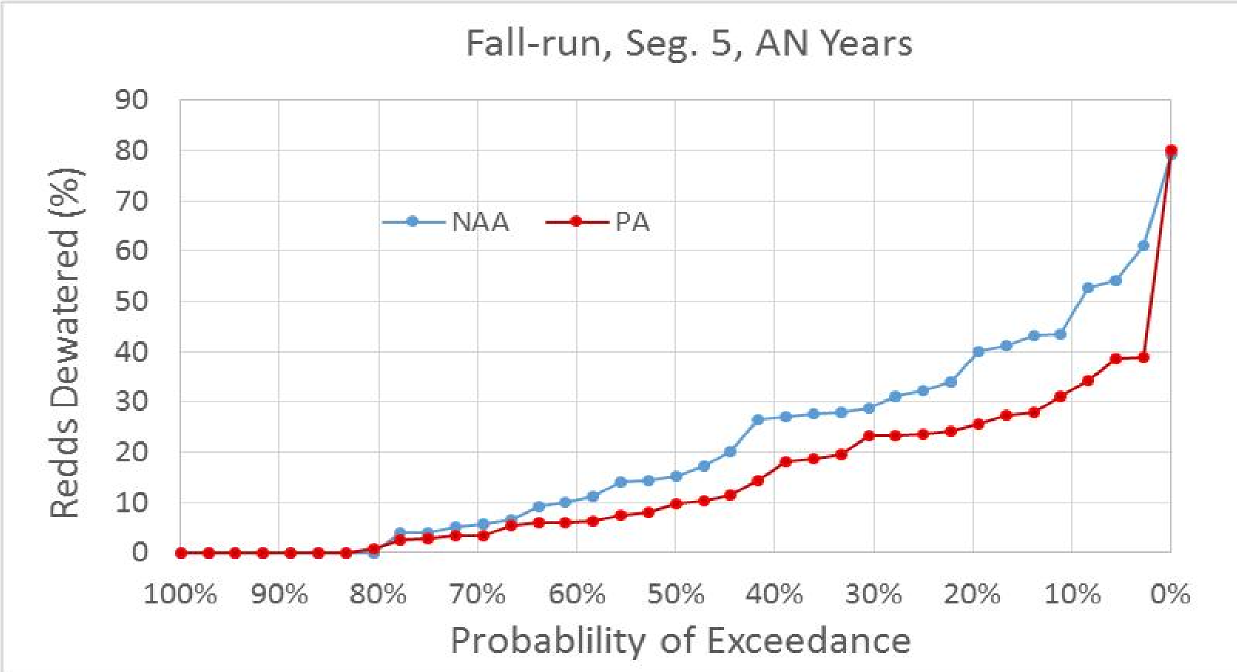

Figure 2-94. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 5, Above Normal Water Years.

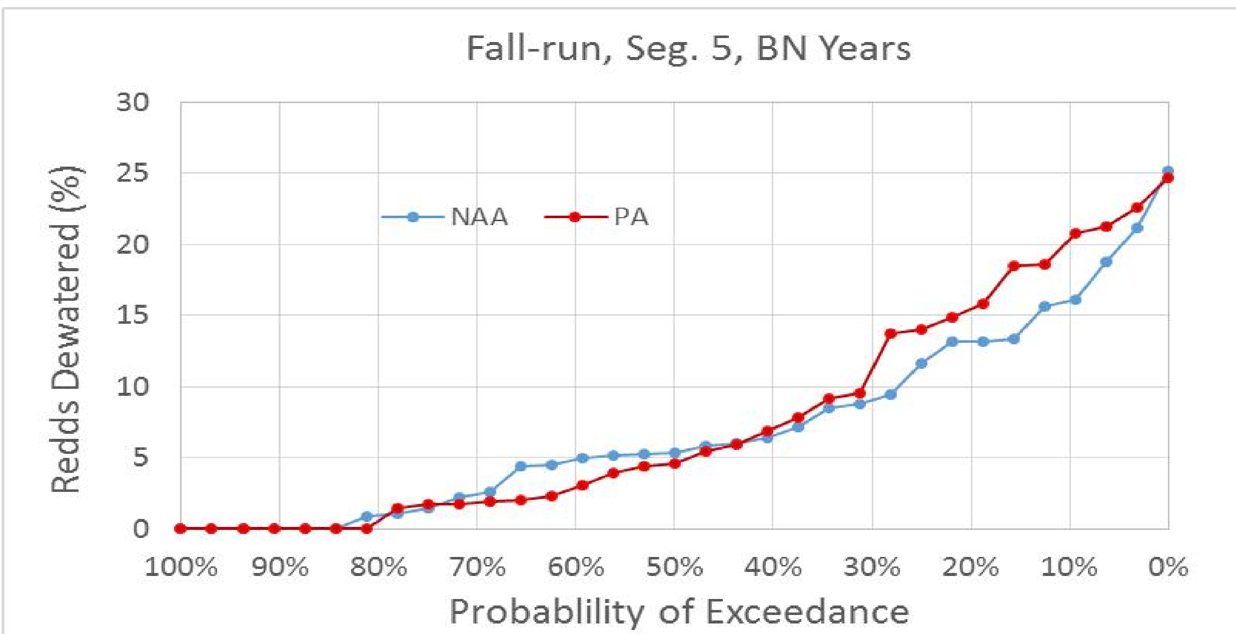

Figure 2-95. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 5, Below Normal Water Years.

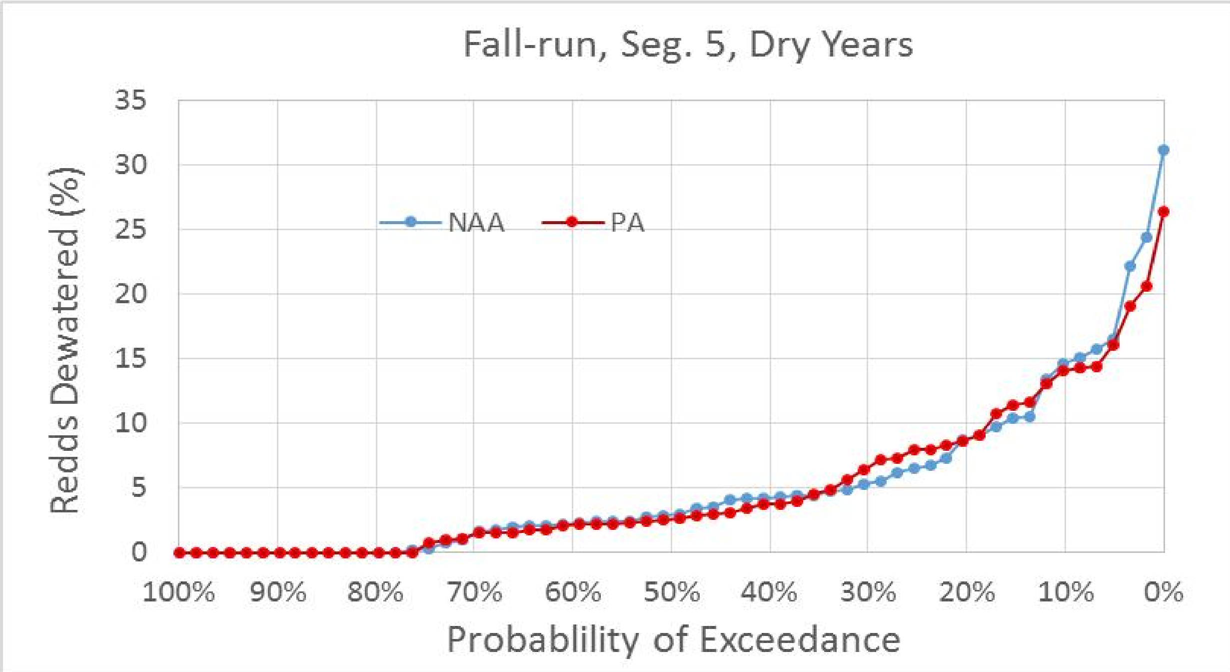

Figure 2-96. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 5, Dry Water Years.

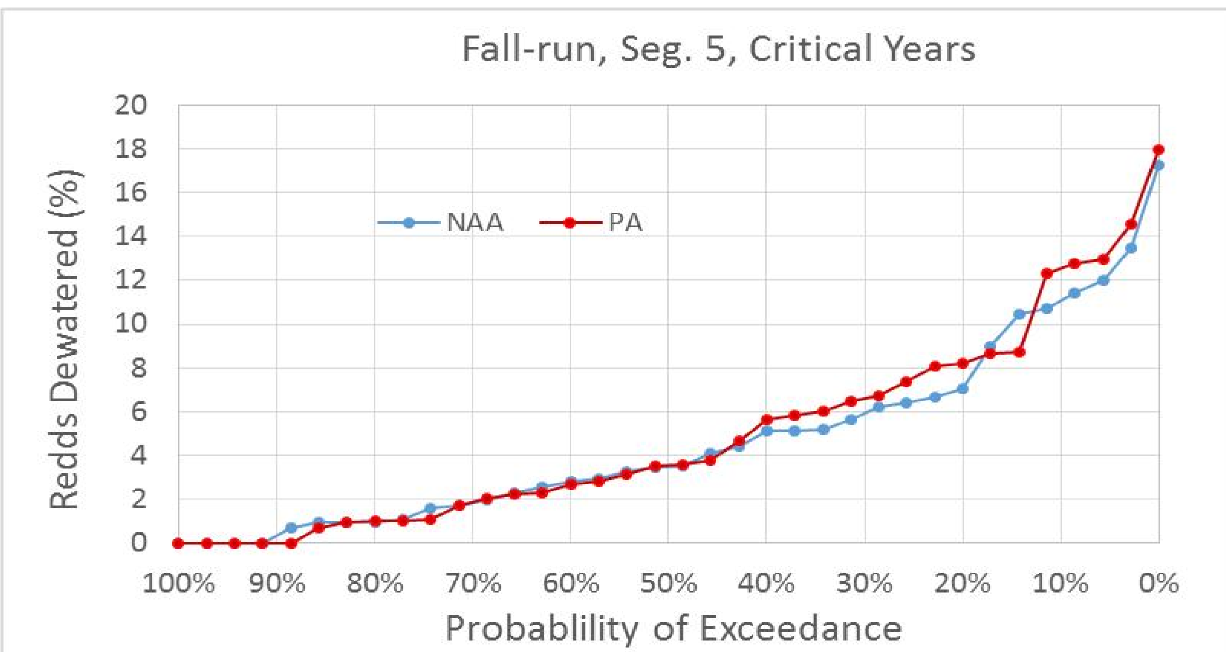

Figure 2-97. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 5, Critical Water Years.

