Appendix 4.A: Longfin Smelt Quantitative Analyses

4.A Longfin Smelt Quantitative Analyses

4.A.1 Delta Outflow/X2 Effects (X2-Relative Abundance General Linear Model)

The abundance index of Longfin Smelt from the annual Fall Midwater Trawl (FMWT) survey is correlated to X2, defined as the distance of the 2-ppt near-bottom salinity isohaline from the Golden Gate Bridge and estimated as the mean during the preceding winter and spring months (January–June) (Kimmerer 2002; Kimmerer et al. 2009). As X2 decreases in response to increases in Delta outflow, Longfin Smelt FMWT abundance increases. The mechanisms behind this relationship are not well understood. Various hypotheses have been suggested, including transport of larval Longfin Smelt out of the Delta to downstream rearing habitats (Moyle 2002), reduced exposure to effects of the south Delta pumping facilities (Baxter et al. 2010), extent of rearing habitat (Kimmerer et al. 2009), and retention of larvae in suitable rearing habitats (Kimmerer et al. 2009). In the analysis described here, an update of previous X2-abundance relationships (Kimmerer et al. 2009; Mount et al. 2013) was used to evaluate potential effects of the PP on Longfin Smelt. The calculated regression (General Linear Model, GLM) predicts the $\log_{10}$(Longfin Smelt fall midwater trawl index) as a function of mean January-June X2 and step changes for the introduction of *Potamocorbula amurensis* and the Pelagic Organism Decline (POD). The log abundance values essentially represent a relative survival index for each of these relationships, which were reverse log-transformed to determine how the PP might influence numbers of Longfin Smelt surviving until the following fall (as expressed as a relative abundance index). The analysis assumes that a reasonable representation of potential future abundance as a function of X2 can be made based on the empirical relationships observed in historic data, although it is acknowledged that the relationship could change as a result of the PP (e.g., change in balance between north and south Delta flows for a given X2).

4.A.1.1 Methods

As noted previously, the analysis essentially updated previously described X2-abundance regressions (Kimmerer et al. 2009; Mount et al. 2013) by adding additional years of data. Updating the analysis allowed full accounting of sources of error in the predictions, allowing calculation of prediction intervals from CalSim-derived estimates of X2 for NAA and PP scenarios, as recommended by Simenstad et al. (2016).

The most recently available Longfin Smelt FWMT index data were obtained (http://www.dfg.ca.gov/delta/data/fmwt/indices.asp?view=single), which included indices for 1967–2014 (excluding 1974 and 1979, when there was no sampling). For each index year, mean X2 during the early life stages was calculated based on X2 from the DAYFLOW database (http://www.water.ca.gov/dayflow/output/Output.cfm), in addition to calculated X2 for earlier years[1].

Similar to Mount et al. (2013), GLMs were run, predicting Longfin Smelt fall midwater trawl relative abundance index as a function of X2 and step changes in 1987/1988 and 2002/2003:

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[1] DAYFLOW provides X2 estimates from water year 1997 onwards, so the DAYFLOW equation (X2(t) = 10.16 + 0.945*X2(t-1) – 1.487log(QOUT(t))) was used to provide X2 for earlier years, based on a starting unpublished estimate of X2 (Mueller-Solger 2012).

$$\text{Log}_{10}(\text{FMWT index}_y) = a + b\cdot(\text{mean X2}_y) + c\cdot\text{period}_y$$

Where *y* indicates year, *a* is the intercept, *b* is the coefficient applied to the mean Delta outflow, and *c* takes one of three values for period: 0 for the Pre-*Potamocorbula* period (1967–1987), and values to be estimated for Post-*Potamocorbula* (1988–2002) and POD (2003–2014) periods.

Regarding the months used for mean X2, Mount et al. (2013: 67) noted the following:

> The months selected in the original analysis [by Jassby et al. 1995] were based on the assumption that the (unknown) X2 mechanism operated during early life history of Longfin Smelt, which smelt experts linked to this period. Autocorrelation in the X2 values through months means that statistical analysis provides little guidance for improving the selection of months. A better understanding of the mechanism(s) underlying the relationship would probably allow this period to be narrowed and focused, but for now there is little basis for selecting a narrower period for averaging X2.

Mount et al. (2013) compared the fit of X2 averaging periods for January–June (i.e., the original period used by Jassby et al. 1995, also used by Kimmerer et al. 2009) and March–May; they selected the former because the fit to the empirical data was slightly superior. In the present analysis, both the January–June and March–May averaging periods were compared for their adequacy of fit, using standard criteria (Akaike's Information Criterion adjusted for small sample sizes, AIC_c; and variation explained, r^2). This showed that the January–June X2 averaging period was better supported in terms of explaining variability in the FWMT index (Table 4.A-1; Figure 4.A-1), so this averaging period was used in the subsequent comparison of NAA and PP based on CalSim outputs.

Table 4.A-1. **Parameter Coefficients for General Linear Models Explaining Longfin Smelt Fall Midwater Trawl Index as a Function of Mean January–June and March–May X2 and Step Changes in 1987/1988 (*Potamocorbula* Invasion) and 2002/2003 (Pelagic Organism Decline).**

	January–June			March–May		
Parameter	**Estimate**	**Standard Error**	***P***	**Estimate**	**Standard Error**	***P***
a (Intercept)	7.3059	0.3299	< 0.0001	6.8100	0.3224	< 0.0001
b (X2)	-0.0542	0.0049	< 0.0001	-0.0475	0.0047	< 0.0001
c (Period: Post-*Potamocorbula*)	-0.5704	0.1174	< 0.0001	-0.6368	0.1271	< 0.0001
c (Period: POD)	-1.4067	0.1244	< 0.0001	-1.4581	0.1351	< 0.0001
Fit						
AIC_c[1]	-47.4904			-39.5492		
r^2	0.8666			0.8414		

Note:
[1]A difference of greater than two AIC_c units between the two GLMs indicates that the January–June mean X2 GLM is better supported in terms of explaining the patterns in the data, per Burnham and Anderson's (2002) rule of thumb.

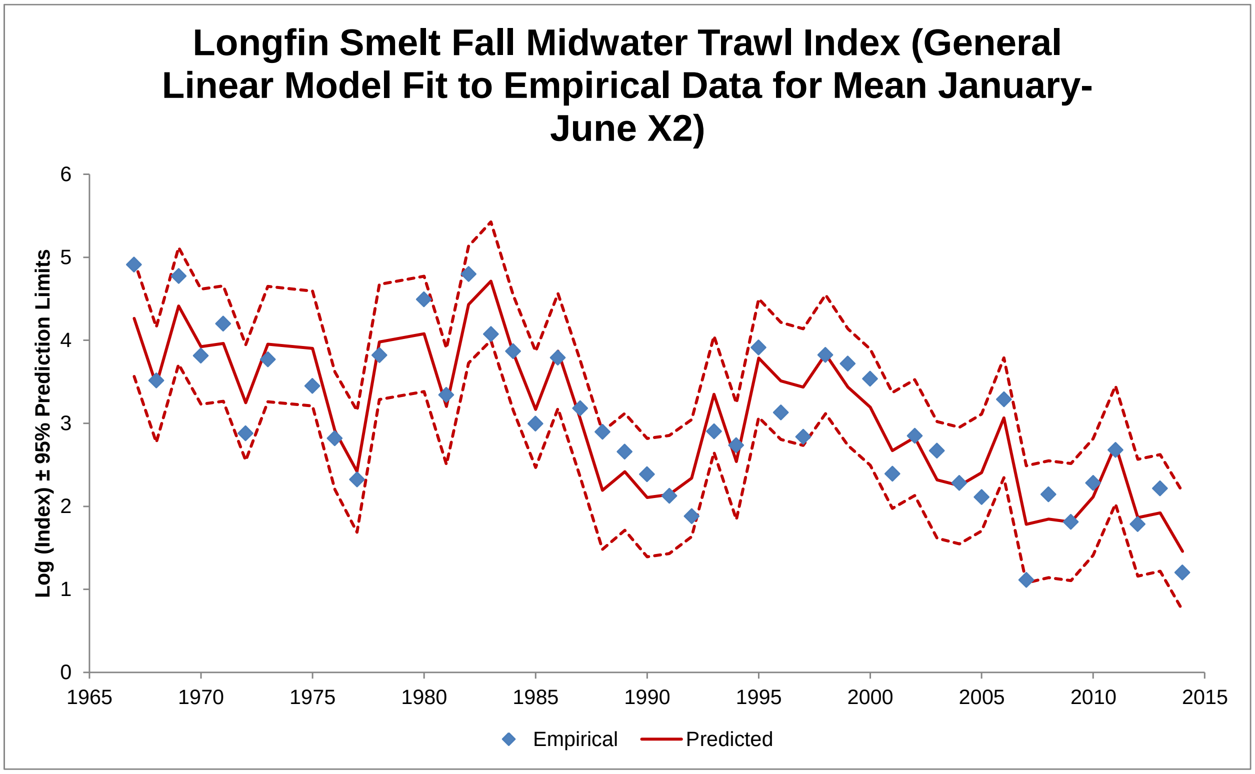


Figure 4.A-1. Fit to Empirical Data of General Linear Model Predicting Longfin Smelt Fall Midwater Trawl Relative Abundance Index as a Function of Mean January–June X2 and Step Changes for *Potamocorbula* and Pelagic Organism Decline.

For the comparison of NAA and PP scenarios, CalSim data outputs[2] were used to calculate mean January–June[3] X2 for each year of the 1922–2003 simulation. The X2-abundance GLM calculated as above was used to estimate relative abundance for the NAA and PP scenarios for the fall midwater trawl index, based on the POD period coefficient in addition to the intercept and X2 slope terms. The log-transformed abundance indices were back-transformed to a linear scale for comparison of NAA and PP. In order to illustrate the variability in predictions from the X2-abundance GLM, annual estimates were made for the mean and upper and lower 95% prediction limits of the abundance indices, as recommended by Simenstad et al. (2016). Statistical analyses were conducted with PROC GLM and PROC PLM in SAS/STAT software, Version 9.4 of the SAS System for Windows.[4]

[2] CalSim modeling methods and results for the NAA and PP are presented in ICF International (2016: Appendix 5.A *CalSim II Modeling and Results*).

[3] CalSim reports ‘Previous X2’, referring to X2 in the previous month to that reported, so this analysis actually used Previous X2 for February–July.

[4] Copyright 2002–2010, SAS Institute Inc. SAS and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA

4.A.1.2 Results

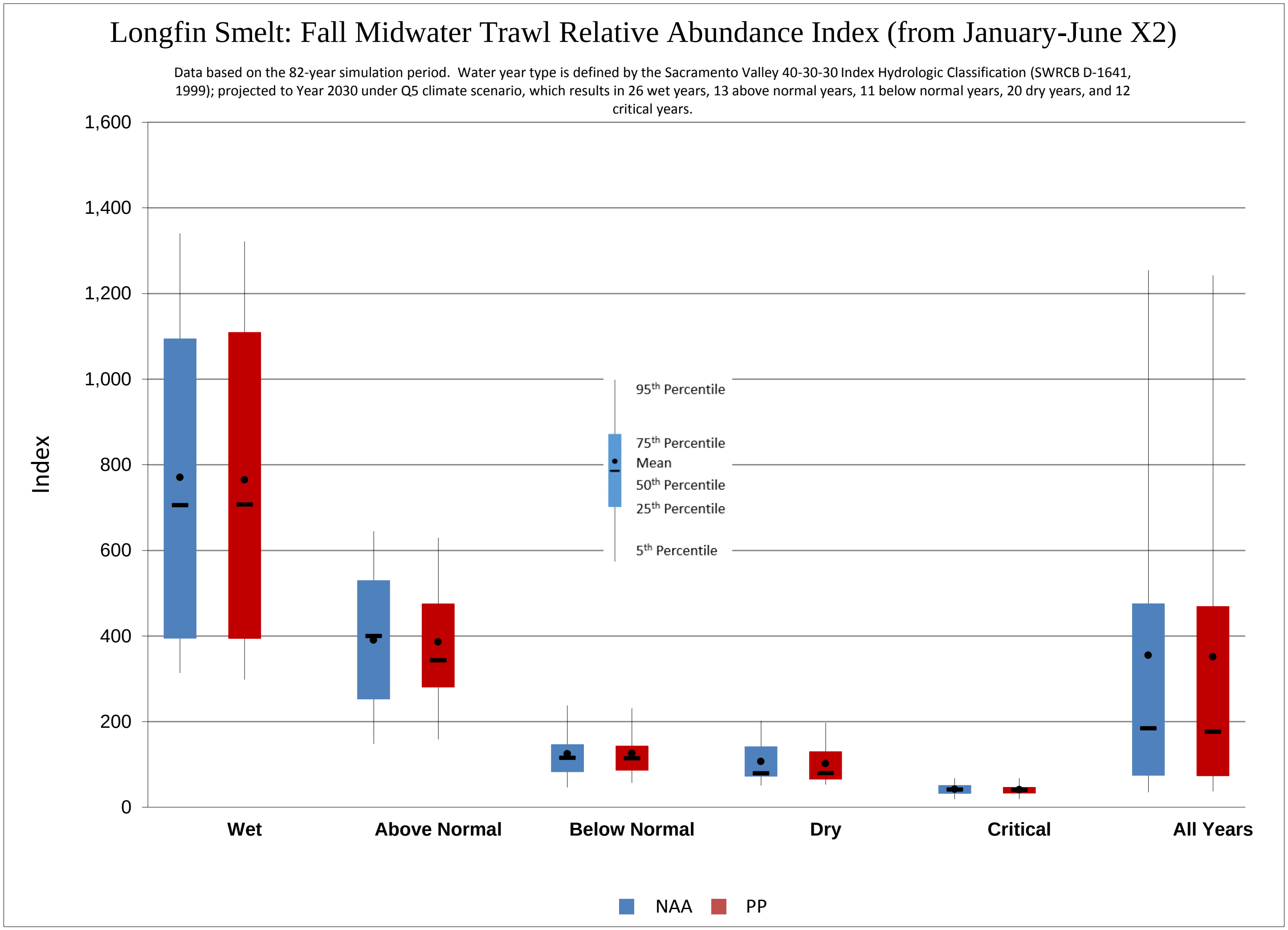
Predicted relative abundance indices from the X2-abundance GLM did not differ greatly between the NAA and PP scenarios (Table 4.A-2, Figure 4.A-2, and Figure 4.A-3). The mean relative abundance indices in wet, above normal, and below normal years were within 1%, whereas there were slightly greater differences in dry years (4% less under PP) and the critical year mean was 3% less under PP than NAA (Table 4.A-2).