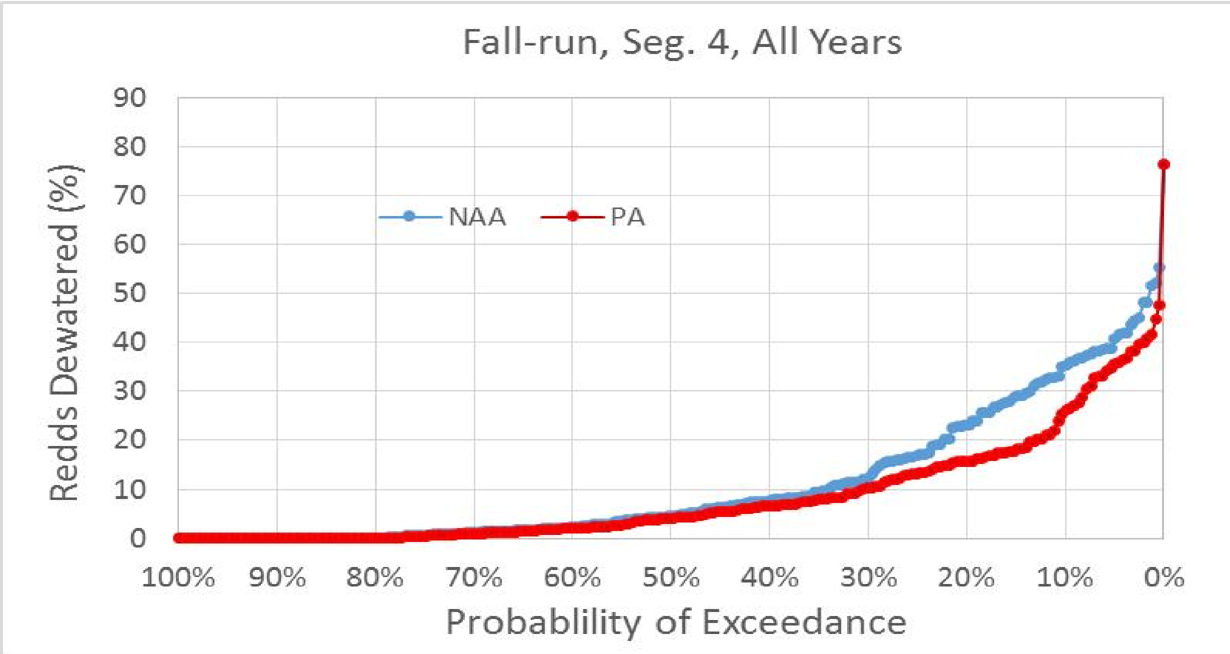

Figure 2-98. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 4, All Water Years.

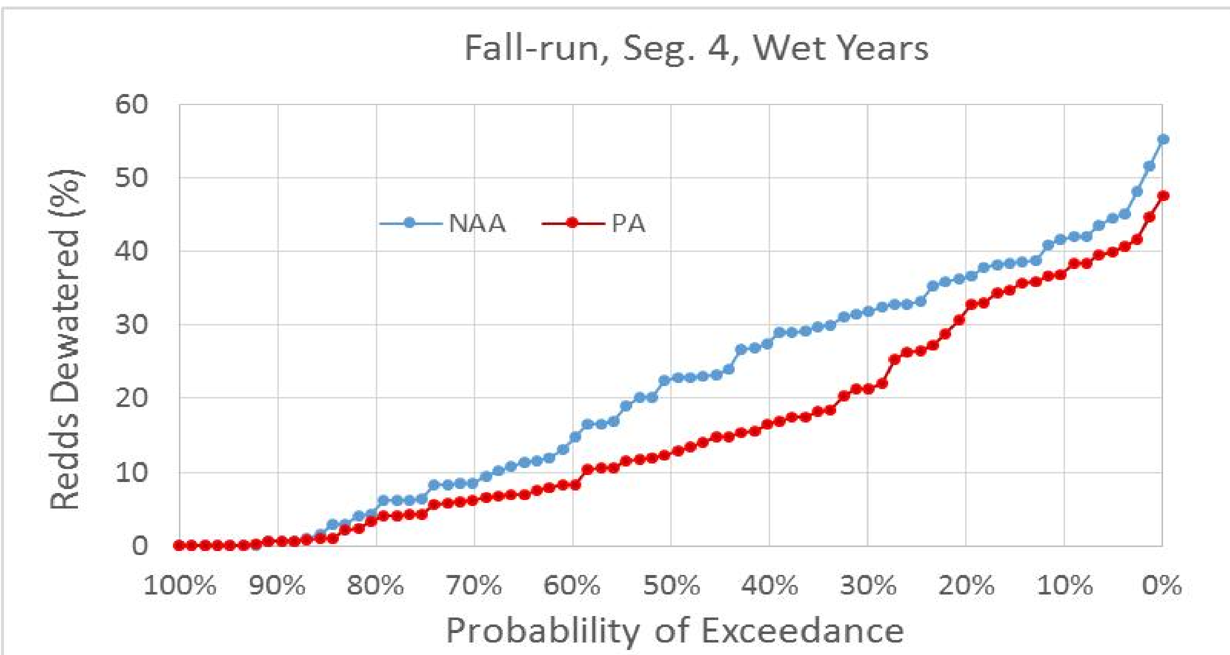

Figure 2-99. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 4, Wet Water Years.

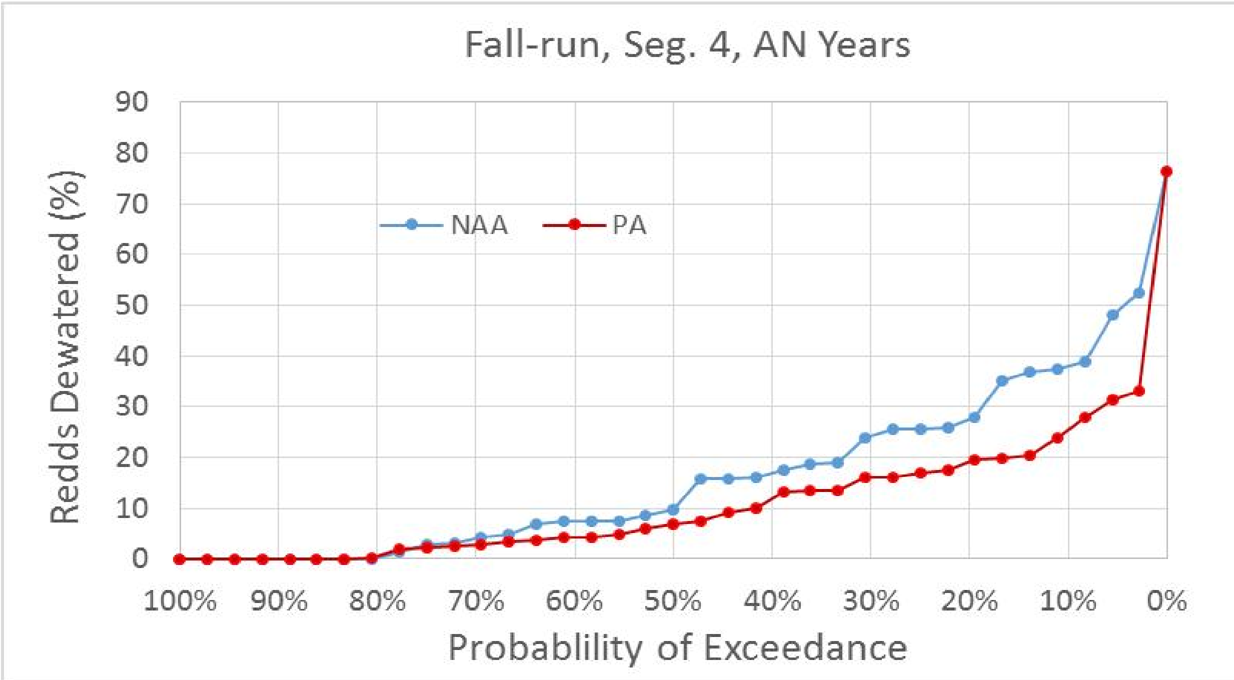

Figure 2-100. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 4, Above Normal Water Years.

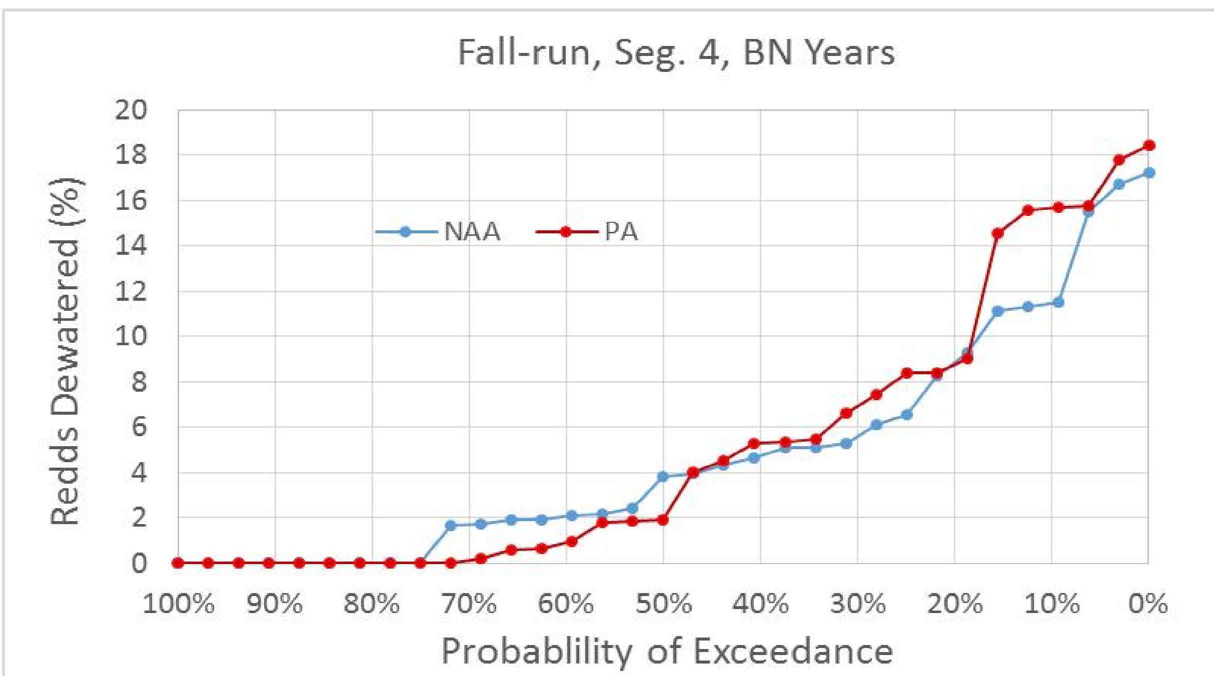

Figure 2-101. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 4, Below Normal Water Years.