There were no years where the 95% prediction intervals of the fall midwater trawl relative abundance indices did not overlap between the NAA and PP scenarios (Figure 4.A-4). Therefore predicted differences in relative abundance between NAA and PP scenarios were small compared to the predictive ability of the regressions. As noted in the independent review panel report for the working draft BA, it is possible that the true annual values could lie near the bottom boundary of the prediction interval for PP and near the top boundary of the prediction interval for NAA (Simenstad et al. 2016). This would result in greater differences than suggested by the comparison of annual mean values. By the same rationale, it is also possible that the true annual values could lie near the top boundary of the prediction intervals for both PA and NAA, in which case the differences would be more similar to the differences between means.

Table 4.A-2. Mean Annual Longfin Smelt Relative Abundance Index (Fall Midwater Trawl Survey), Estimated from General Linear Model Based on Mean January–June X2[1], Grouped by Water Year Type.

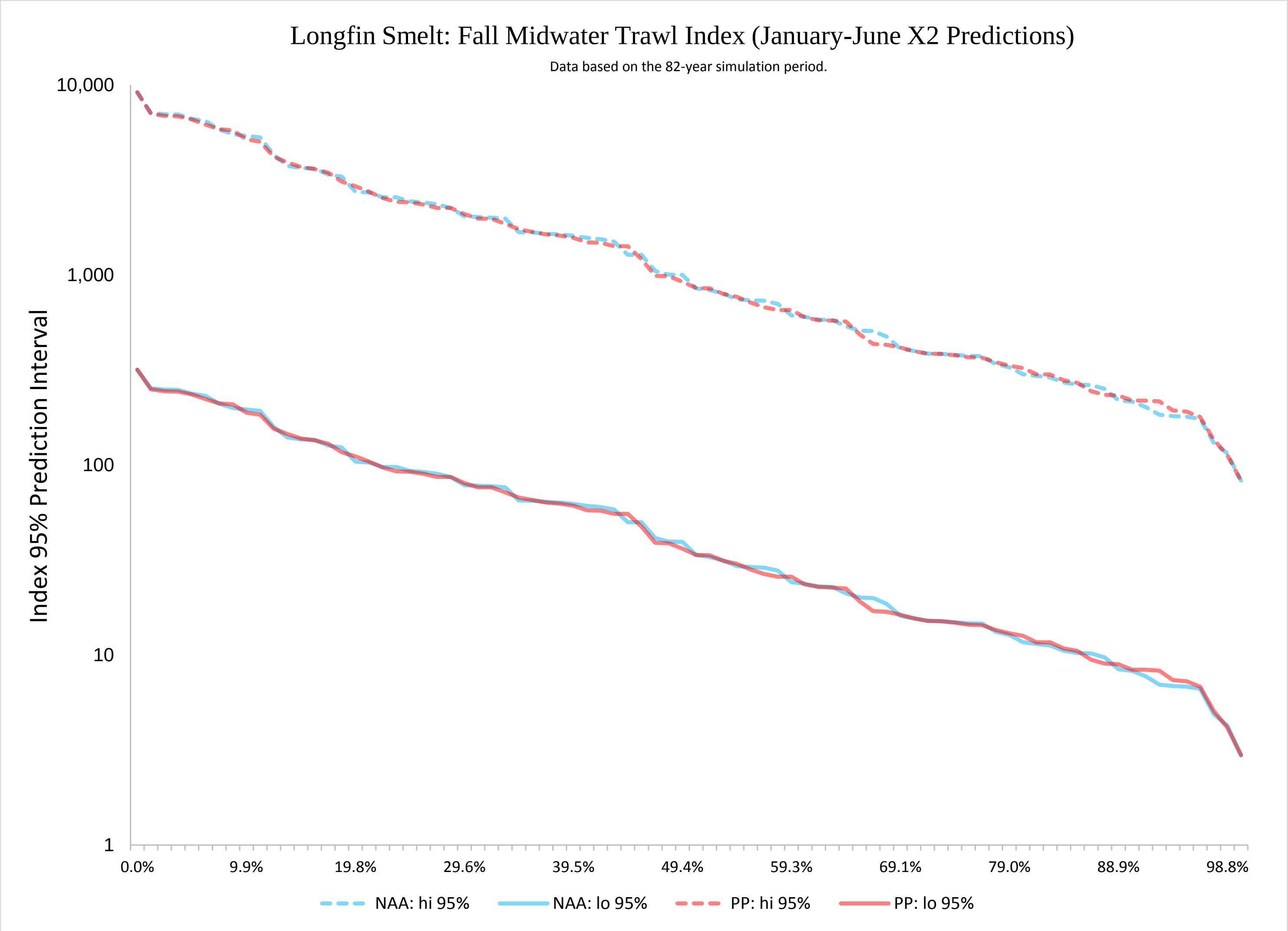
Water Year Type	NAA	PP	PP vs. NAA[2]
Wet	770	765	-5 (-1%)
Above Normal	390	386	-4 (-1%)
Below Normal	125	126	1 (1%)
Dry	107	102	-5 (-4%)
Critical	42	41	-1 (-3%)

1A step change for the Pelagic Organism Decline (POD) was also included in the General Linear Model.
2Negative values indicate lower abundance index under the proposed project (PP) than under the no action alternative (NAA).



Note: Plot only includes mean responses and does not consider model uncertainty.

Figure 4.A-2. Box Plot of Longfin Smelt Fall Midwater Trawl Relative Abundance Index, Estimated from the General Linear Model Including Mean January–June X2, Grouped by Water Year Type.



Note: Data are sorted by mean estimate, with only 95% prediction intervals shown.

Figure 4.A-3. Exceedance Plot of Longfin Smelt Fall Midwater Trawl Relative Abundance Index, Estimated from the General Linear Model Including Mean January–June X2.

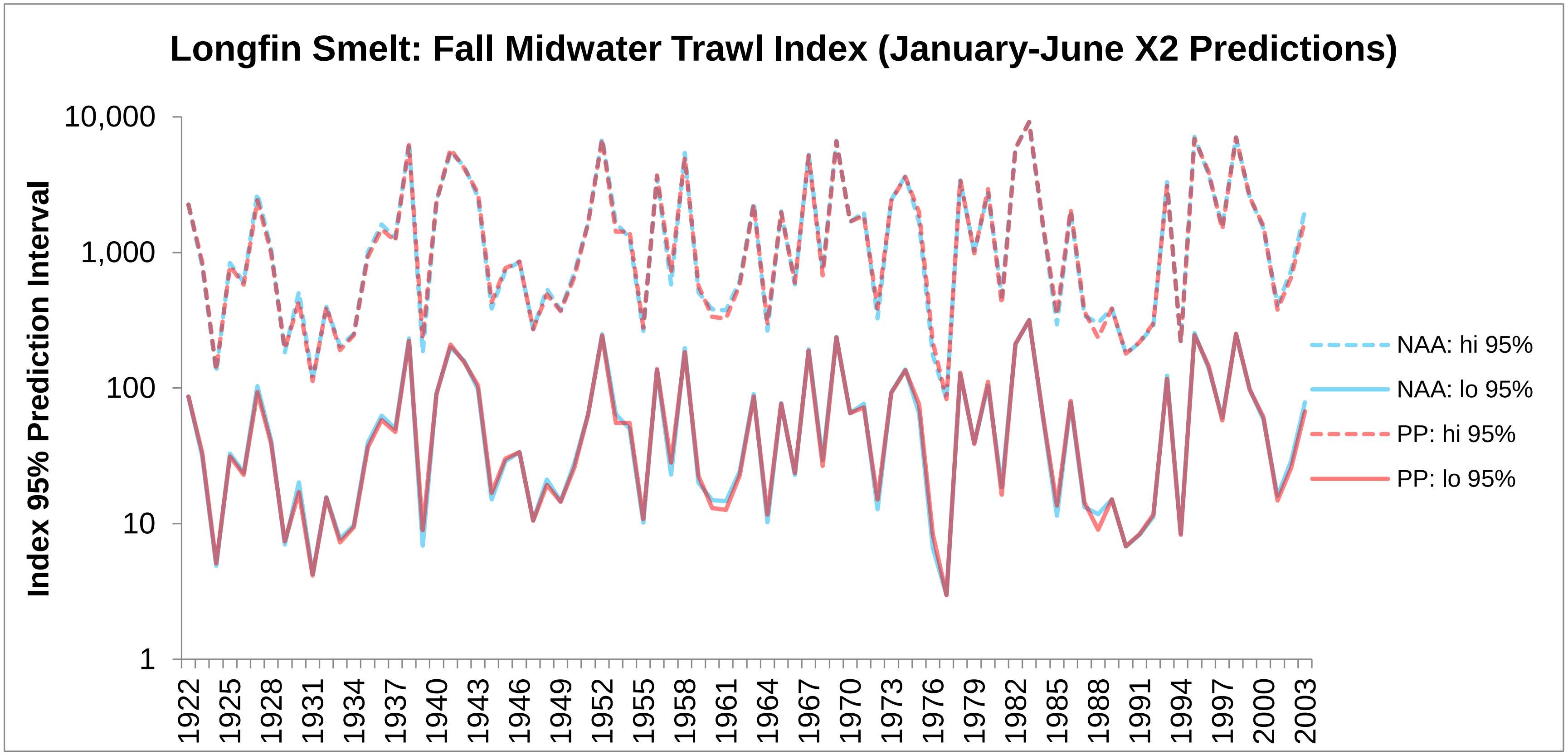


Figure 4.A-4. Time Series of 95% Prediction Interval Longfin Smelt Bay Midwater Trawl Index, from the General Linear Model Including Mean January–June X2.

4.A.1.3 Particle Tracking Modeling of Larval Entrainment and South Delta Entry

Larval Longfin Smelt have the potential to be entrained by water diversions in the Delta, including the south Delta export facilities, the North Bay Aqueduct (NBA) and, to a much lesser degree, the proposed NDD. As discussed in Chapter 4, the frequency of occurrence of Longfin Smelt near the NDD is very low, and there are no suitable recent data to provide an estimate of the relative density of Longfin Smelt near the NDD compared to other areas of the Delta. An analysis was undertaken based on Smelt Larval Survey (SLS) data from 2009–2014, combined with DSM2-PTM (particle tracking modeling) results, in order to compare Longfin Smelt larval potential entrainment loss for the NAA and PP scenarios.

4.A.1.4 Methods

4.A.1.4.1 Derivation of Larval Longfin Smelt Hatching Locations

The potential effect of the PP on larval Longfin Smelt entrainment in the Delta and Suisun Marsh was evaluated through a particle tracking model (PTM) of neutrally buoyant particles representing newly hatched larvae inserted at various locations in the Delta. The first step in the analysis involved determining appropriate weights for particle insertion points to reflect the hatching locations of larval Longfin Smelt. Insertion points for comparisons of NAA to PP effects were determined through examination of the spatial distributions of larvae observed in the SLS from 2009 to 2014. This methodology is consistent with the approach used by DFG in its effects and ITP analysis for SWP and CVP Data (California Department of Fish and Game 2009a). Data were obtained from the CDFW website (ftp://ftp.delta.dfg.ca.gov/Delta%20Smelt/SLS.mdb). For most of this time period, the SLS generally included 5-6 surveys at 35 stations in the Delta and Suisun Bay/Marsh during January-March; stations 323 to 343 in the Napa River were added in 2014, but are not considered in the present analysis because there is only one year of data. Data were filtered to include Longfin Smelt larvae ≤ 6-mm TL, which represents mostly newly hatched larvae, but includes some larvae up to 8 days old, assuming conservative hatch lengths as low of 4-mm SL and growth rate of 0.25 mm d^{-1} (California Department of Fish and Game 2009b). Inspection of size distribution and presence of yolk-sacs of the larval Longfin Smelt catch from the SLS data suggest that most newly hatched larvae are around 6-mm TL (Figure 4.A-5), which is consistent with the presumed range of 4- to 8-mm SL (Wang 2007; California Department of Fish and Game 2009b).