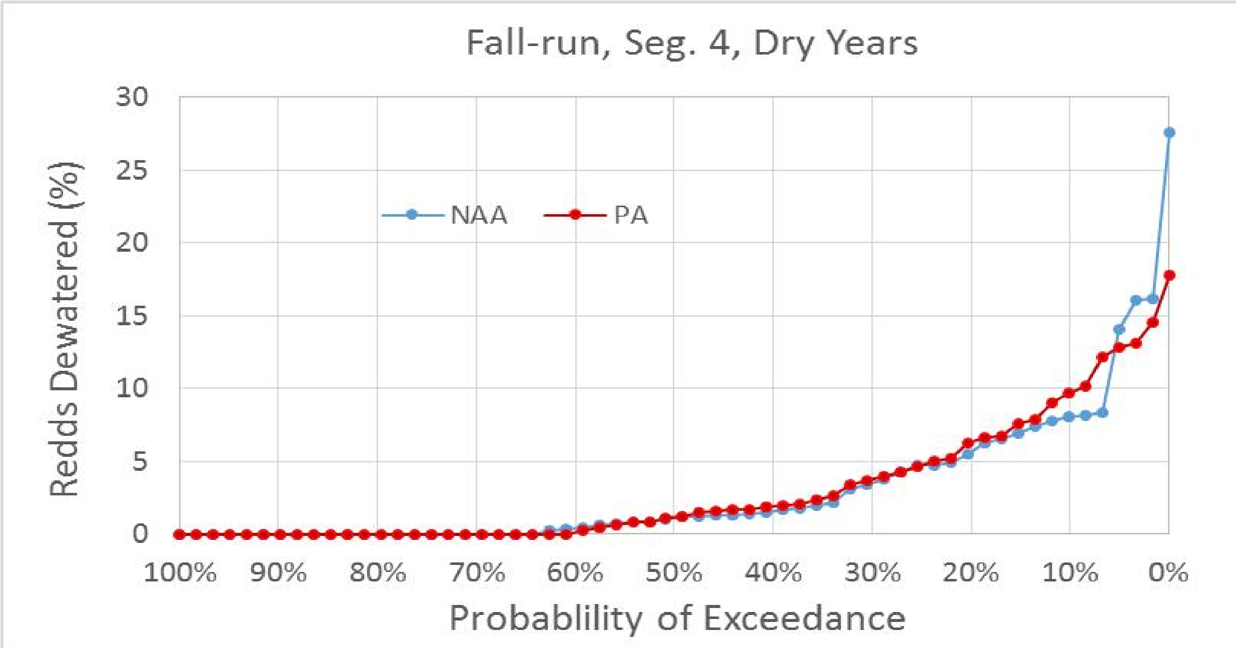

Figure 2-102. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 4, Dry Water Years.

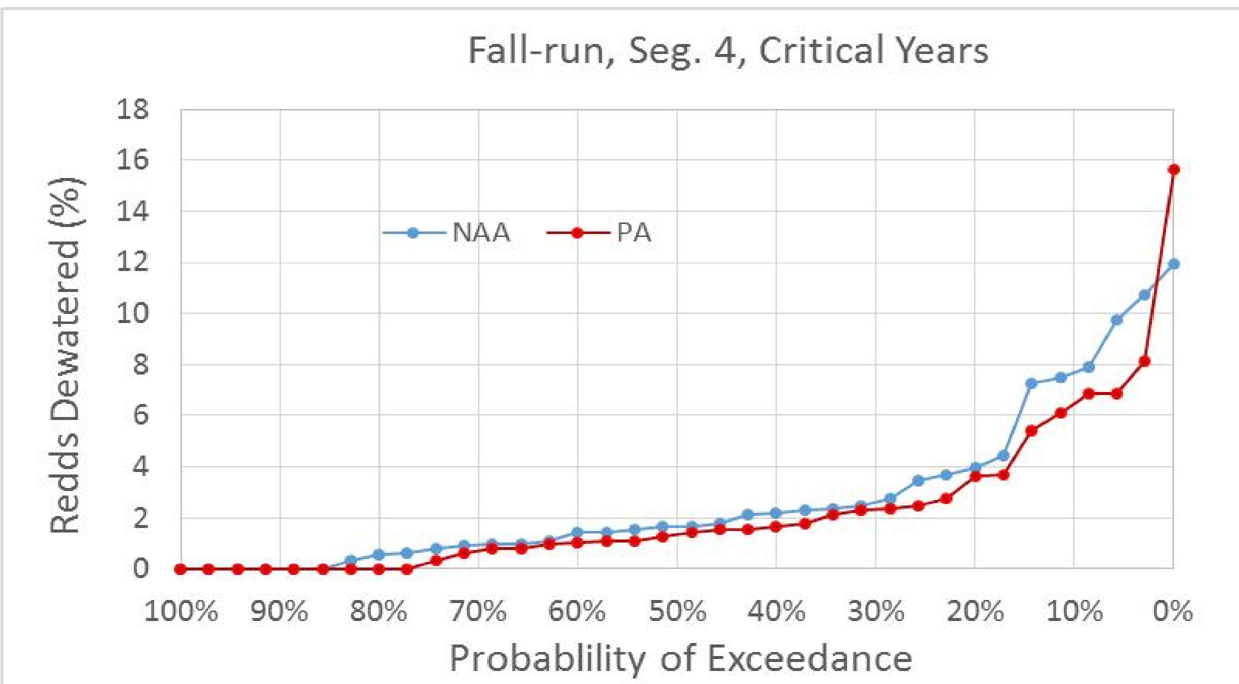

Figure 2-103. Exceedance Plot of Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 4, Critical Water Years.

The exceedance curves show that the PA would not increase redd dewatering under most water year types relative to the NAA.

Tabular results from the BA show that differences between the PA and NAA in the mean percentage of redds dewatered in each river segment for each month of spawning under each water year type and all water year types combined would be minimal. The exception is moderate reductions in the mean percent of redds dewatered during November of wet and above normal water year types in all three river segments and a small increase in October of below normal years in river segments 5 and 6 (Table 2-142 through Table 2-143). The percent differences between the PA and the NAA in the percent of redds dewatered range up to a 208% increase under the PA for November of critical water years in Segment 4 (Table 2-144). However, this increase and most of the large relative changes in percent of redds dewatered are artifacts of the low percentages of redds dewatered under both scenarios that were used in computing the percent changes.

Similar to the redd dewatering exceedance plots, the tabular results show little difference in redd dewatering risk between the PA and NAA. However, for purposes of the analysis in Section 2.7 Integration and Synthesis of the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts, the impact to fall-run Chinook salmon is a concern, particularly in wet years. During November of wet years, the percentage of dewatered redds ranges between 15 and 36% across all river segments for the PA. Redd dewatering under the PA in November of dry years is much lower compared to wet years, ranging between just 3 and 5%.

Table 2-142. Fall-run Chinook Salmon Percent of Redds Dewatered (Percent of Total Redds) and Differences (Percent Differences) in River Segment 6 Between Model Scenarios. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	NAA	PA	PA vs. NAA
	Wet	31.1	33.0	2 (6%)
	Above Normal	19.0	17.7	-1.25 (-7%)
	Below Normal	6.5	3.4	-3 (-47%)
	Dry	3.9	2.6	-1.3 (-33%)
	Critical	6.9	5.3	-1.6 (-24%)
September	All	15.7	15.2	-0.5 (-3%)
October	Wet	15.0	10.3	-4.7 (-32%)
	Above Normal	13.0	13.6	0.7 (5%)
	Below Normal	9.5	15.9	6.4 (67%)
	Dry	8.2	10.3	2.1 (25%)
	Critical	7.0	6.4	-0.6 (-8%)
	All	11.1	11.0	-0.1 (-1%)
November	Wet	35.9	18.7	-17.2 (-48%)
	Above Normal	33.9	15.2	-18.7 (-55%)
	Below Normal	7.2	5.4	-1.8 (-25%)
	Dry	4.7	3.2	-1.5 (-31%)
	Critical	1.6	4.5	2.9 (176%)
	All	18.9	10.4	-8.5 (-45%)

Table 2-143. Fall-run Chinook Salmon Percent of Redds Dewatered (Percent of Total Redds) and Differences (Percent Differences) in River Segment 5 between Model Scenarios. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	NAA	PA	PA vs. NAA
	Wet	30.2	31.9	1.7 (6%)
	Above Normal	17.9	16.5	-1.5 (-8%)
	Below Normal	5.6	2.7	-2.9 (-52%)
	Dry	3.1	1.9	-1.2 (-38%)
	Critical	6.0	4.4	-1.6 (-26%)
September	All	14.8	14.2	-0.6 (-4%)
October	Wet	14.5	9.9	-4.6 (-32%)
	Above Normal	12.4	13.1	0.6 (5%)
	Below Normal	9.1	15.4	6.3 (70%)
	Dry	7.9	9.9	2 (26%)
	Critical	6.7	6.1	-0.6 (-9%)
	All	10.7	10.6	-0.1 (-1%)
November	Wet	35.6	18.5	-17.1 (-48%)
	Above Normal	33.7	15.2	-18.5 (-55%)
	Below Normal	7.0	5.2	-1.8 (-25%)
	Dry	4.7	3.3	-1.4 (-30%)
	Critical	1.6	4.5	2.9 (178%)
	All	18.8	10.4	-8.4 (-45%)

Table 2-144. Fall-run Chinook Salmon Percent of Redds Dewatered (Percent of Total Redds) and Differences (Percent Differences) in River Segment 4 Between Model Scenarios. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	NAA	PA	PA vs. NAA
	Wet	24.9	26.5	1.6 (6%)
	Above Normal	13.5	12.2	-1.39 (-10%)
	Below Normal	3.1	1.2	-1.9 (-63%)
	Dry	1.0	0.6	-0.4 (-37%)
	Critical	3.5	1.7	-1.8 (-51%)
September	All	11.2	10.9	-0.3 (-3%)
October	Wet	9.3	6.6	-2.7 (-29%)
	Above Normal	8.9	10.0	1.1 (12%)
	Below Normal	6.4	10.9	4.4 (69%)
	Dry	5.0	6.2	1.3 (25%)
	Critical	4.0	2.8	-1.3 (-31%)
	All	7.0	7.0	0 (0%)
November	Wet	29.8	15.3	-14.5 (-49%)
	Above Normal	28.2	12.6	-15.6 (-55%)
	Below Normal	5.1	3.5	-1.6 (-31%)
	Dry	3.4	2.5	-0.9 (-27%)
	Critical	0.8	2.6	1.7 (208%)
	All	15.4	8.2	-7.2 (-46%)

SALMOD results presented in the BA (Error! Reference source not found.) are another source of information suggesting that redd dewatering in the Sacramento River is a concern for purposes of the analysis in Section 2.7 Integration and Synthesis of the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts, especially in wet years comes. The SALMOD model provides predicted flow-related mortality of fall-run Chinook salmon spawning, eggs and alevins in the Sacramento River. The SALMOD results for flow-related mortality are presented in Error! Reference source not found.. The flow-related mortality of fall-run Chinook salmon spawning, eggs, and alevins is divided into "incubation" (which refers to redd dewatering and scour) and "superimposition" (which refers to redd overlap) mortality (see Attachment 5.D.2, SALMOD Model). The number of fall-run Chinook salmon eggs and alevins predicted to die from redd dewatering and scour during incubation ranges from 94,913 in above normal years to 4,066,702 in wet years, with an average over all water year types of 1,477,164 (Reclamation 2016).

Collectively, the estimated percentage of redd dewatering presented in the exceedance plots (Figure 2-86 through Figure 2-103) and (Table 2-142 through Table 2-144) indicate that Sacramento River redd dewatering under the PA is a high magnitude stressor to fall-run Chinook salmon in wet years and a medium stressor under relatively dry conditions. The SALMOD results show that the combined effect of redd dewatering and scour under the PA places a high magnitude stress on fall-run Chinook salmon in the Sacramento River. The certainty of these magnitude rankings is medium given the limitations of using results based on monthly flows to understand the magnitude of impacts that occur over daily time scale. In addition, only 61% of the spawning habitat was evaluated which leaves uncertainty about the red dewatering impacts to the remaining 40% of spawning habitat.

2.5.1.2.2.5.1.2 Late Fall-run Chinook Salmon

Late fall-run Chinook salmon eggs and alevins in the Sacramento River are vulnerable to dewatering from the time when spawning begins in December through June when fry emergence from the streambed ends (Vogel and Marine 1991, U.S. Department of the Interior 2016). The vast majority of late fall-run Chinook salmon redds are distributed in the upper portion of the Sacramento River, with 68% occurring upstream of ACID Dam and 94% occurring upstream of Red Bluff Diversion Dam (BA Table 5.D.1-1 in Appendix 5D Attachment 1).

The percentage of late fall-run Chinook salmon redds dewatered by reductions in Sacramento River flow was estimated from CALSIM II estimates of monthly mean flows during the 3 months following each month of spawning (BA Appendix 5.D.2.2, Spawning Flows, Methods, Table 5-4-2). This analysis employed functional relationships developed in field studies by the U.S. Fish and Wildlife Service (2006) that predicted percentages of redds dewatered from an array of paired spawning and dewatering flows. CALSIM II flows for the three upstream river segments (segments 4, 5 and 6) were used to estimate redd dewatering under the PA and NAA. Note that unlike the analyses used to model weighted usable area, the analysis used to model redd dewatering combines the field observations of water depth, flow velocity, and substrate from the three river segments and, therefore, differences in redd dewatering estimates among the segments result only from differences in the CALSIM II flows. Further information on redd dewatering analysis methods is provided in the BA in Appendix 5.D.2.2, Spawning Flows, Methods.

Differences in late fall-run Chinook salmon redd dewatering under the PA and NAA were examined using exceedance plots of mean monthly percent dewatered for the December through April spawning months[8] (see Figures 5.E-168 through 5.E-185 in the BA). Because 67% of late fall-run Chinook salmon spawning occurs in river Segment 6 and the results for segments 4 and 5 are similar to those for Segment 6, conclusions regarding effects are primarily based on the Segment 6 results (Figure 2-104 through Figure 2-109). The exceedance curves show little difference between the PA and the NAA in the percentage of redds dewatered for all water years combined or for individual water year types, except for marginally greater redd dewatering under the PA for wet years (Figure 2-105).

[8] Analyzing redd dewatering for three months following December through April covers the full time period (i.e., December through June) that eggs and alevins are in the streambed and thus vulnerable to redd dewatering.

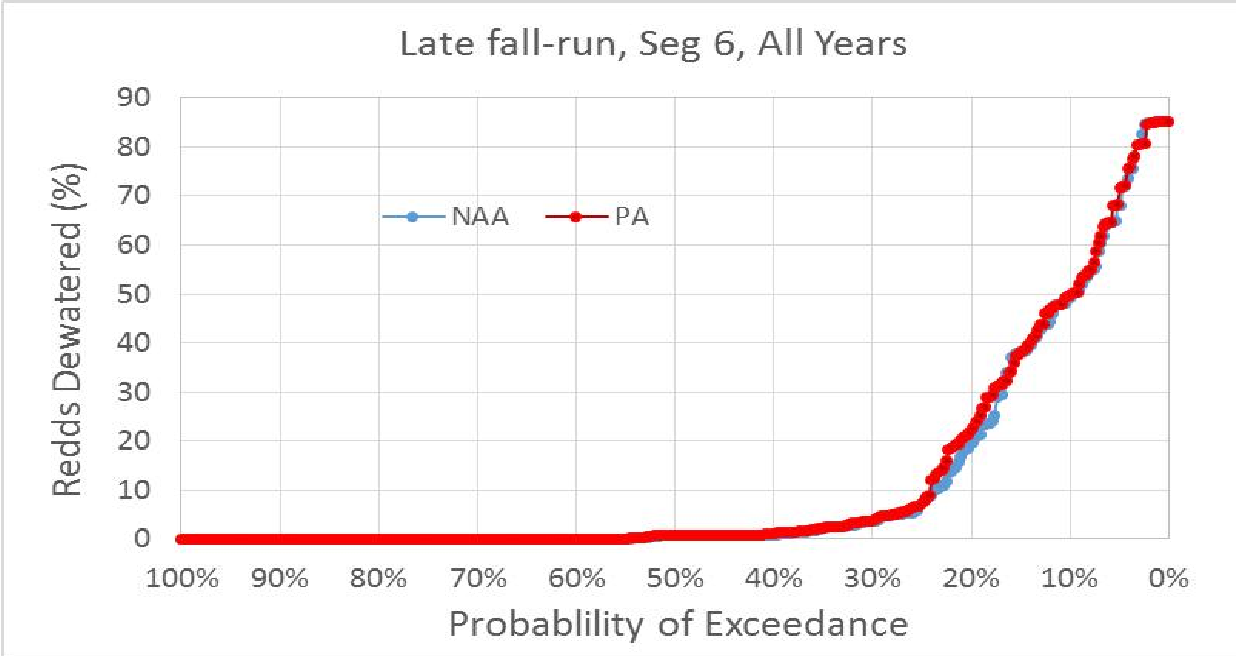

Figure 2-104. Exceedance Plot of Late Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 6, All Water Years.

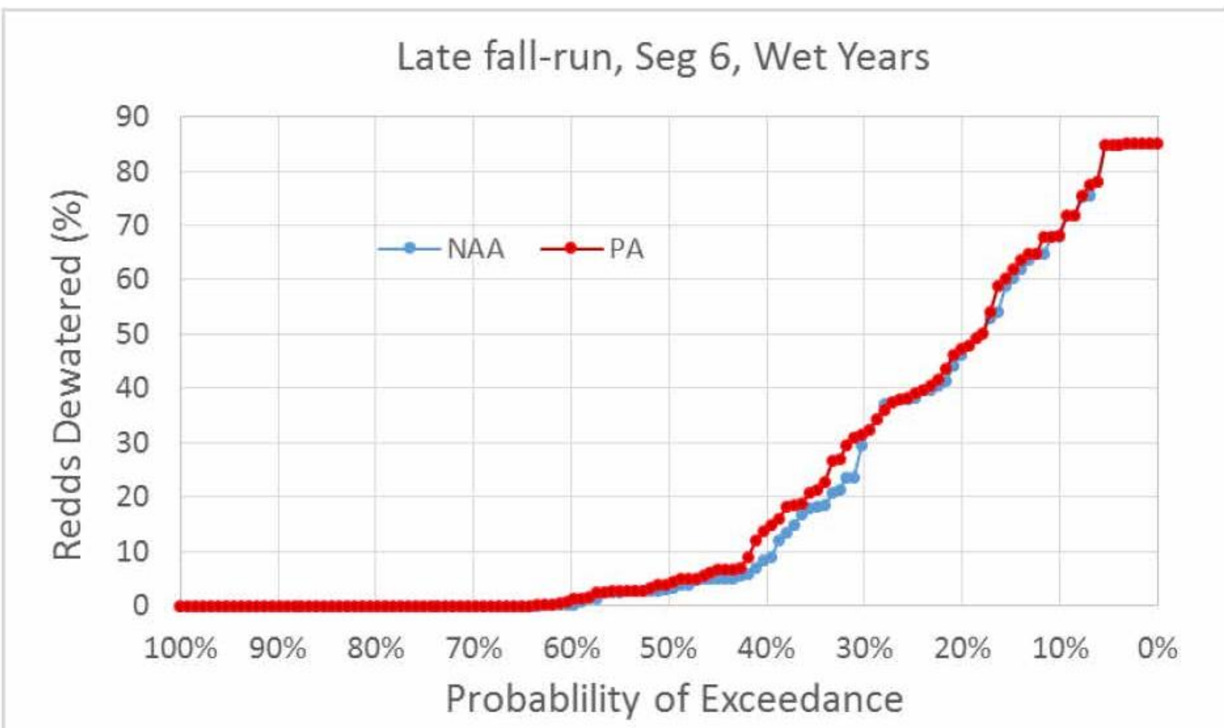

Figure 2-105. Exceedance Plot of Late Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 6, Wet Water Years.