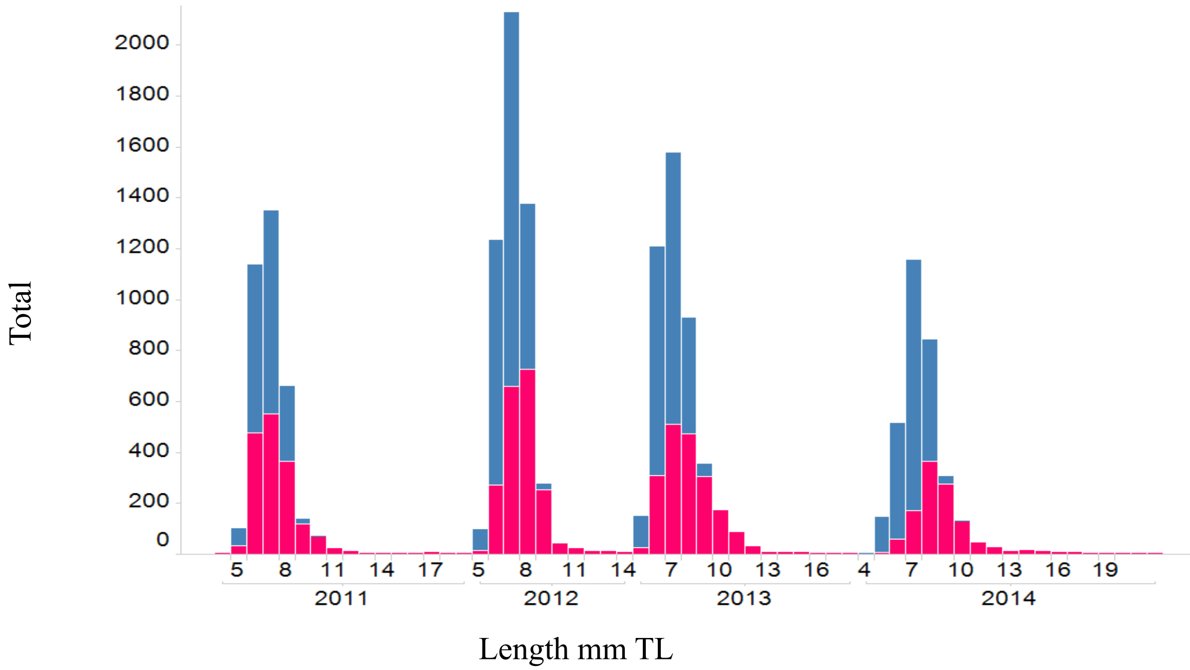


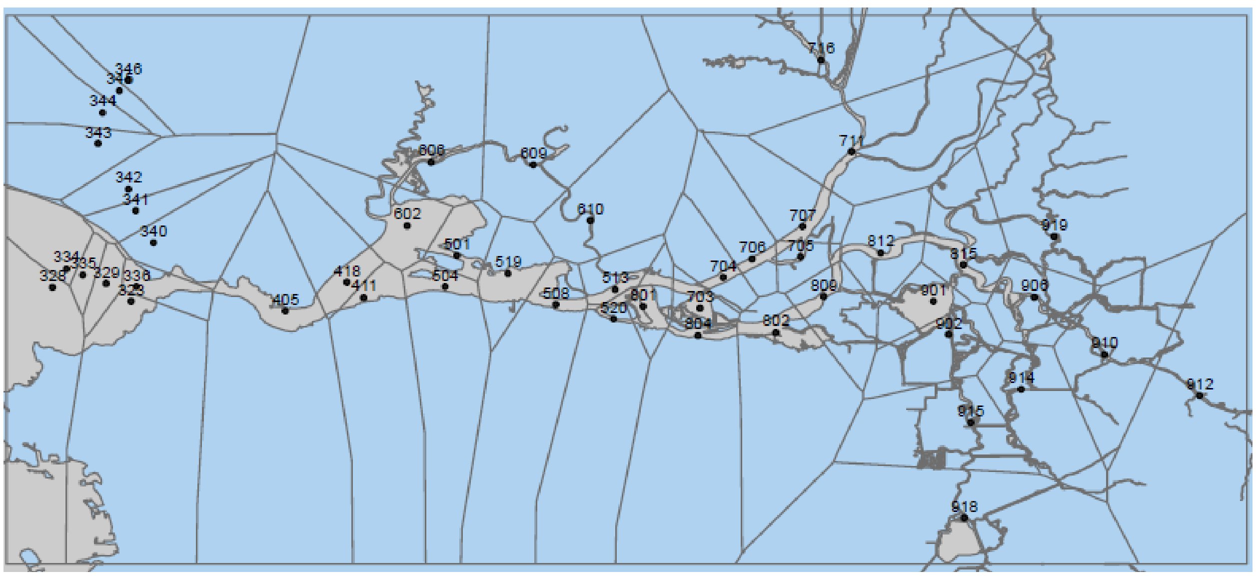
Figure 4.A-5. Length-frequency histogram of Longfin Smelt larvae collected in the SLS. Larvae with yolk-sacs are represented by blue bars. DFG did not distinguish yolk sac larvae in 2009 and 2010

The density of larvae (≤ 6 mm TL) per cubic meter sampled at each station was calculated as:

Density = Number of larvae/(0.37*(26873+99999)*Net meter reading),

where the conversion factor derives from calibration of the net flow meter used during SLS sampling.[5]

The SLS includes a subset of the stations that are used for the March-June 20-mm survey for larval/juvenile delta smelt. Saha (2008) estimated the areas and volumes that each of the 20-mm stations represents within the Delta and Suisun Bay/Marsh using a Voronoi diagram (Figure 4.A-6). There is a station (723) that was not part of the 20-mm Survey when Saha (2008) made the area and volume calculations; this station is close to station 716, so the area and volume represented by station 716 were halved for the present analysis, with the other half being considered to be the area and volume represented by station 723 (Table 4.A-3).



Source: Saha (2008).

Figure 4.A-6. Division of the Delta and Suisun Bay/Marsh Around 20-mm Survey Stations With a Voronoi Diagram.

Table 4.A-3. Area and Volume Represented by Smelt Larval Survey Stations.

Station	Area (ac)	Volume (ac-ft)	Area (m^2)	Volume (m^3)
405	3,547	139,804	14,354,198	172,445,718
411	2,119	37,344	8,575,288	46,063,152
418	2,756	63,186	11,153,135	77,938,794
501	3,692	36,856	14,940,992	45,461,213
504	2,403	44,046	9,724,595	54,329,948
508	2,296	53,344	9,291,581	65,798,864
513	1,703	41,921	6,891,796	51,708,799
519	4,101	67,942	16,596,156	83,805,234

[5] See Eijkelkamp Agrisearch Equipment (no date) for further details.

Station	Area (ac)	Volume (ac-ft)	Area (m^2)	Volume (m^3)
520	438	12,130	1,772,523	14,962,137
602	7,361	72,852	29,788,907	89,861,631
606	1,332	17,685	5,390,412	21,814,129
609	727	8,114	2,942,064	10,008,473
610	259	3,156	1,048,136	3,892,869
703	2,091	25,853	8,461,976	31,889,210
704	605	15,952	2,448,348	19,676,505
705	277	3,741	1,120,979	4,614,456
706	931	24,539	3,767,623	30,268,415
707	1,859	37,076	7,523,105	45,732,579
711	1,994	39,391	8,069,431	48,588,089
716*	3,110	51,796	12,583,699	63,889,434
723*	3,110	51,796	12,583,699	63,889,434
801	2,226	45,662	9,008,301	56,323,255
802	3,546	45,094	14,350,151	55,622,637
804	1,195	32,119	4,835,993	39,618,208
809	1,392	33,562	5,633,224	41,398,123
812	1,767	43,810	7,150,795	54,038,846
815	4023	72053	16,280,502	88,876,079
901	3,822	33,855	15,467,084	41,759,533
902	1,744	22,095	7,057,717	27,253,785
906	1,780	32,694	7,203,404	40,327,461
910	1,925	25,760	7,790,198	31,774,496
912	1,225	13,747	4,957,399	16,956,677
914	1,554	23,552	6,288,814	29,050,968
915	1,146	13,302	4,637,697	16,407,778
918	1601	14,685	6,479,016	18,113,683
919	2,043	20,702	8,267,727	25,535,544

Source: Saha (2008).
*See text for discussion of values for stations 716 and 723.

The total number of Longfin Smelt larvae ≤ 6 mm in the volume of water represented by each station (Table 4.A-3) was calculated by multiplying the density of larvae by the volume of each station.[6] The proportion of larvae in the volume of water represented by each SLS station was

[6] For reference, the overall estimated number of larvae across all stations ranged from around 600,000 (survey 6 in 2014) to around 160,000,000 (survey 4 in 2009). Dividing these estimates by fecundity of 7,500 (California Department of Fish and Game 2009b: Figure 3) for a 2-year-old female and multiplying by 2 (under the assumption of a 1:1 sex ratio) gives an estimate of adult Longfin Smelt abundance, assuming 100% survival from eggs to larvae . Applying 10%, 50%, and 90% survival from eggs to larvae gives estimates of adult population size of around 500-2,300 (survey 6 in 2014) to 130,000-650,000 (survey 4 in 2009). These estimates bracket the "tens of thousands" of adults suggested by Newman (pers. comm. to California Department of Fish and Game 2009b), perhaps providing some indication that the numbers are of a reasonable order of magnitude for the purposes of the present analysis. Note, however, that the analysis is not dependent on absolute numbers of larvae to be accurately represented, as gear

calculated for each survey as the number of larvae per station divided by the total sum of larvae across all stations (Table 4.A-4).

efficiency for smaller stages would need to be refined. This is examined further in Section 4.2.7 *Analysis of Potential for Jeopardy* of Chapter 4 *Take Analysis*.

Table 4.A-4. Volume-Weighted Proportion of Longfin Smelt Larvae ≤ 6 mm By Station, 2009-2014.

Year	Survey	405	411	418	501	504	508	513	519	520	602	606	609	610	703	704	705	706	707	711	716	723	801	804	809	812	815	901	902	906	910	912	914	915	918	919
2009	1	0.0466	0.0000	0.0000	0.0118	0.0000	0.0151	0.2600	0.0217	0.0079	0.0000	0.0164	0.0000	0.0000	0.0164	0.0173	0.0104	0.2071	0.0365	0.0504	0.0161	0.0470	0.1693	0.0089	0.0193	0.0000	0.0000	0.0110	0.0000	0.0106	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	2	0.0000	0.0000	0.0000	0.0034	0.0000	0.1338	0.0993	0.0057	0.0227	0.0142	0.0015	0.0014	0.0033	0.0144	0.0771	0.0221	0.0779	0.2020	0.0296	0.0254	0.0045	0.0437	0.0848	0.0651	0.0150	0.0179	0.0324	0.0000	0.0000	0.0000	0.0000	0.0000	0.0027	0.0000	0.0000
	3	0.0000	0.0000	0.0000	0.0035	0.0021	0.0479	0.0019	0.0099	0.0099	0.0029	0.0083	0.0037	0.0009	0.0774	0.0369	0.0125	0.1055	0.1392	0.0355	0.1416	0.1250	0.0784	0.0316	0.0437	0.0632	0.0124	0.0056	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006	0.0000	0.0000
	4	0.1055	0.0222	0.0320	0.0052	0.0016	0.0773	0.2536	0.0267	0.0164	0.0827	0.0007	0.0013	0.0005	0.0126	0.0231	0.0027	0.0101	0.0309	0.0000	0.0305	0.0302	0.1554	0.0467	0.0209	0.0016	0.0028	0.0050	0.0008	0.0000	0.0000	0.0000	0.0008	0.0005	0.0000	0.0000
	5	0.0152	0.0190	0.0447	0.1238	0.0582	0.2174	0.1067	0.0734	0.0199	0.0931	0.0095	0.0012	0.0002	0.0129	0.0052	0.0015	0.0062	0.0139	0.0000	0.0178	0.0185	0.0587	0.0543	0.0047	0.0084	0.0064	0.0090	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2010	1	0.0130	0.0118	0.0218	0.0429	0.0161	0.1210	0.0807	0.0456	0.0451	0.0300	0.0000	0.0014	0.0006	0.0048	0.0105	0.0078	0.0526	0.1396	0.0035	0.0639	0.0745	0.0257	0.0383	0.0734	0.0421	0.0000	0.0272	0.0038	0.0000	0.0000	0.0000	0.0021	0.0000	0.0000	0.0000
	4	0.0506	0.0167	0.0480	0.0663	0.1274	0.0574	0.0304	0.0226	0.0283	0.0371	0.0000	0.0019	0.0033	0.0086	0.0753	0.0031	0.0841	0.1396	0.0038	0.0225	0.0094	0.0457	0.0631	0.0208	0.0095	0.0133	0.0097	0.0019	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	5	0.0670	0.1457	0.0848	0.1239	0.0744	0.0428	0.0147	0.0515	0.0162	0.0436	0.0000	0.0011	0.0000	0.0280	0.0164	0.0038	0.0361	0.0436	0.0106	0.0197	0.0534	0.0400	0.0274	0.0283	0.0175	0.0000	0.0071	0.0016	0.0000	0.0000	0.0000	0.0000	0.0000	0.0011	0.0000
	6	0.0171	0.0000	0.0000	0.0000	0.0106	0.1488	0.3585	0.0163	0.0095	0.0103	0.0095	0.0000	0.0005	0.0143	0.0479	0.0000	0.1063	0.0431	0.0167	0.0220	0.1016	0.0112	0.0161	0.0120	0.0138	0.0000	0.0088	0.0000	0.0000	0.0000	0.0000	0.0000	0.0022	0.0000	0.0029
2011	1	0.0130	0.0110	0.0187	0.0146	0.0212	0.1665	0.0837	0.2172	0.0349	0.0542	0.0204	0.0008	0.0006	0.0159	0.0576	0.0030	0.0682	0.1289	0.0000	0.0096	0.0102	0.0034	0.0278	0.0186	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	2	0.0336	0.0024	0.0307	0.0287	0.0181	0.0758	0.0363	0.0819	0.0251	0.0191	0.0053	0.0005	0.0044	0.0029	0.0314	0.0042	0.0487	0.0846	0.0193	0.0785	0.1454	0.0624	0.0531	0.0296	0.0137	0.0134	0.0490	0.0013	0.0000	0.0000	0.0008	0.0000	0.0000	0.0000	0.0000
	3	0.0000	0.0079	0.0062	0.0150	0.0301	0.0522	0.0043	0.0143	0.0067	0.0000	0.0000	0.0009	0.0010	0.0725	0.0207	0.0069	0.0611	0.1476	0.0775	0.2083	0.1842	0.0000	0.0228	0.0259	0.0190	0.0075	0.0075	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	4	0.0000	0.0038	0.0000	0.0916	0.1170	0.2984	0.0612	0.0802	0.0198	0.0184	0.0000	0.0000	0.0005	0.0113	0.0252	0.0030	0.0097	0.1250	0.0144	0.0057	0.0846	0.0128	0.0044	0.0000	0.0050	0.0000	0.0049	0.0031	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	5	0.2285	0.0972	0.0192	0.0641	0.1032	0.0171	0.0000	0.0814	0.0078	0.2402	0.0000	0.0000	0.0009	0.0236	0.0183	0.0012	0.0000	0.0000	0.0124	0.0000	0.0289	0.0000	0.0100	0.0096	0.0259	0.0000	0.0106	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2012	1	0.0000	0.0000	0.0127	0.0206	0.0000	0.1460	0.1212	0.0000	0.0075	0.0282	0.0017	0.0022	0.0000	0.0224	0.0130	0.0028	0.0766	0.1361	0.0000	0.1099	0.1076	0.0275	0.0437	0.0819	0.0196	0.0189	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	2	0.2521	0.0066	0.0415	0.0310	0.0193	0.0884	0.0153	0.0077	0.0072	0.0519	0.0029	0.0010	0.0009	0.0301	0.0301	0.0011	0.0460	0.0765	0.0000	0.0543	0.0935	0.0384	0.0047	0.0355	0.0373	0.0000	0.0203	0.0035	0.0019	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012
	3	0.0000	0.0000	0.0143	0.0081	0.0000	0.1628	0.0815	0.0082	0.0225	0.0258	0.0000	0.0009	0.0024	0.0026	0.0182	0.0024	0.0551	0.1591	0.0164	0.1159	0.1445	0.0047	0.0522	0.0050	0.0373	0.0508	0.0095	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	4	0.0593	0.0053	0.0236	0.0390	0.0248	0.0813	0.0322	0.1418	0.0230	0.0000	0.0000	0.0011	0.0000	0.0099	0.0250	0.0015	0.0829	0.1637	0.0168	0.0388	0.1124	0.0754	0.0192	0.0043	0.0000	0.0000	0.0102	0.0063	0.0000	0.0000	0.0000	0.0000	0.0000	0.0019	0.0000
	6	0.0894	0.0469	0.0522	0.0211	0.2308	0.1499	0.0583	0.0204	0.0683	0.1683	0.0000	0.0000	0.0048	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0151	0.0000	0.0392	0.0082	0.0000	0.0274	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2013	1	0.1422	0.0980	0.0000	0.0635	0.1968	0.0000	0.2731	0.0000	0.0000	0.1031	0.0000	0.0000	0.0000	0.0000	0.0078	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0208	0.0000	0.0141	0.0192	0.0000	0.0614	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	2	0.0124	0.0147	0.1148	0.0597	0.0858	0.0918	0.0308	0.1344	0.0087	0.1266	0.0000	0.0000	0.0000	0.0330	0.0013	0.0009	0.0704	0.0787	0.0034	0.0423	0.0280	0.0224	0.0202	0.0117	0.0000	0.0000	0.0079	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	3	0.0440	0.0000	0.0713	0.0527	0.0554	0.0301	0.0232	0.0568	0.0187	0.0499	0.0000	0.0000	0.0000	0.0514	0.0289	0.0037	0.0223	0.0807	0.0462	0.0927	0.1084	0.0435	0.0099	0.0472	0.0098	0.0164	0.0348	0.0000	0.0018	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	4	0.0000	0.0548	0.0103	0.0188	0.0253	0.0369	0.0194	0.0912	0.0116	0.0510	0.0000	0.0000	0.0000	0.0045	0.0296	0.0035	0.0585	0.1107	0.0934	0.1044	0.1985	0.0276	0.0201	0.0110	0.0036	0.0000	0.0134	0.0017	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	5	0.0689	0.0000	0.0506	0.0253	0.0280	0.1278	0.0172	0.0957	0.0245	0.0084	0.0000	0.0000	0.0000	0.0083	0.0134	0.0029	0.0422	0.1206	0.0498	0.0531	0.1243	0.0666	0.0384	0.0192	0.0115	0.0000	0.0034	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	6	0.0000	0.0680	0.0000	0.0000	0.0000	0.0000	0.1270	0.0000	0.0550	0.0000	0.0000	0.0000	0.0000	0.0411	0.0000	0.0000	0.3130	0.0000	0.0000	0.0000	0.0000	0.0000	0.3286	0.0000	0.0000	0.0000	0.0673	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2014	1	0.0000	0.0000	0.0190	0.0094	0.0000	0.2113	0.2272	0.0000	0.0332	0.0382	0.0053	0.0022	0.0100	0.0320	0.0287	0.0008	0.0131	0.0197	0.0276	0.0126	0.0259	0.0814	0.0425	0.0773	0.0467	0.0175	0.0183	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0494	0.0598	0.0291	0.0171	0.0373	0.0020	0.0009	0.0007	0.0137	0.0079	0.0021	0.0095	0.0501	0.0446	0.2024	0.2176	0.0570	0.0096	0.0156	0.1374	0.0143	0.0162	0.0057	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	3	0.0000	0.0168	0.0415	0.0223	0.0137	0.0434	0.0381	0.0462	0.0159	0.0413	0.0000	0.0042	0.0000	0.0148	0.0024	0.0046	0.0042	0.0230	0.0367	0.2676	0.1165	0.1119	0.0160	0.0664	0.0324	0.0000	0.0201	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	4	0.0000	0.0000	0.0000	0.0000	0.0098	0.0124	0.0606	0.1058	0.0194	0.0000	0.0000	0.0018	0.0014	0.0208	0.0358	0.0000	0.0762	0.1184	0.0000	0.0980	0.2803	0.1038	0.0000	0.0280	0.0207	0.0000	0.0070	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	5	0.0000	0.0000	0.2679	0.0000	0.1638	0.0460	0.0423	0.0652	0.0338	0.0000	0.0000	0.0000	0.0105	0.0000	0.0000	0.0000	0.0221	0.0000	0.0000	0.0000	0.0000	0.0900	0.1203	0.0316	0.0391	0.0000	0.0673	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	6	0.0000	0.0000	0.0000	0.0000	0.3797	0.0000	0.0000	0.0000	0.1078	0.0000	0.0000	0.0000	0.0338	0.0000	0.0000	0.0000	0.4788	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Note: Surveys 2 and 3 in 2010 and 5 in 2012 had missing data and were excluded from the analysis.