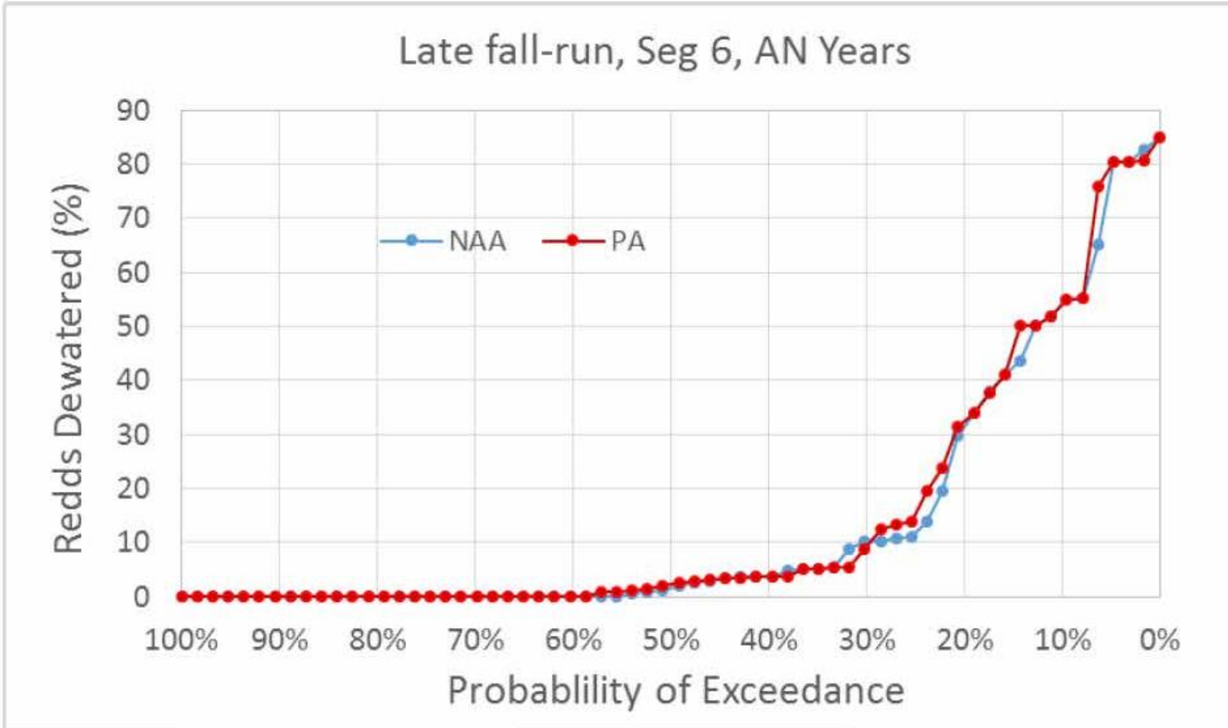

Figure 2-106. Exceedance Plot of Late Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 6, Above Normal Water Years.

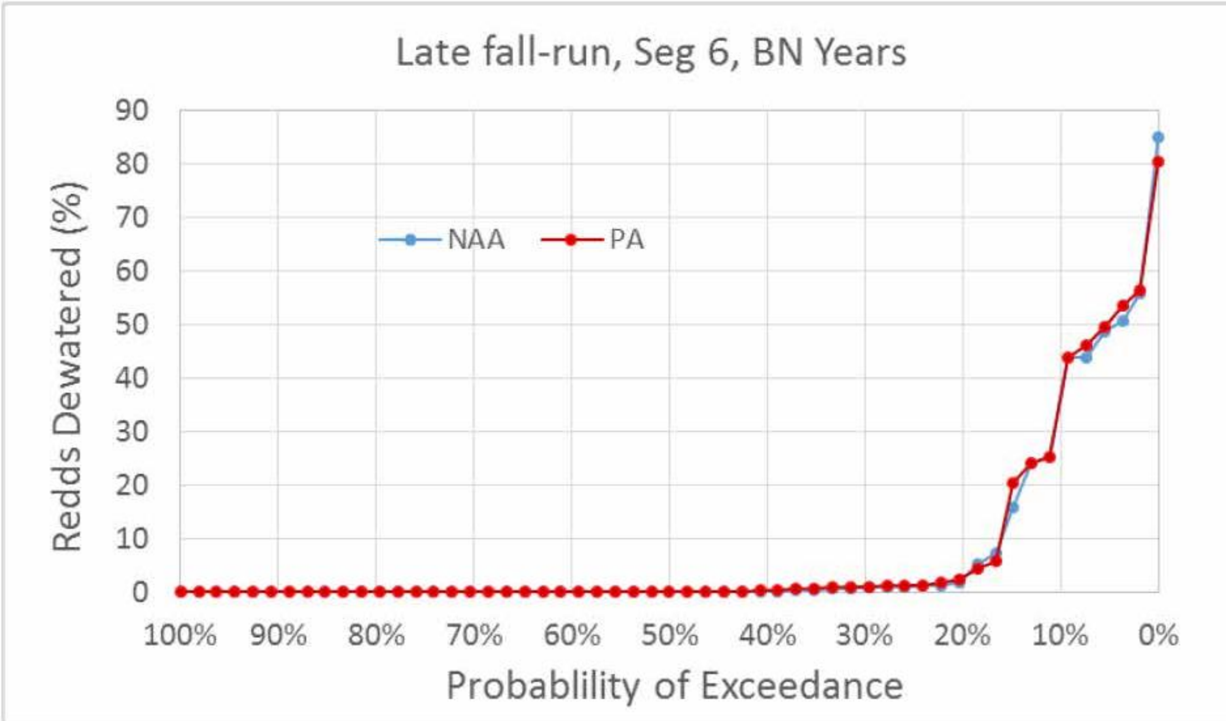

Figure 2-107. Exceedance Plot of Late Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 6, Below Normal Water Years.

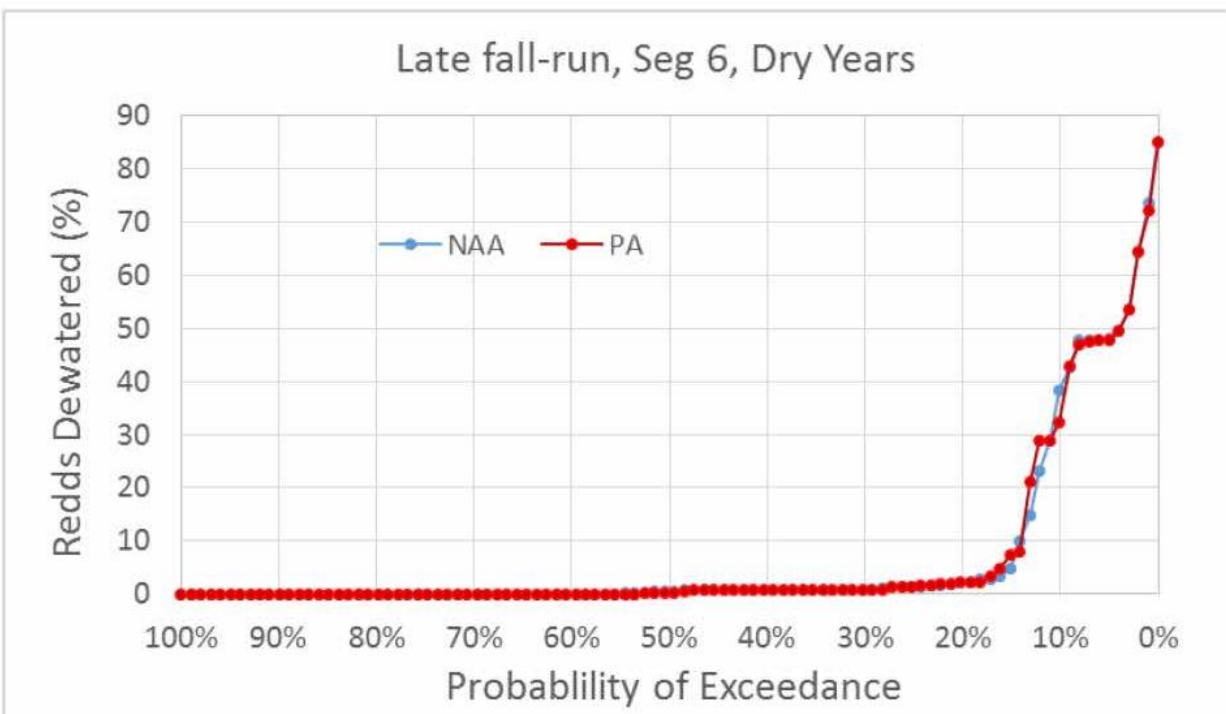

Figure 2-108. Exceedance Plot of Late Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 6, Dry Water Years.

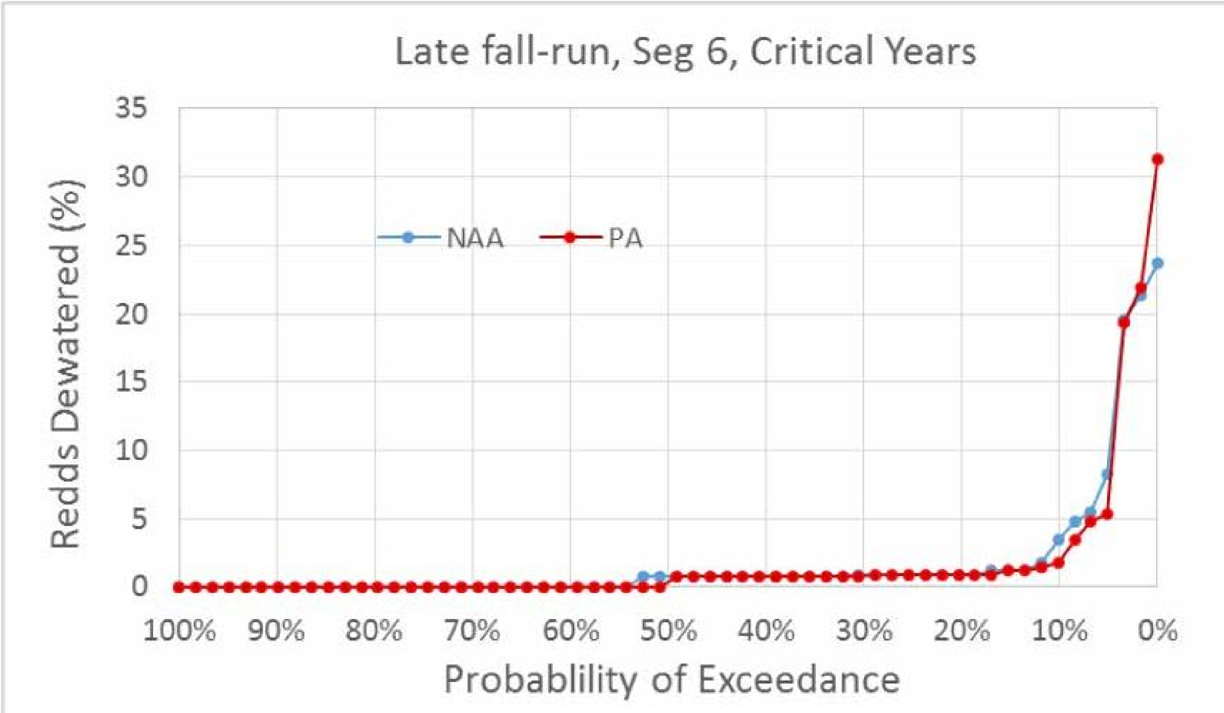

Figure 2-109. Exceedance Plot of Late Fall-run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios in River Segment 6, Critical Water Years.

The exceedance curves show that the PA would not increase redd dewatering under most water year types relative to the NAA.

The following description and tabular results from the BA show that differences between the PA and NAA in the mean percentage of late fall-run Chinook salmon redds dewatered in each river segment for each month of spawning under each water year type and all water year types combined would minimal (Tables 5.E-51 through 5.E-53). The percent of redds dewatered under the PA was little different from that under the NAA for all months and water year types, ranging up to 2.9% greater under the PA for January of wet years in Segment 5 (Table 5.E-52). The percent differences in the percent of redds dewatered between the PA and the NAA range up to a 130% increase under the PA for January of critical water years in Segment 6 (Table 5.E-51), but this increase and the other large relative changes in percent of redds dewatered are artifacts of the low percentages of redds dewatered under both scenarios that were used in computing the percent differences.

Similar to the redd dewatering exceedance plots, the tabular results show little difference between the PA and NAA. However, for purposes of the analysis in Section 2.7 Integration and Synthesis of the combined effect of PA implementation when added to the environmental baseline and modeled climate change impacts, the impact to late fall-run Chinook salmon is a concern, particularly in wet and above normal years. During February of wet and above normal years under the PA the percentage of dewatered redds ranges between 37% and 39% across river segments 4, 5, and 6. Redd dewatering under the PA in February of dry years is much lower (than wet years) ranging between just 0.6% and 2%. However, the bulk of the redd dewatering in dry years occurs in January, with 17% to 18% of all redds being dewatered across river segments 4, 5, and 6.

Table 2-145. Late Fall-run Chinook Salmon Percent of Redds Dewatered (Percent of Total Redds) and Differences (Percent Differences) in River Segment 6 Between Model Scenarios. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	NAA	PA	PA vs. NAA
	Wet	11.1	12.0	0.9 (8%)
	Above Normal	7.4	6.3	-1.1 (-15%)
	Below Normal	11.1	10.7	-0.4 (-3%)
	Dry	16.4	16.8	0.4 (2%)
	Critical	0.8	0.6	-0.2 (-22%)
December	All	10.3	10.5	0.1 (1%)
January	Wet	18.7	21.5	2.8 (15%)
	Above Normal	11.3	11.4	0.1 (1%)
	Below Normal	11.3	10.9	-0.5 (-4%)
	Dry	16.9	17.2	0.4 (2%)
	Critical	2.1	4.8	2.7 (130%)
	All	13.7	15.0	1.3 (10%)
February	Wet	36.7	37.5	0.8 (2%)
	Above Normal	37.5	38.2	0.7 (2%)
	Below Normal	13.7	14.8	1 (7%)
	Dry	0.6	0.6	0.1 (10%)
	Critical	3.0	0.4	-2.6 (-87%)
	All	20.0	20.1	0.1 (1%)
March	Wet	29.0	28.9	-0.1 (-0.2%)
	Above Normal	13.6	16.1	2.5 (18%)
	Below Normal	1.4	2.1	0.6 (45%)
	Dry	1.5	1.3	-0.2 (-12%)
	Critical	0.1	0.1	0 (0%)
	All	11.9	12.4	0.4 (4%)
April	Wet	6.7	6.7	0 (0%)
	Above Normal	1.6	1.8	0.2 (11%)
	Below Normal	0.1	0.0	-0.1 (-69%)
	Dry	0.9	0.4	-0.4 (-50%)
	Critical	3.1	3.0	0 (-2%)
	All	3.1	3.0	-0.1 (-3%)

Table 2-146. Late Fall-run Chinook Salmon Percent of Redds Dewatered (Percent of Total Redds) and Differences (Percent Differences) in River Segment 5 Between Model Scenarios. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	NAA	PA	PA vs. NAA
	Wet	11.1	12.0	0.9 (8%)
	Above Normal	7.5	6.5	-1.01 (-14%)
	Below Normal	11.0	10.6	-0.4 (-3%)
	Dry	16.5	16.8	0.3 (2%)
	Critical	0.8	0.7	-0.1 (-7%)
December	All	10.4	10.5	0.2 (2%)
January	Wet	18.8	21.7	2.9 (15%)
	Above Normal	11.5	11.6	0.1 (1%)
	Below Normal	11.4	10.9	-0.5 (-4%)
	Dry	17.0	17.3	0.3 (2%)
	Critical	2.2	5.0	2.8 (125%)
	All	13.8	15.1	1.4 (10%)
February	Wet	37.1	37.9	0.8 (2%)
	Above Normal	37.7	38.5	0.8 (2%)
	Below Normal	13.9	14.9	1 (7%)
	Dry	0.7	0.8	0.1 (14%)
	Critical	3.1	0.4	-2.7 (-86%)
	All	20.2	20.4	0.2 (1%)
March	Wet	29.6	29.6	-0.1 (-0.2%)
	Above Normal	14.0	16.5	2.6 (19%)
	Below Normal	1.5	2.2	0.7 (47%)
	Dry	1.7	1.5	-0.2 (-10%)
	Critical	0.1	0.1	0 (0.2%)
	All	12.2	12.7	0.5 (4%)
April	Wet	7.2	7.2	0 (-0.2%)
	Above Normal	1.7	1.9	0.2 (11%)
	Below Normal	0.1	0.0	-0.1 (-65%)
	Dry	0.9	0.5	-0.5 (-49%)
	Critical	3.0	3.0	-0.1 (-2%)
	All	3.2	3.1	-0.1 (-3%)

Table 2-147. Late Fall-run Chinook Salmon Percent of Redds Dewatered (Percent of Total Redds) and Differences (Percent Differences) in River Segment 4 Between Model Scenarios. (Green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher.)

Month	WYT	NAA	PA	PA vs. NAA
	Wet	11.1	12.2	1 (9%)
	Above Normal	6.9	6.5	-0.45 (-6%)
	Below Normal	10.4	10.4	0 (0%)
	Dry	17.4	17.6	0.1 (1%)
	Critical	1.4	1.4	-0.1 (-4%)
December	All	10.5	10.8	0.3 (3%)
January	Wet	19.1	21.7	2.6 (13%)
	Above Normal	11.9	12.0	0 (0%)
	Below Normal	13.9	13.3	-0.6 (-4%)
	Dry	17.3	17.7	0.4 (2%)
	Critical	3.4	6.1	2.7 (79%)
	All	14.6	15.8	1.2 (8%)
February	Wet	37.4	38.1	0.7 (2%)
	Above Normal	36.8	37.2	0.4 (1%)
	Below Normal	14.0	15.1	1.1 (8%)
	Dry	1.9	2.0	0.1 (5%)
	Critical	3.6	0.9	-2.7 (-74%)
	All	20.6	20.6	0.1 (0%)
March	Wet	28.5	28.4	-0.1 (-0.3%)
	Above Normal	14.9	17.4	2.6 (17%)
	Below Normal	1.5	2.4	0.8 (53%)
	Dry	3.2	2.8	-0.3 (-10%)
	Critical	0.5	0.5	0 (1.6%)
	All	12.4	12.9	0.4 (3%)
April	Wet	6.8	6.8	0 (-0.1%)
	Above Normal	2.0	2.2	0.2 (8%)
	Below Normal	0.2	0.1	-0.1 (-70%)
	Dry	1.1	0.7	-0.4 (-38%)
	Critical	2.5	2.4	-0.1 (-5%)
	All	3.1	3.0	-0.1 (-4%)

Collectively, the estimated percentage of redd dewatering presented in the exceedance plots (Figure 2-104 through Figure 2-109) and tables (Table 2-145 through Table 2-147) indicate that Sacramento River redd dewatering under the PA is a high magnitude stressor to late fall-run Chinook salmon in wet and above normal years and a medium stressor under dry conditions. The certainty of these magnitude rankings is medium given the limitations of using results based on monthly flows to understand the magnitude of impacts that occur over daily time scale.

2.5.1.2.2.5.2 American River

Only fall-run Chinook salmon redd dewatering is evaluated in this section because late-fall Chinook salmon do not spawn in the American River.

2.5.1.2.2.5.2.1 Fall-run Chinook salmon Risk and Exposure

Fall-run Chinook salmon eggs and alevins in the American River are vulnerable to dewatering from the time when spawning begins in October through February when fry emergence from the streambed ends (Vogel and Marine 1991, Bratovich 2005). The vast majority of fall-run Chinook salmon spawning (i.e., 90%) in the American River occurs upstream between Ancil Hoffman Park at river mile 16 to Nimbus Dam at RM 3 (BA Table 5.D.1-4 in Appendix 5D Attachment 1).

The analysis of fall-run Chinook salmon redd dewatering for the American River relies on the analysis presented in the BA. In the BA, the percentage of fall-run Chinook salmon redds dewatered by reductions in American River flow was estimated from CALSIM II estimates of monthly mean flows during the 3 months following each of the months that fall-run Chinook salmon spawn (Section 5.D.2.2, Spawning Flow Methods, Table 5-4-2). No model for predicting percentages of redds dewatered, such as that developed for the Sacramento River (USFWS 2006), has been developed for the American River. Therefore, the maximum reduction in American River flow for the 3 months following each of the months during which fall-run Chinook salmon spawn was used as a proxy for percent of redds dewatered. CALSIM II flows at Nimbus were used for this analysis. Larger maximum flow reductions during the spawning, egg, and alevin life stages are assumed to increase the percent of redds dewatered and, therefore, to have a negative effect on fall-run Chinook salmon. Further information on the redd dewatering analysis is provided in the BA in Appendix 5.D.2.2, Spawning Flow Methods.

As described in the BA, differences in maximum flow reductions under the PA and NAA were examined using exceedance plots of mean monthly maximum flow reductions, expressed as a percentage of the spawning flows, for the months that American River fall-run Chinook salmon spawn (October and November) (Figure 2-110 through Figure 2-115). The exceedance curves for all water year types combined (Figure 2-110) and those for wet and above normal years (Figure 2-111 through Figure 2-112) indicate that the PA would generally have lower flow reductions than the NAA. Differences for the other three water year types would be minor (Figure 2-114 through Figure 2-115).