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There was little evidence that the general distribution of Longfin Smelt larvae from the SLS varied by year in relation to hydrological conditions, at least for the groups of stations examined herein[7] (Table 4.A-5). Therefore an overall mean distribution was used to weigh the results of the DSM2-PTM analysis, based on the mean proportion by station from all surveys during 2009–2014.

Table 4.A-5. Mean Proportion of Longfin Smelt Larvae In Each Group of SLS Stations.

Year	Mean Dec.-Mar. Delta Outflow (cfs)	400s	500s	600s	700s	800s	900s
2009	13,808	0.06	0.33	0.05	0.35	0.20	0.02
2010	19,863	0.12	0.39	0.03	0.32	0.12	0.02
2011	55,663	0.09	0.37	0.07	0.37	0.07	0.02
2012	11,946	0.12	0.33	0.06	0.36	0.13	0.01
2013	23,600	0.13	0.31	0.06	0.35	0.13	0.03
2014	8,331	0.06	0.31	0.03	0.38	0.19	0.02
Mean		**0.09**	**0.34**	**0.05**	**0.36**	**0.14**	**0.02**
See Figure 4.A-11 for station locations.							

4.A.1.4.2 DSM2-PTM Runs

Sixty-day-long DSM2-PTM[8] runs were undertaken for the NAA and PP scenarios at 39 particle injection locations in the Delta and Suisun Bay/Marsh (Table 4.A-6) during January, February, and March in 1922–2003. For each run, 4,000 neutrally buoyant passive particles were injected evenly every hour (i.e., about 160 particles per hour) over a 24.75-hour period at the beginning of the month. The fate of the particles was output at forty-five days, which was assumed to represent the duration that newly hatched larvae could be considered to act as neutrally buoyant particles with relatively poor swimming ability, and would therefore be susceptible to movement by prevailing channel currents, including entrainment. By the time larvae develop air bladders at around 12-mm TL, they are able to manipulate their position in the water column (Bennett et al. 2002), although they are still susceptible to entrainment, which is not represented by the tracking of particles for 45 days in the present analysis.

Each particle injection location was assigned to one or more SLS stations, and some SLS stations had multiple particle injection locations assigned to them, reflecting the relative distribution of the nearest SLS station to particle injection locations (e.g., station 919 had five injection locations assigned to it, whereas station 901 had one injection location assigned to it; Table 4.A-6). The weight assigned to the particles injected at each PTM injection location reflected the mean proportion of larvae captured at the associated SLS station (Table 4.A-4) divided by the number of injection locations at a given station. As an example, station 707 was assigned two particle injection locations: Threemile Slough (location no. 15) and Sacramento River at Rio Vista (location no. 31) (Table 4.A-6). The overall mean proportion of larval Longfin Smelt at station 707 across all surveys in 2009–2014 was 0.078 (mean of values in the 707 column of Table 4.A-4). This 0.078 (i.e., 7.8% of larvae) was then divided equally among the two particle

[7] This does not preclude the possibility of a considerable proportion of the population occurring downstream of the SLS sampling area during wet years, for example.

injection locations assigned to SLS station 707, giving a weight of 0.039 (i.e., 3.9% of larvae) for the particles injected at both locations (Table 4.A-6).

SLS stations downstream of the Sacramento-San Joaquin river confluence (i.e., stations numbered 400s to 600s) were considered to be downstream of the influence of the SWP/CVP export facilities, and so were not included in the PTM analysis (but were used in the calculation of proportions; see Table 4.A-4). Similarly, PTM injection locations downstream of the confluence were assigned zero weight, because these particles would not be susceptible to entrainment at the locations of interest. In addition, particles injected in the Sacramento River at Sacramento and Sutter Slough were assigned zero weight because they are upstream of the range of the SLS (suggesting that this portion of the river is of minor concern for Longfin Smelt management, as appears to be justified by historic sampling in that area; see discussion in Section 4.2.2.2 *Entrainment and South Delta Entry* of Chapter 4). The summed weight of all the PTM injection locations in the analysis was 0.52, reflecting that 0.48 of the larval population was assumed to be downstream of the confluence and therefore not susceptible to entrainment in the Delta (see sum of the 400s, 500s, and 600s stations in Table 4.A-5). As discussed further in Section 4.A.2.1.3 *Note on Proportion of Larval Population Outside the Delta and Suisun Bay/Marsh*, the spatial extent of the SLS data used in the present analysis includes only the Delta and Suisun Bay/Marsh, but the full extent of the distribution of larval Longfin Smelt may be considerably greater.

Table 4.A-6. Particle Injection Locations, Associated SLS Stations, and Location Weight for the DSM2-PTM Analysis of Potential Larval Longfin Smelt Entrainment.

PTM Injection Location Number	PTM Injection Location Name	SLS Station	Weight
1	San Joaquin River at Vernalis	912	0.000014
2	San Joaquin River at Mossdale	912	0.000014
3	San Joaquin River D/S of Rough and Ready Island	910	0.000000
4	San Joaquin River at Buckley Cove	910	0.000000
5	San Joaquin River near Medford Island	906	0.000463
6	San Joaquin River at Potato Slough	815	0.003088
7	San Joaquin River at Twitchell Island	812	0.021832
8	Old River near Victoria Canal	918	0.000032
9	Old River at Railroad Cut	915	0.000191
10	Old River near Quimby Island	902	0.000957
11	Middle River at Victoria Canal	918	0.000032
12	Middle River u/s of Mildred Island	914	0.000094
13	Grant Line Canal	918	0.000032
14	Frank's Tract East	901	0.017578
15	Threemile Slough	707	0.038899
16	Little Potato Slough	919	0.000026
17	Mokelumne River d/s of Cosumnes confluence	919	0.000026
18	South Fork Mokelumne	919	0.000026

[8] DSM2 modeling methods and results for the NAA and PP are presented in ICF International (2016: Appendix 5.B *DSM2 Modeling and Results*).

PTM Injection Location Number	PTM Injection Location Name	SLS Station	Weight
19	Mokelumne River d/s of Georgiana confluence	815	0.003088
20	North Fork Mokelumne	919	0.000026
21	Georgiana Slough	919	0.000026
22	Miner Slough	716+723	0.028025
23	Sacramento Deep Water Ship Channel	716+723	0.028025
24	Cache Slough at Shag Slough	716+723	0.028025
25	Cache Slough at Liberty Island	716+723	0.028025
26	Lindsey Slough at Barker Slough	716+723	0.028025
27	Sacramento River at Sacramento	upstream	0.000000
28	Sacramento River at Sutter Slough	upstream	0.000000
29	Sacramento River at Ryde	711	0.009815
30	Sacramento River near Cache Slough confluence	711	0.009815
31	Sacramento River at Rio Vista	707	0.038899
32	Sacramento River d/s of Decker Island	705+706	0.075899
33	Sacramento River at Sherman Lake	704	0.022743
34	Sacramento River at Port Chicago	downstream	0.000000
35	Montezuma Slough near National Steel	downstream	0.000000
36	Montezuma Slough at Suisun Slough	downstream	0.000000
37	San Joaquin River d/s of Dutch Slough	703+804	0.058814
38	Sacramento River at Pittsburg	801	0.048938
39	San Joaquin River near Jersey Point	809	0.026464

For each simulated month in the DSM2-PTM analysis, the percentage of particles from each particle injection location was output for several fates: entrainment (the SWP's Clifton Court Forebay, the CVP's Jones Pumping Plant, the proposed NDD, and the NBA Barker Slough Pumping Plant), entry into the south Delta (defined as the sum of particles entering Big Break, Dutch Slough, False River, Fishermans Cut, Old River mouth, Middle River mouth, Columbia Cut, and Turner Cut), and reaching Chipps Island. These percentages were multiplied by the weight for each particle injection location (Table 4.A-6), and then summed across all injection locations to give a relative comparison of the overall percentage of larvae that would have been entrained or entered the south Delta under the NAA and PP scenarios. Note that these percentages are not intended to represent an absolute estimate of the actual percentage of larvae that would be entrained, and should be interpreted only as a comparison of two operational scenarios (NAA and PP). However, discussion of the potential absolute percentage of larvae entrained is provided in Section 4.2.5.3.1 *North Delta Exports* and Section 4.2.5.3.2 *South Delta Exports* in Chapter 4. The latest version of DSM2-PTM allows the user to not allow particles to be entrained into small agricultural diversions; this option was used for the present analysis in order to represent the hypothesis that such losses may not be substantial for Longfin Smelt (based on observations for delta smelt; Nobriga et al. 2004) and because losses at agricultural diversions were not the focus of the present analysis. In addition to reporting of the above fates, the percentage of particles remaining in the DSM2-PTM modeling domain after 45 days (i.e., neither entrained nor having left the domain) was also calculated.

4.A.1.4.3 Note on Proportion of Larval Population Outside the Delta and Suisun Bay/Marsh

The spatial distribution of newly hatched larvae determined from the SLS is likely much broader than observed, especially during wet years. Grimaldo et al. (2014) recently showed that larval Longfin Smelt are hatching in shallow water and tidal marsh habitats in salinities up to 8 ppt. Previously thought to concentrate spawning in freshwater (Rosenfield and Baxter 2007; California Department of Fish and Game 2009a,b; Kimmerer et al. 2009), the analysis presented here and work by Grimaldo et al. (2014) shows that Longfin Smelt hatching is broadly distributed throughout Suisun Bay in most years (Table 4.A-4). The proportion of newly hatched larvae from Delta stations was consistently lower than densities observed in Suisun Bay. Further, because overall larval Longfin Smelt abundance in the SLS is lowest during wet years, it is likely that spawning and hatching is occurring in San Pablo Bay and adjacent tributaries (e.g., Napa River, Petaluma River) when the area becomes suitable for spawning. Ultimately, this does not affect interpretation of results presented here (Section 4.A.2.2.1 *Entrainment*) because relative comparisons of NAA and PP were made using data for observations of larvae. The potential effects of survey bias would be more relevant for real-time operations where interpretation of proportional losses are likely to be affected by the observed versus actual distribution of larvae in the SLS survey.

4.A.1.5 Results

The analyses of entrainment and entry into the south Delta presented in the following sections relied on the processing of the raw DSM2-PTM outputs described in Section 4.A.2.1, *Methods*. In order to allow DFW to examine raw outputs as necessary, these are provided electronically as attachment 4.A.5.1, *Raw DSM2-PTM Outputs*.

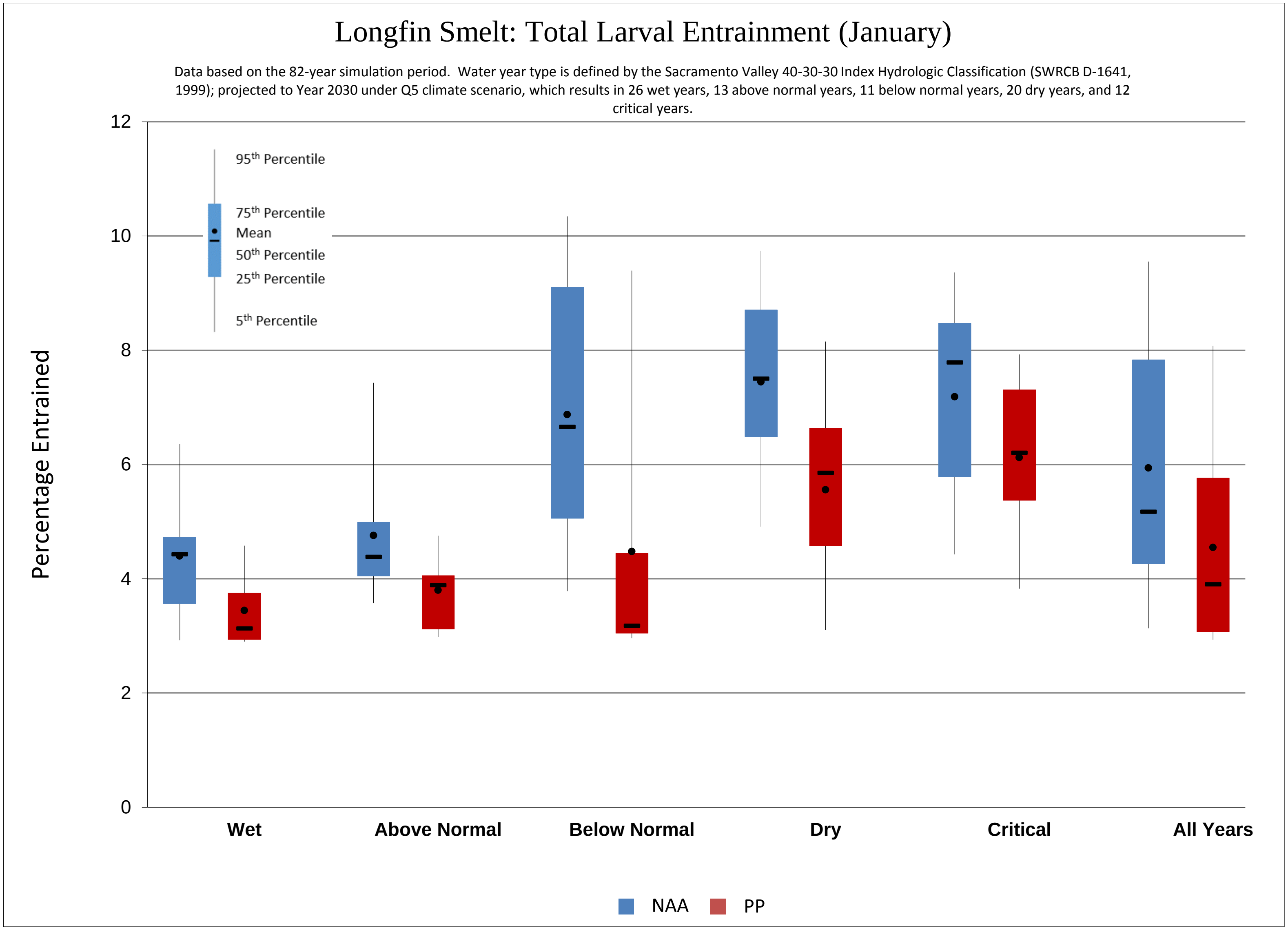
4.A.1.5.1 Entrainment

The DSM2-PTM analysis indicates that Longfin Smelt larval total entrainment in January could be less under PP than NAA in all years (Figure 4.A-7 and Figure 4.A-8). Differences in mean total entrainment by water year ranged from 15% less in critical years to 35% less in below normal years (Table 4.A-7). The majority of total entrainment was at the NBA, and at this location there was essentially no difference between NAA and PP scenarios, with little difference between water year types. This result reflected near 100% entrainment of the 0.029 (2.9%) of particles released in Lindsey Slough at Barker Slough (PTM injection location number 26 in Table 4.A-6). Differences in total entrainment reflected differences modeled at the SWP/CVP south Delta export facilities, which ranged from 21-27% less under PP in critical years to 60-67% less under PP in wet years (Table 4.A-7).

For February, the analysis again indicated that total entrainment generally could be less under PP than NAA (Figure 4.A-9 and Figure 4.A-10), with differences in mean annual entrainment ranging from 1% less under PP in critical years to 23% less under PP in wet years (Table 4.A-7). As with January, most entrainment was at the NBA, so differences between NAA and PP were driven by differences in south Delta entrainment, which ranged from 13–17% less under PP in critical years to 94–97% less under PP in wet years. There generally were minimal differences between NAA and PP in NBA entrainment, except in critical years, for which there was slightly greater entrainment under PP; this difference reflected a slightly greater allocation of water for pumping under the PP compared to the NAA. DSM2 only includes a simplistic representation of NBA diversion at the Barker Slough Intake. The monthly diversion amount determined by CalSim II is assumed to be diverted each day of the month in DSM2, and does not reflect any operational changes that occur on a sub-monthly scale.

Total entrainment in March, as in January and February, generally could be less under PP than NAA (Figures 4.A-11 and 4.A-12). Differences in total mean annual entrainment ranged from 1% less under PP in dry years to 31% less under PP in above normal years (Table 4.A-7). As with the other months, the differences were driven primarily by differences in south Delta entrainment, for which entrainment in wet and above normal years under PP was minimal (98-99% less entrainment than under NAA), whereas differences in other water year types were smaller (ranging from 6% greater under PP in dry years at CVP to 38% less under PP in below normal years at SWP; Table 4.A-7). Differences in NBA entrainment again were mostly minimal and varied little between water year types, except in critical years, for which entrainment was 10% less under PP; as for February, this difference reflected a slightly greater allocation of water for pumping under the PP compared to the NAA.

Entrainment at the NDD was zero in all months, which reflects the zero weight assigned to the particle injection locations upstream of the NDD (Sacramento River at Sacramento) and the fact that net downstream flows in the Sacramento River would not allow neutrally buoyant particles injected downstream to move into the vicinity of the NDD. The assumption of no Longfin Smelt upstream of the NDD appears reasonable given the very low abundance of Longfin Smelt observed in the vicinity of the NDD from historical surveys (see discussion in Chapter 4) and the fact that existing surveys such as the SLS focus on the main area of occurrence in the Delta and Suisun Bay/Marsh.



1

2 **Figure 4.A-7. Box Plot of Longfin Smelt Larval Total Entrainment in January from DSM2-PTM Modeling, Grouped by Water Year Type.**

3

Figure 4.A-8. Exceedance Plot of Longfin Smelt Larval Total Entrainment in January from DSM2-PTM Modeling.

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Table 4.A-7. Mean Annual Percentage of Larval Longfin Smelt Entrained at Locations Within the Delta By Water Year Type, from DSM2-PTM Analysis of January-March 1922-2003.

Month	Water Year Type	SWP (Clifton Court Forebay)			CVP (Jones Pumping Plant)			NDD			NBA			Total Entrainment		
		NAA	PP	PP vs. NAA[1]	NAA	PP	PP vs. NAA[1]	NAA	PP	PP vs. NAA[1]	NAA	PP	PP vs. NAA[1]	NAA	PP	PP vs. NAA[1]
January	Wet	1.03	0.34	-0.69 (-67%)	0.45	0.18	-0.27 (-60%)	0.00	0.00	0.00 (0%)	2.91	2.92	0.01 (0%)	4.40	3.44	-0.95 (-22%)
	Above Normal	1.23	0.64	-0.59 (-48%)	0.63	0.26	-0.37 (-59%)	0.00	0.00	0.00 (0%)	2.89	2.90	0.01 (0%)	4.76	3.80	-0.96 (-20%)
	Below Normal	2.47	0.96	-1.51 (-61%)	1.52	0.62	-0.90 (-59%)	0.00	0.00	0.00 (0%)	2.89	2.90	0.01 (0%)	6.87	4.48	-2.40 (-35%)
	Dry	2.82	1.56	-1.26 (-45%)	1.71	1.08	-0.63 (-37%)	0.00	0.00	0.00 (0%)	2.92	2.92	0.00 (0%)	7.44	5.55	-1.89 (-25%)
	Critical	2.75	1.99	-0.75 (-27%)	1.54	1.22	-0.32 (-21%)	0.00	0.00	0.00 (0%)	2.90	2.90	0.00 (0%)	7.19	6.12	-1.07 (-15%)
February	Wet	0.66	0.02	-0.64 (-97%)	0.27	0.02	-0.26 (-94%)	0.00	0.00	0.00 (0%)	2.90	2.91	0.01 (0%)	3.82	2.94	-0.89 (-23%)
	Above Normal	1.23	0.66	-0.57 (-46%)	0.60	0.19	-0.40 (-68%)	0.00	0.00	0.00 (0%)	2.91	2.92	0.01 (0%)	4.74	3.78	-0.96 (-20%)
	Below Normal	1.43	1.00	-0.43 (-30%)	0.75	0.60	-0.15 (-20%)	0.00	0.00	0.00 (0%)	2.90	2.90	0.00 (0%)	5.08	4.49	-0.58 (-12%)
	Dry	1.67	1.16	-0.51 (-31%)	0.91	0.68	-0.23 (-25%)	0.00	0.00	0.00 (0%)	2.91	2.91	0.00 (0%)	5.48	4.74	-0.74 (-13%)
	Critical	1.35	1.17	-0.18 (-13%)	0.59	0.49	-0.10 (-17%)	0.00	0.00	0.00 (0%)	2.42	2.66	0.24 (10%)	4.36	4.32	-0.05 (-1%)
March	Wet	0.73	0.01	-0.72 (-99%)	0.32	0.01	-0.32 (-98%)	0.00	0.00	0.00 (0%)	2.90	2.90	0.01 (0%)	3.95	2.92	-1.03 (-26%)
	Above Normal	0.93	0.01	-0.93 (-99%)	0.42	0.00	-0.42 (-99%)	0.00	0.00	0.00 (0%)	2.88	2.90	0.03 (1%)	4.24	2.91	-1.32 (-31%)
	Below Normal	1.13	0.70	-0.43 (-38%)	0.53	0.46	-0.08 (-15%)	0.00	0.00	0.00 (0%)	2.90	2.92	0.02 (1%)	4.56	4.07	-0.49 (-11%)
	Dry	0.96	0.87	-0.09 (-9%)	0.50	0.53	0.03 (6%)	0.00	0.00	0.00 (0%)	2.89	2.89	0.00 (0%)	4.35	4.29	-0.05 (-1%)
	Critical	0.62	0.39	-0.23 (-37%)	0.25	0.24	-0.01 (-4%)	0.00	0.00	0.00 (0%)	2.16	1.93	-0.23 (-10%)	3.03	2.56	-0.46 (-15%)

[1] Negative values indicate lower entrainment loss under the proposed project (PP) than under the no action alternative (NAA).