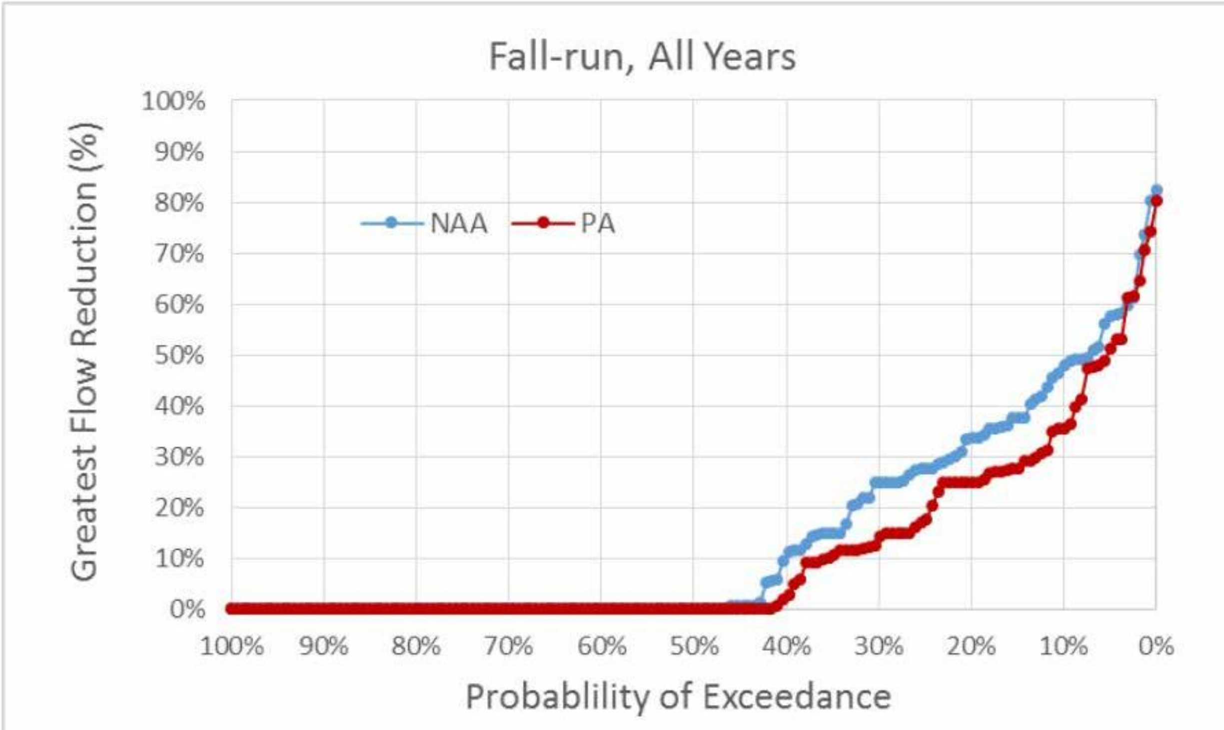

Figure 2-110. Exceedance Plot of Maximum Flow Reductions (Percent) for 3-Month Period After Fall-run Chinook Salmon Spawning for NAA and PA Model Scenarios, All Water Years.

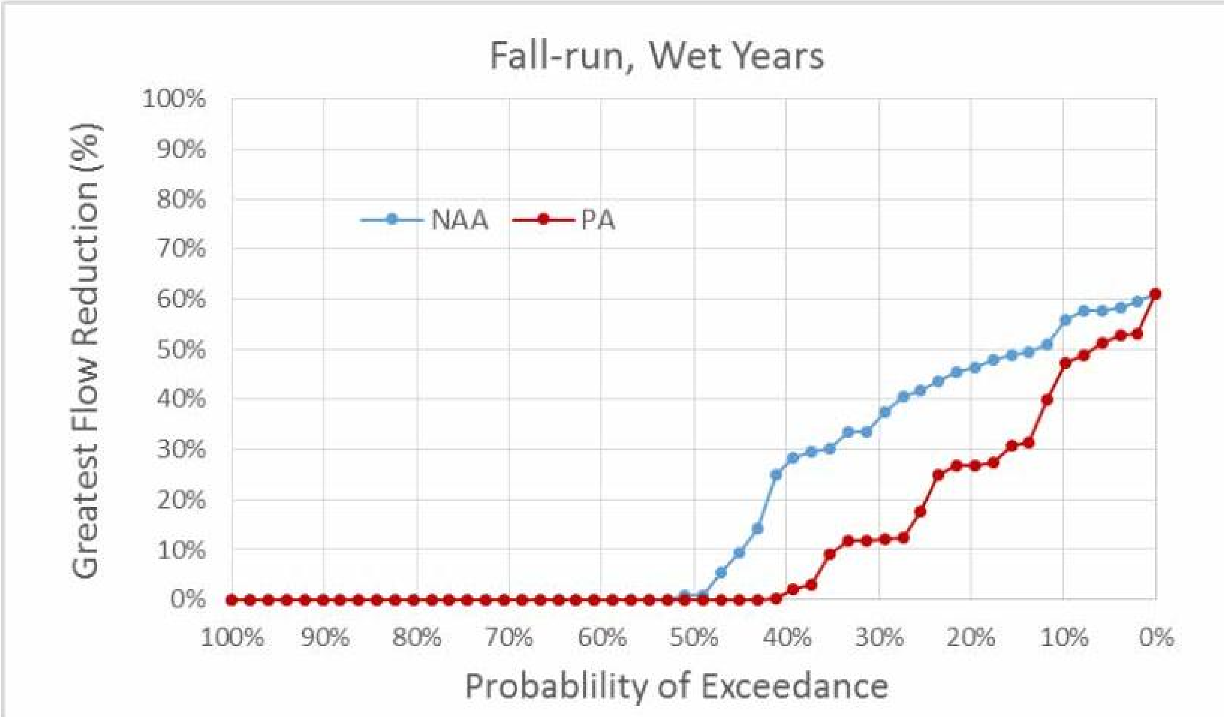

Figure 2-111. Exceedance Plot of Maximum Flow Reductions (Percent) for 3-Month Period After Fall-run Chinook Salmon Spawning for NAA and PA Model Scenarios, Wet Water Years.

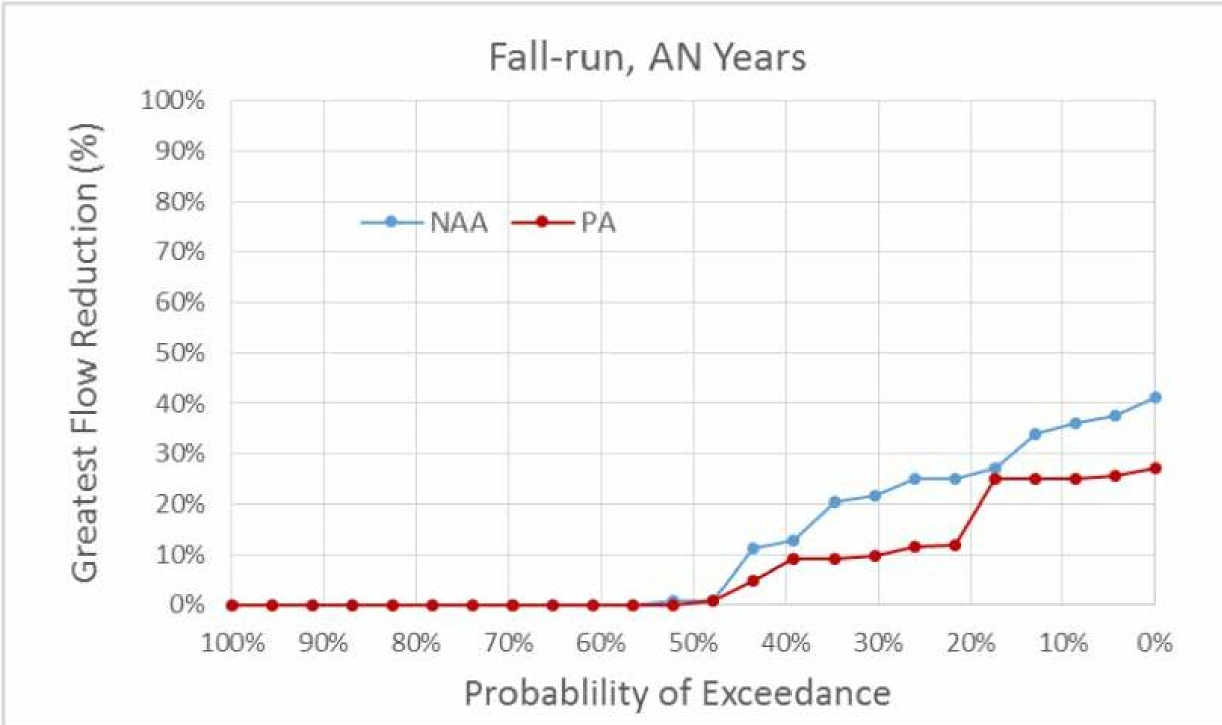

Figure 2-112. Exceedance Plot of Maximum Flow Reductions (Percent) for 3-Month Period After Fall-run Chinook Salmon Spawning for NAA and PA Model Scenarios, Above Normal Water Years.

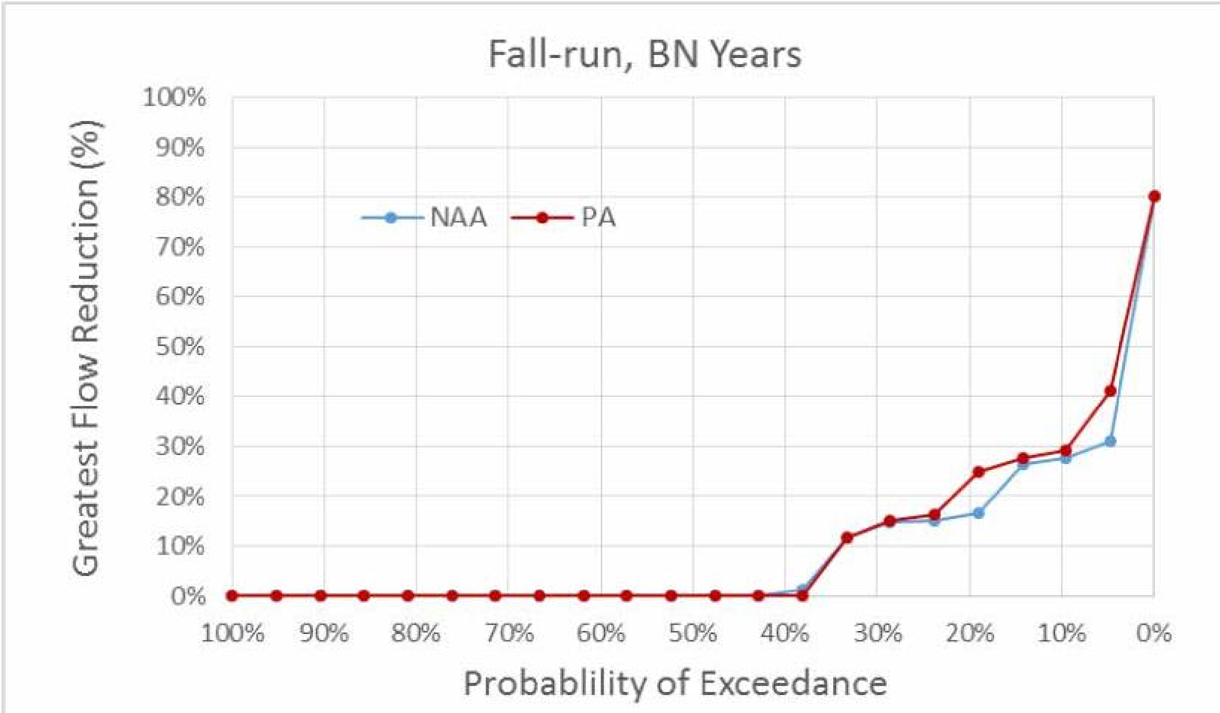

Figure 2-113. Exceedance Plot of Maximum Flow Reductions (Percent) for 3-Month Period After Fall-run Chinook Salmon Spawning for NAA and PA Model Scenarios, Below Normal Water Years.