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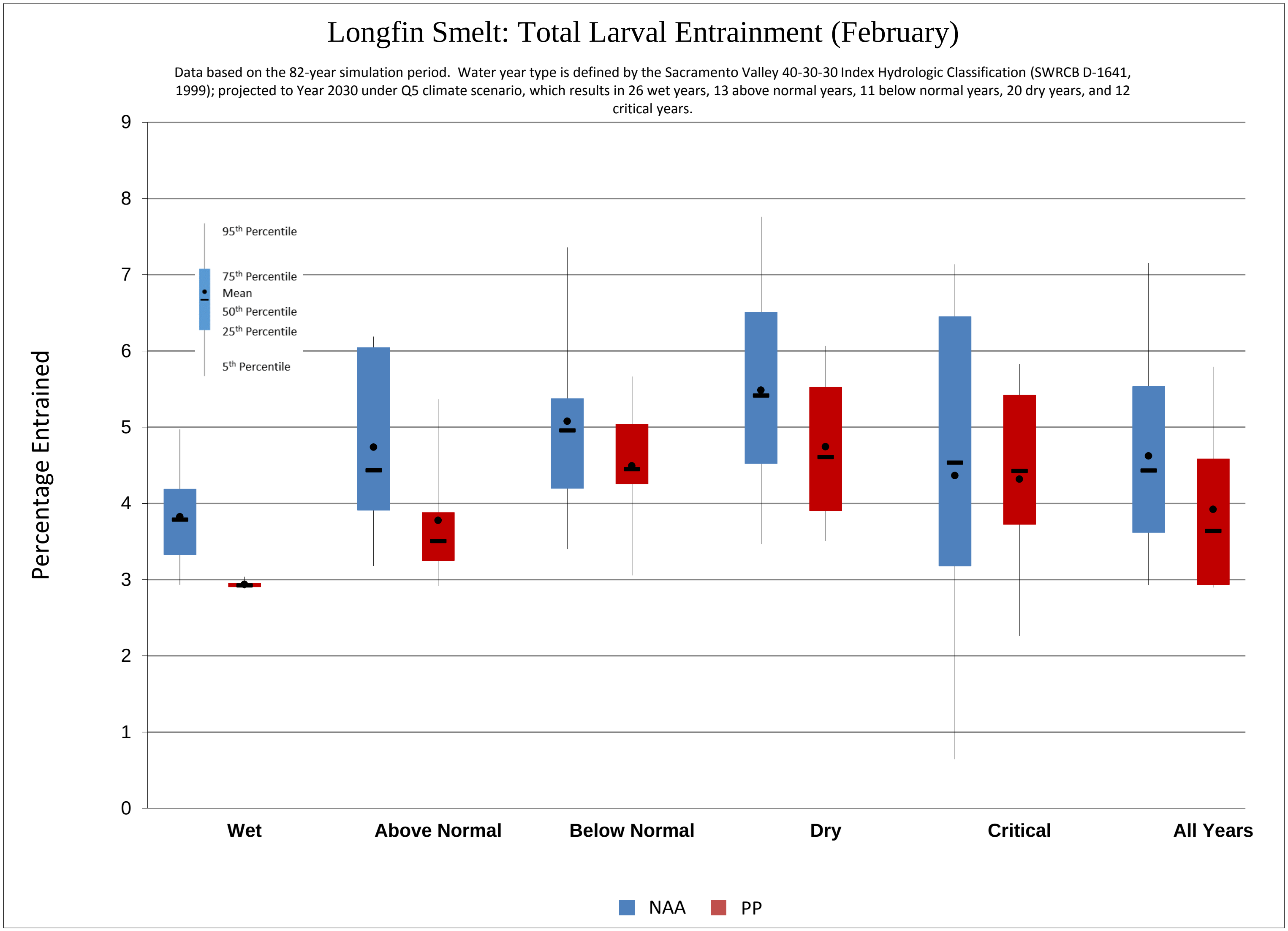
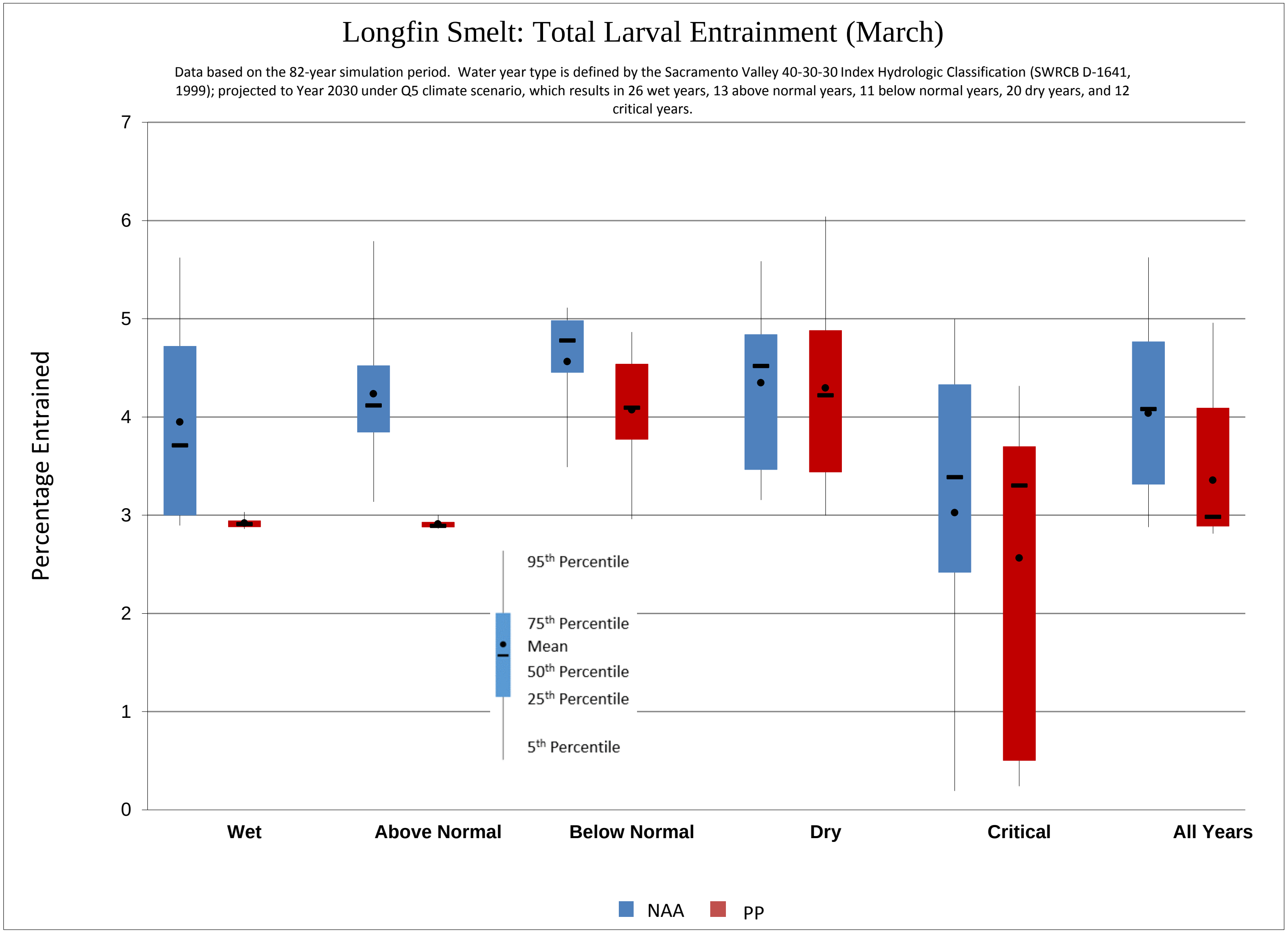


Figure 4.A-9. Box Plot of Longfin Smelt Larval Total Entrainment in February from DSM2-PTM Modeling, Grouped by Water Year Type.

1

2 **Figure 4.A-10. Exceedance Plot of Longfin Smelt Larval Total Entrainment in February from DSM2-PTM Modeling.**

3

1


2 **Figure 4.A-11. Box Plot of Longfin Smelt Larval Total Entrainment in March from DSM2-PTM Modeling, Grouped by Water Year Type.**

3

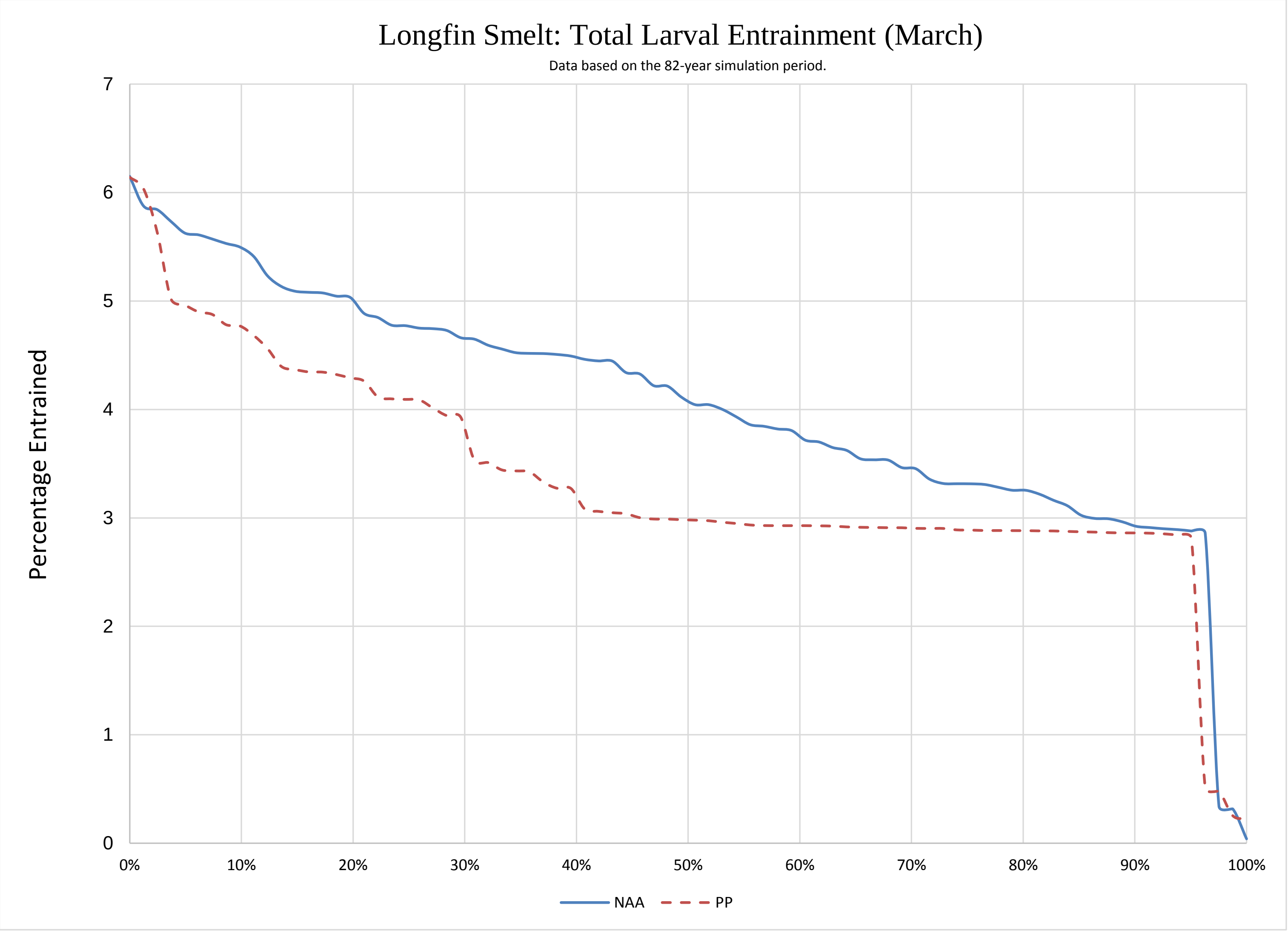


Figure 4.A-12. Exceedance Plot of Longfin Smelt Larval Total Entrainment in March from DSM2-PTM Modeling.

4.A.1.5.2 Entry Into the South Delta

The potential for Longfin Smelt larvae to enter the south Delta through Big Break, Dutch Slough, False River, Fishermans Cut, Old River mouth, Middle River mouth, Columbia Cut, or Turner Cut, was less under PP than NAA, as assessed with DSM2-PTM (Figure 4.A-13, Figure 4.A-14, and Table 4.A-8; Figure 4.A-15 and Figure 4.A-16; Figure 4.A-17 and Figure 4.A-18). Negative south Delta entry percentages indicate net exiting of the south Delta, and a percentage of zero indicates a balance in the percentage of particles entering and the percentage of particles exiting. In January, 0% or more of particles entered the south Delta in ~40% of years under PP, compared to ~65% of years under NAA (Figure 4.A-14). In February, 0% or more of particles entered the south Delta in ~35% of years under PP, compared to just under 50% of years under NAA (Figure 4.A-16). In March, 0% or more of particles entered the south Delta in ~25% of years under PP, compared to ~45% of years under NAA (Figure 4.A-18). There was a mean net exit of particles (i.e., south Delta entry percentage below zero) from the south Delta under the PP in wet and above normal years in January and February, and in wet, above normal, and below normal years in March; whereas under the NAA, there was a mean net exit of particles only in wet years in January and February, and in wet and above normal years in March (Table 4.A-8).

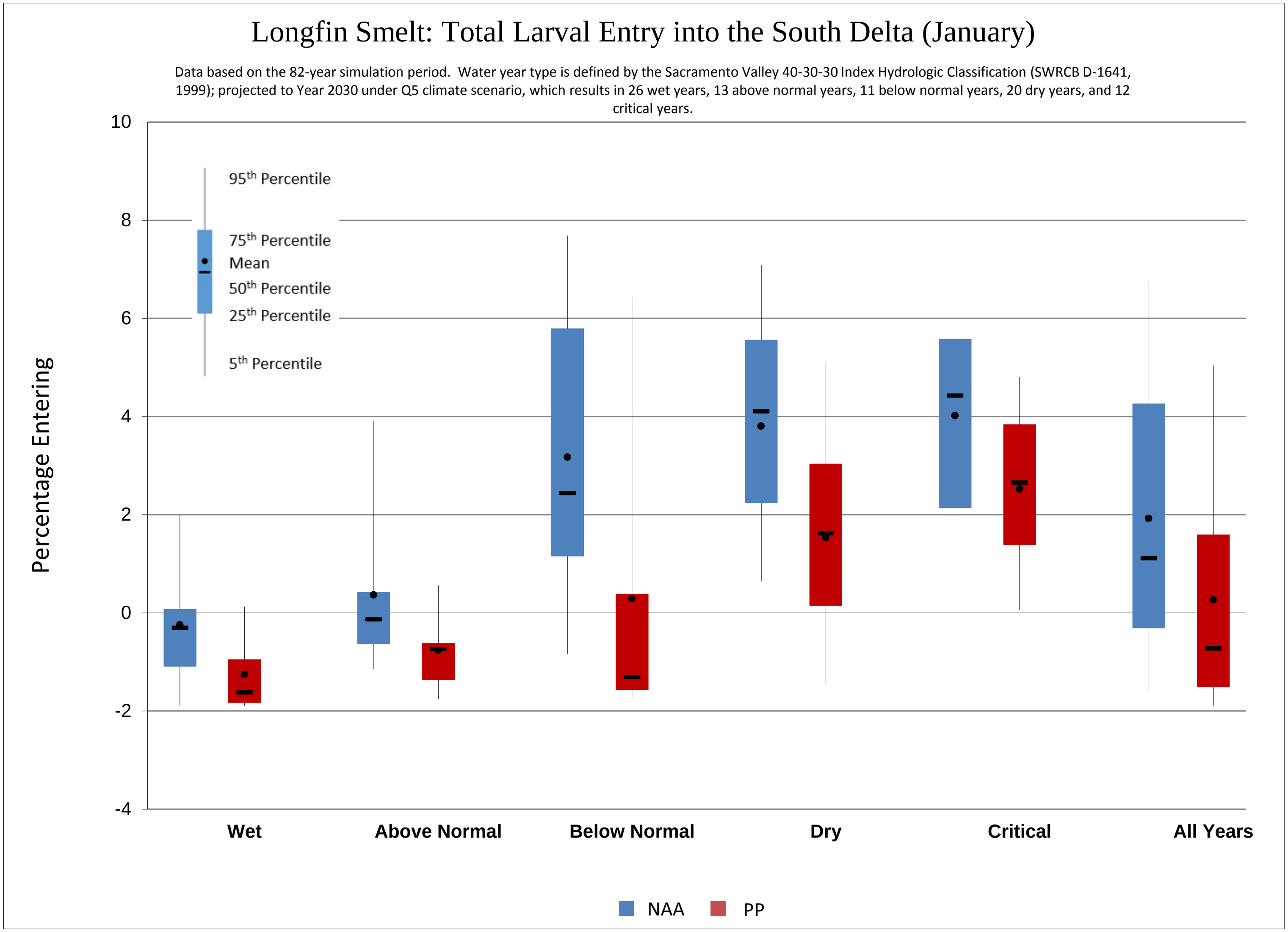


Figure 4.A-13. Box Plot of Longfin Smelt Larval South Delta Entry in January from DSM2-PTM Modeling, Grouped by Water Year Type.

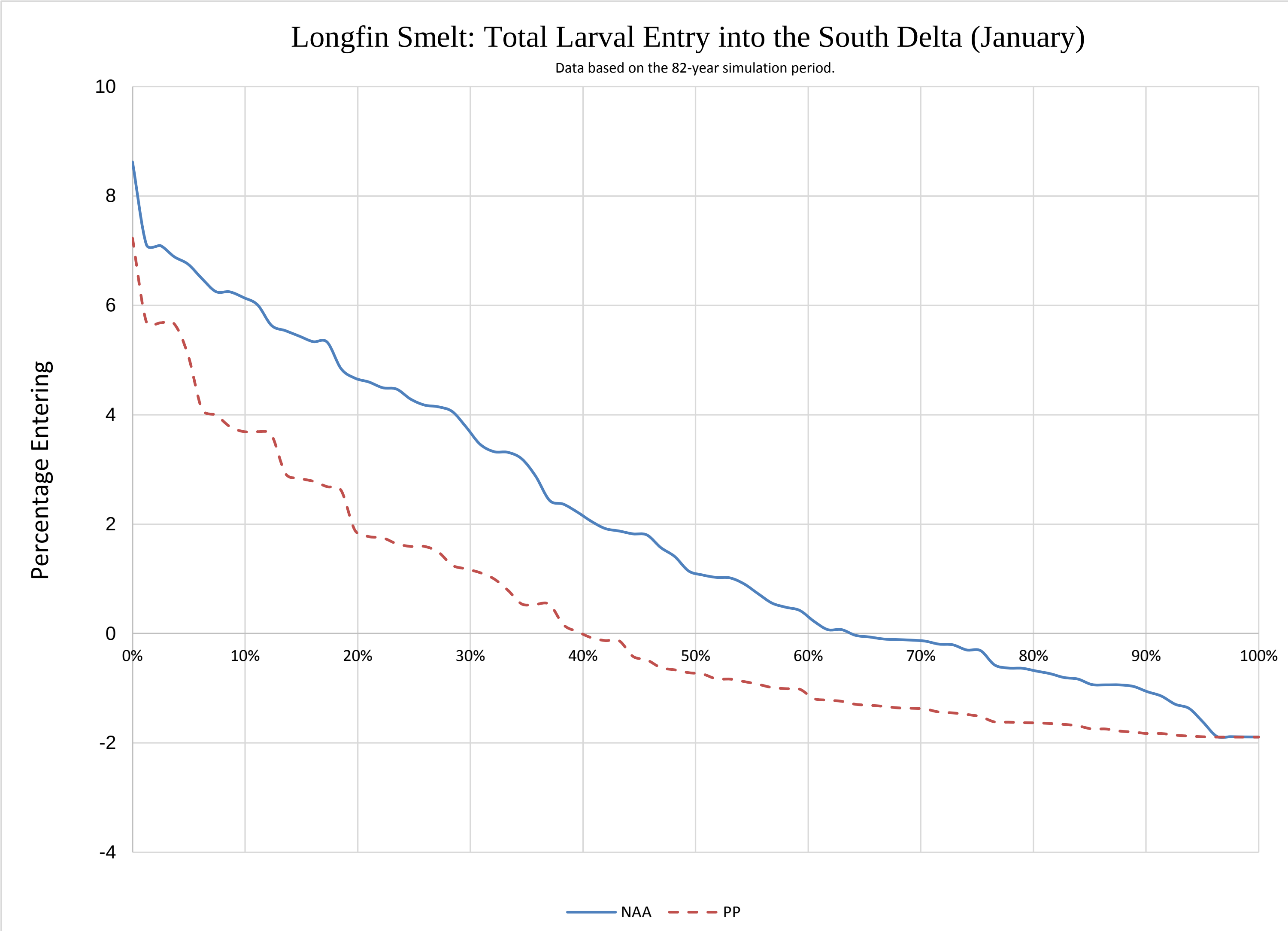


Figure 4.A-14. Exceedance Plot of Longfin Smelt Larval South Delta Entry in January from DSM2-PTM Modeling.

Table 4.A-8. Mean Annual Percentage of Larval Longfin Smelt Entering the South Delta By Water Year Type, from DSM2-PTM Analysis of January-March 1922-2003.

Water Year Type	January			February			March		
	NAA	PP	PP vs. NAA[1]	NAA	PP	PP vs. NAA[1]	NAA	PP	PP vs. NAA[1]
Wet	-0.25	-1.26	-1.01 (-412%)	-0.88	-1.83	-0.95 (-108%)	-0.74	-1.85	-1.11 (-152%)
Above Normal	0.36	-0.76	-1.13 (-311%)	0.20	-0.74	-0.94 (-477%)	-0.33	-1.83	-1.49 (-446%)
Below Normal	3.17	0.29	-2.88 (-91%)	0.87	0.13	-0.74 (-85%)	0.46	-0.29	-0.76 (-163%)
Dry	3.81	1.54	-2.27 (-60%)	1.46	0.54	-0.92 (-63%)	0.30	0.15	-0.15 (-49%)
Critical	4.01	2.52	-1.49 (-37%)	1.14	0.76	-0.38 (-33%)	0.39	0.05	-0.34 (-87%)

Note:
[1] Negative values indicated lower entry into the south Delta under the proposed project (PP) than under the no action alternative (NAA).

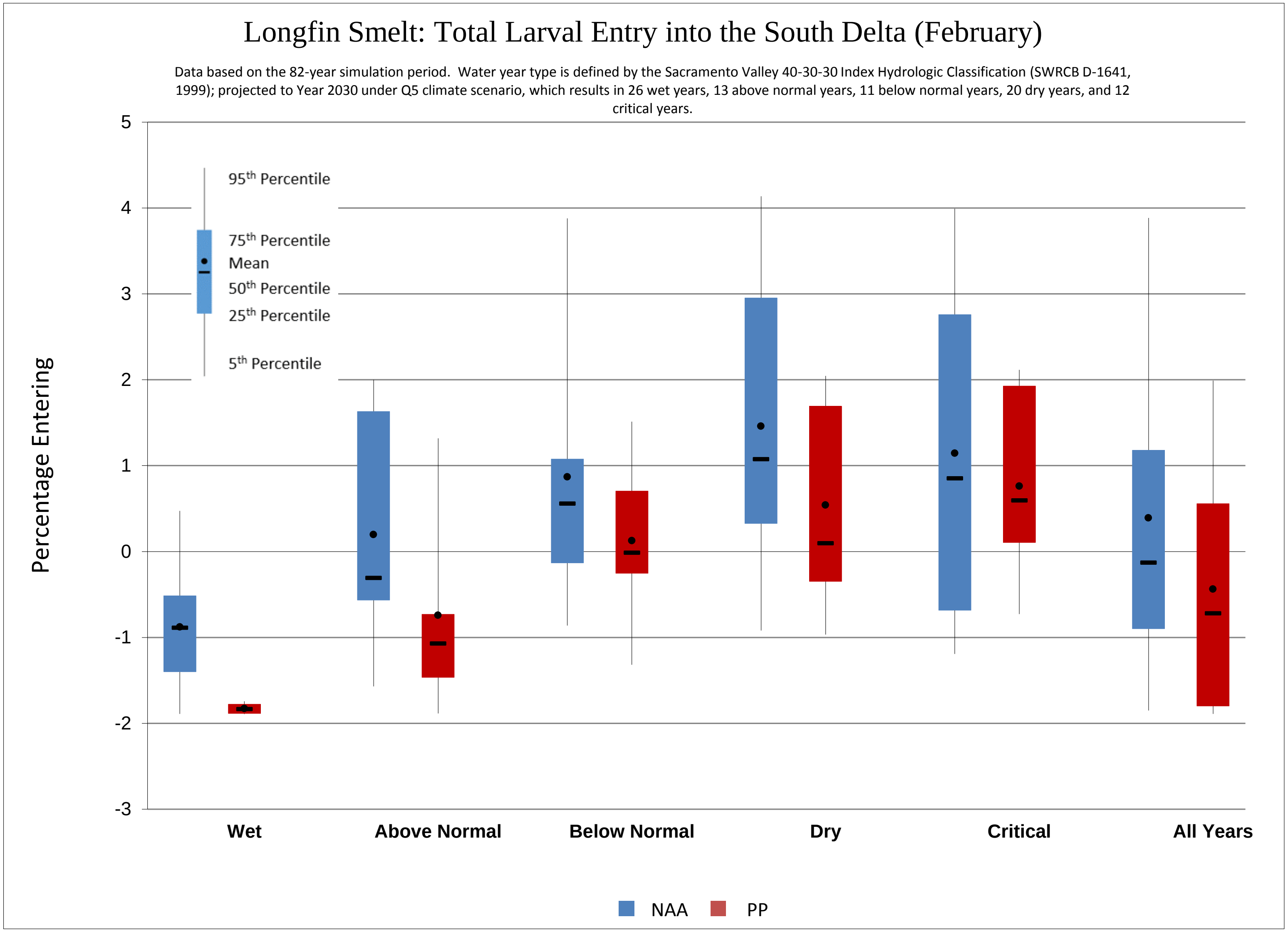


Figure 4.A-15. Box Plot of Longfin Smelt Larval South Delta Entry in February from DSM2-PTM Modeling, Grouped by Water Year Type.

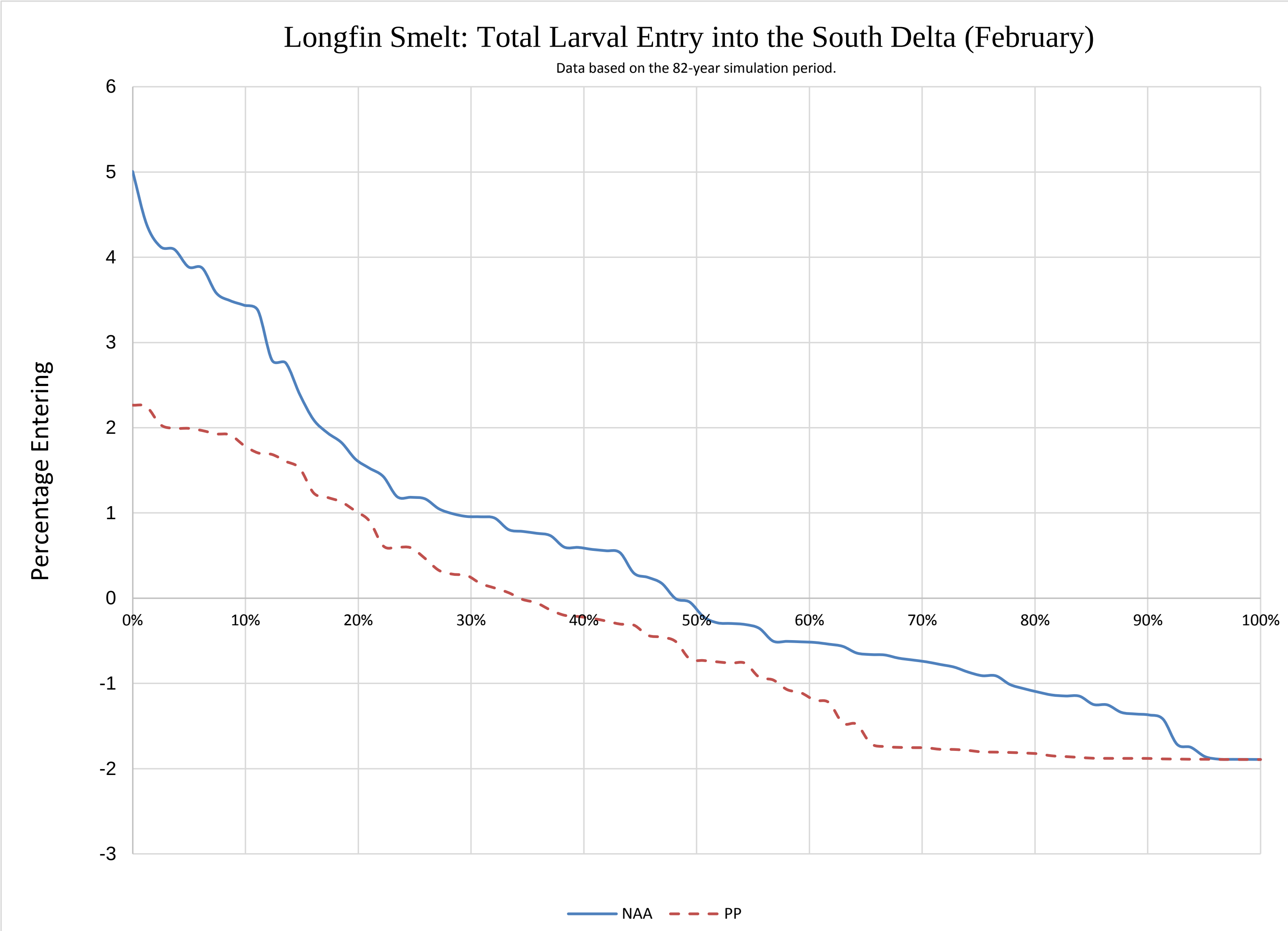


Figure 4.A-16. Exceedance Plot of Longfin Smelt Larval South Delta Entry in February from DSM2-PTM Modeling.