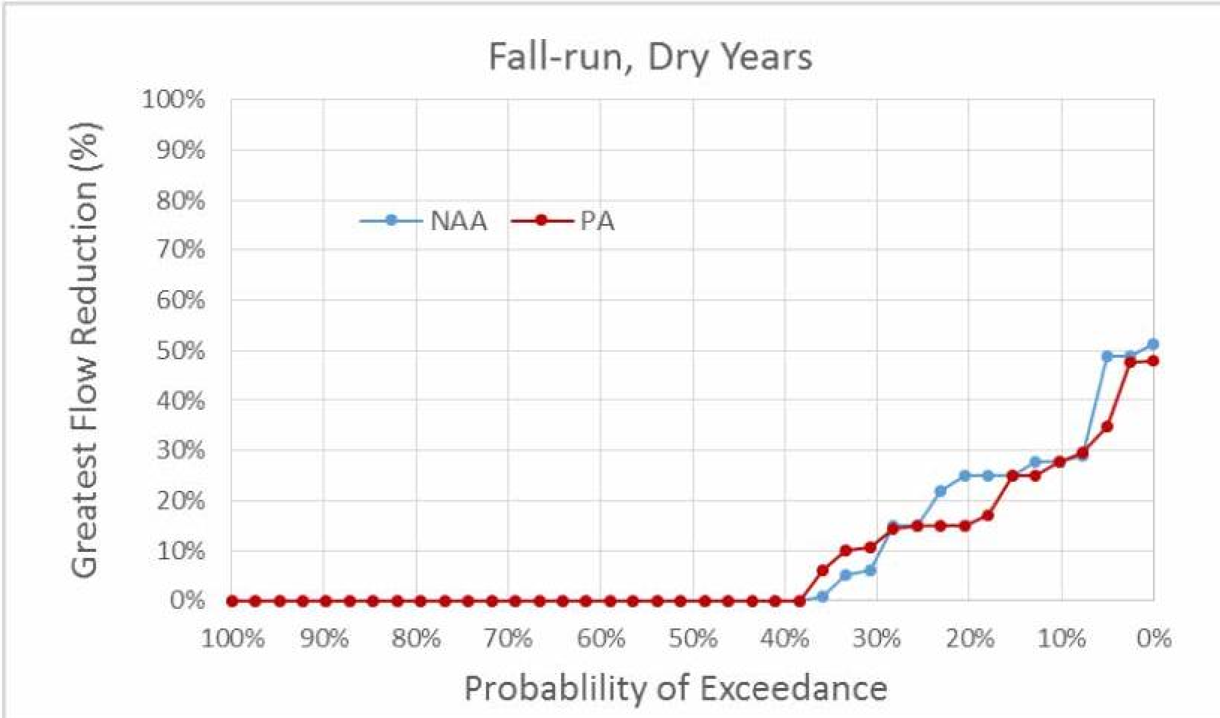

Figure 2-114. Exceedance Plot of Maximum Flow Reductions for 3-Month Period After Fall-run Chinook Salmon Spawning for NAA and PA Model Scenarios, Dry Water Years.

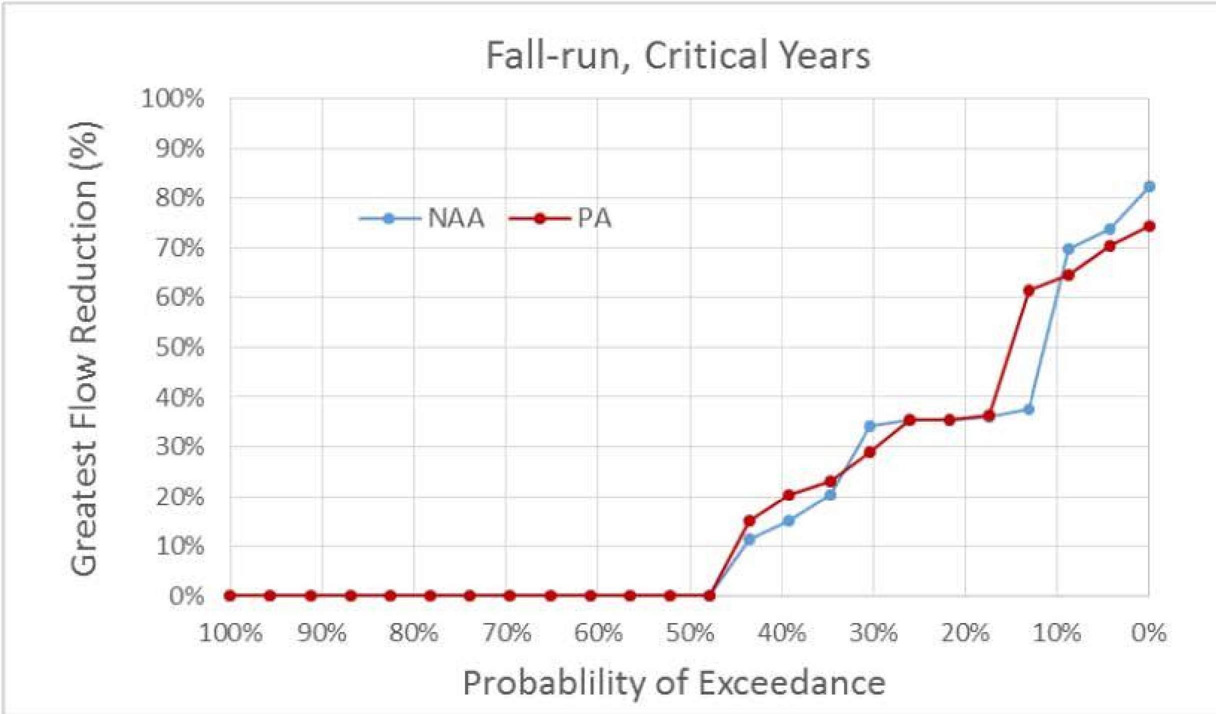

Figure 2-115. Exceedance Plot of Maximum Flow Reductions for 3-Month Period After Fall-run Chinook Salmon Spawning for NAA and PA Model Scenarios, Critical Water Years.

For the redd dewatering analysis in this Opinion, we take things one step further than the BA by assuming that a 25% reduction from the spawning flow will result in at least some redd dewatering, and a 50% reduction from the spawning flow will result in extensive redd dewatering. Making these general assumptions provides additional context for understanding how redd dewatering under the PA may impact fall-run Chinook salmon in the American River. These assumptions were made because: (1) fall-run Chinook salmon often spawn in shallow areas, which are more susceptible to being dewatered with a reduction in flow than deep areas; and (2) they are generally supported by the relationship between redd dewatering and flow for fall-run Chinook salmon on the Sacramento River with the ACID Dam boards out (Table 5.D-57 in the Appendix 5D of the BA). For example, 30% of all fall-run Chinook salmon redds would be dewatered on the Sacramento River if spawning flows of 10,000 cfs were reduced to 5,000 cfs after spawning (a 50% reduction from the spawning flow). In other words, a 50% flow reduction resulted in 30% redd dewatering, which fits a characterization of “extensive” redd dewatering. A 25% drop in spawning flows would dewater 9% of all redds (Table 5.D-57 in the Appendix 5D of the BA), which fits a characterization of “at least some” redd dewatering. The percentage of time that 25% (at least some redd dewatering) or 50% (i.e., extensive redd dewatering) reductions in spawning flow would occur under the PA by water year type are shown in Table 2-148.

Table 2-148. Percentage of Time that 25% (at Least Some Redd Dewatering) or 50% (i.e., Extensive Redd Dewatering) Reductions in American River Fall-run Chinook Salmon Spawning Flow Would Occur During the Egg and Alevin Life Stages Under the PA by Water Year Type.

Water Year Type	At Least Some Redd Dewatering	Extensive Redd Dewatering
Wet	24%	8%
Above Normal	18%	0%
Below Normal	19%	4%
Dry	15%	0%
Critical	34%	16%
All Years	23%	6%

At least some fall-run Chinook salmon redd dewatering is expected to occur in the American River in approximately 23% of all water years combined. Extensive redd dewatering is expected in 6% of the years. The most redd dewatering is expected in critical water years, with at least some dewatering occurring in 34% of critical years and extensive dewatering occurring in 16% of critical years. The least amount of redd dewatering is expected in dry years. Overall, the magnitude of redd dewatering is medium given that at least some redd dewatering is expected in 15 to 34% of years, and extensive redd dewatering has a relatively low frequency of occurrence. The certainty of this medium magnitude ranking is low given that the specific relationship between American River flow and fall-run Chinook salmon redd dewatering is unknown, and there are limitations of using results based on monthly flows to understand the magnitude of impacts that occur over a daily time scale.

2.5.1.2.3 Redd Scour

Streambed scour resulting from high flows is a physical factor that can reduce salmonid egg survival and limit population productivity. High flows can mobilize sediments in the river bed causing direct egg mortality if scour occurs to the depth of the top of the egg pocket. Scour can also increase fine sediment infiltration and indirectly decrease egg survival (DeVries 1997).

This redd scour analysis directly incorporates the methods and results presented in the BA. The redd scour analysis primarily relies upon a flow analysis whereby the probability of flows occurring under the PA and the NAA that would be high enough to mobilize sediments and scour Chinook salmon and steelhead redds was estimated from CALSIM II estimates of mean monthly flows by applying a relationship determined from the historical record between actual mean monthly flow and maximum daily flow (BA Appendix 5.D, Section 5.D.2.2, Spawning Flows Methods). The actual monthly and daily flow data used in the analysis are from gage records just below Keswick Dam and at Bend Bridge. CALSIM II estimates used to compare probabilities of redd scour for the PA and the NAA are for the Keswick Dam and Red Bluff locations. As discussed in Appendix 5.D, Section 5.D.2.2, Spawning Flow Methods of the BA, 40,000 cfs is treated as the minimum daily flow at which redd scour occurs in the Sacramento River. Analysis of the Keswick Dam gage data shows that for months with a mean monthly flow of at least 27,300 cfs, the maximum daily flow in that month is always at least 40,000 cfs. The Bend Bridge gage data show that for months with a mean flow of at least 21,800 cfs, the maximum daily flow in that month is always 40,000 cfs. Therefore, redd scour probabilities for the PA and the NAA were evaluated by comparing frequencies of CALSIM II flows greater than 27,300 cfs at Keswick Dam or greater than 21,800 cfs at Red Bluff during the respective spawning and