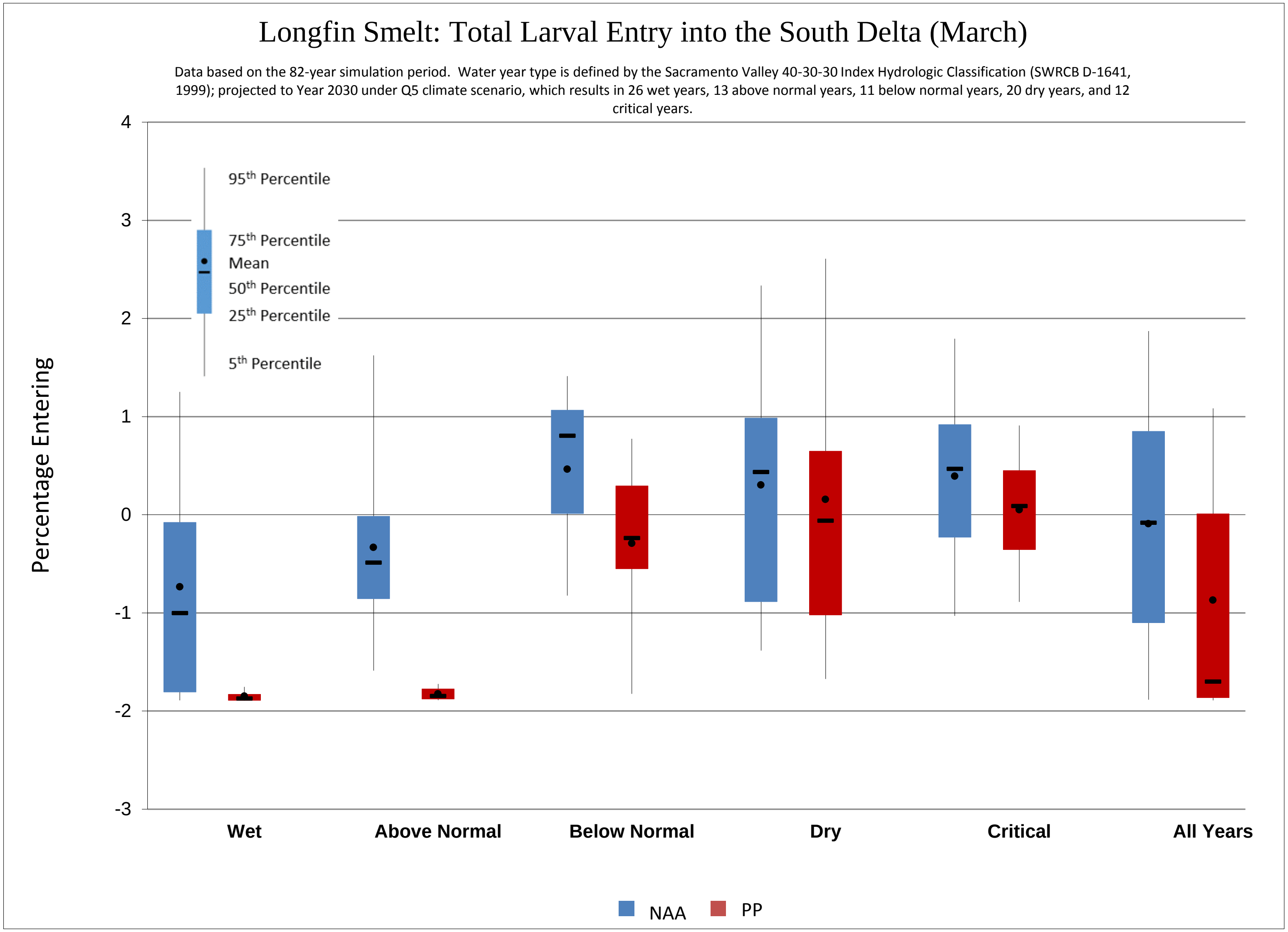


Figure 4.A-17. Box Plot of Longfin Smelt Larval South Delta Entry in March from DSM2-PTM Modeling, Grouped by Water Year Type.

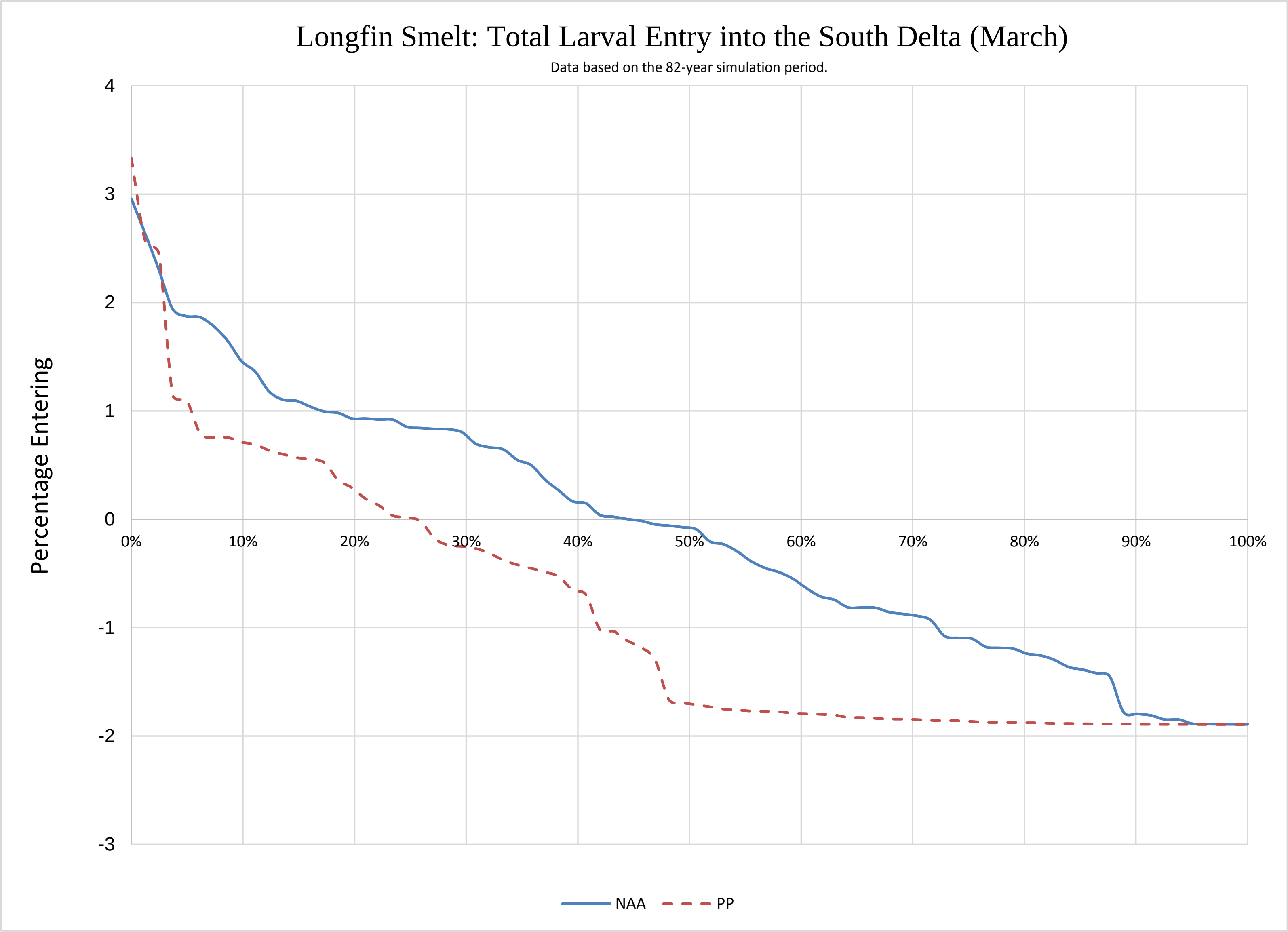


Figure 4.A-18. Exceedance Plot of Longfin Smelt Larval South Delta Entry in March from DSM2-PTM Modeling.

4.A.1.5.3 Particles Reaching Chipps Island

The percentage of particles reaching Chipps Island after 45 days was similar or somewhat greater under the PP than the NAA in January (Figures 4.A-19 and 4.A-20) and generally similar between PP and NAA in February and March (Figures 4.A-21, 4.A-22, 4A-23, and 4.A-24), with the exception of a low percentage (25%) remaining in the domain in one critical year under PP (Figure 4.A-24). The difference in the mean percentage of particles reaching Chipps Island decreased from January (~1–4% greater under PP; 2–11% in relative terms) to March (0.5% less under PP to ~1.5% greater under PP; -1–4% in relative terms).

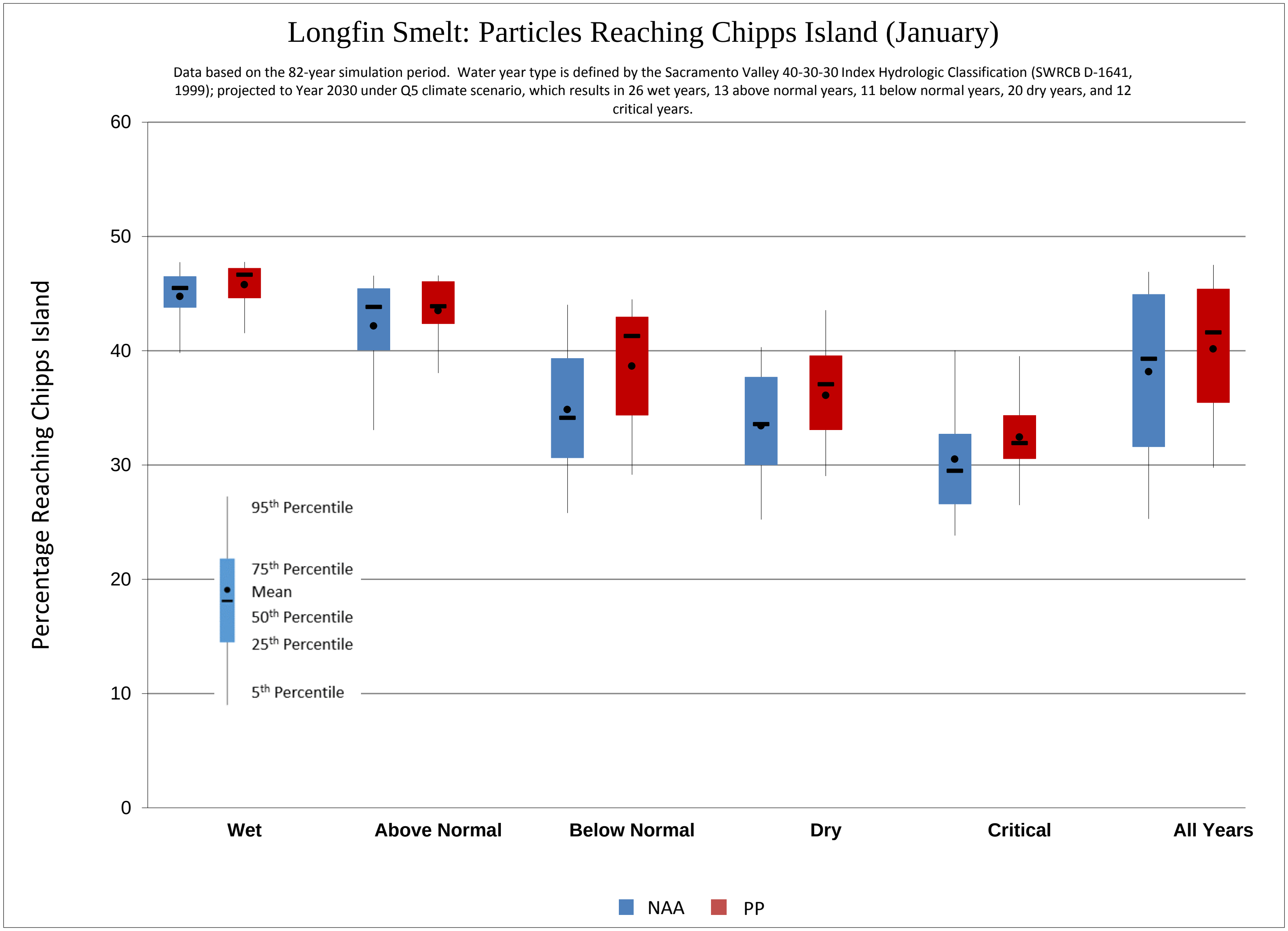
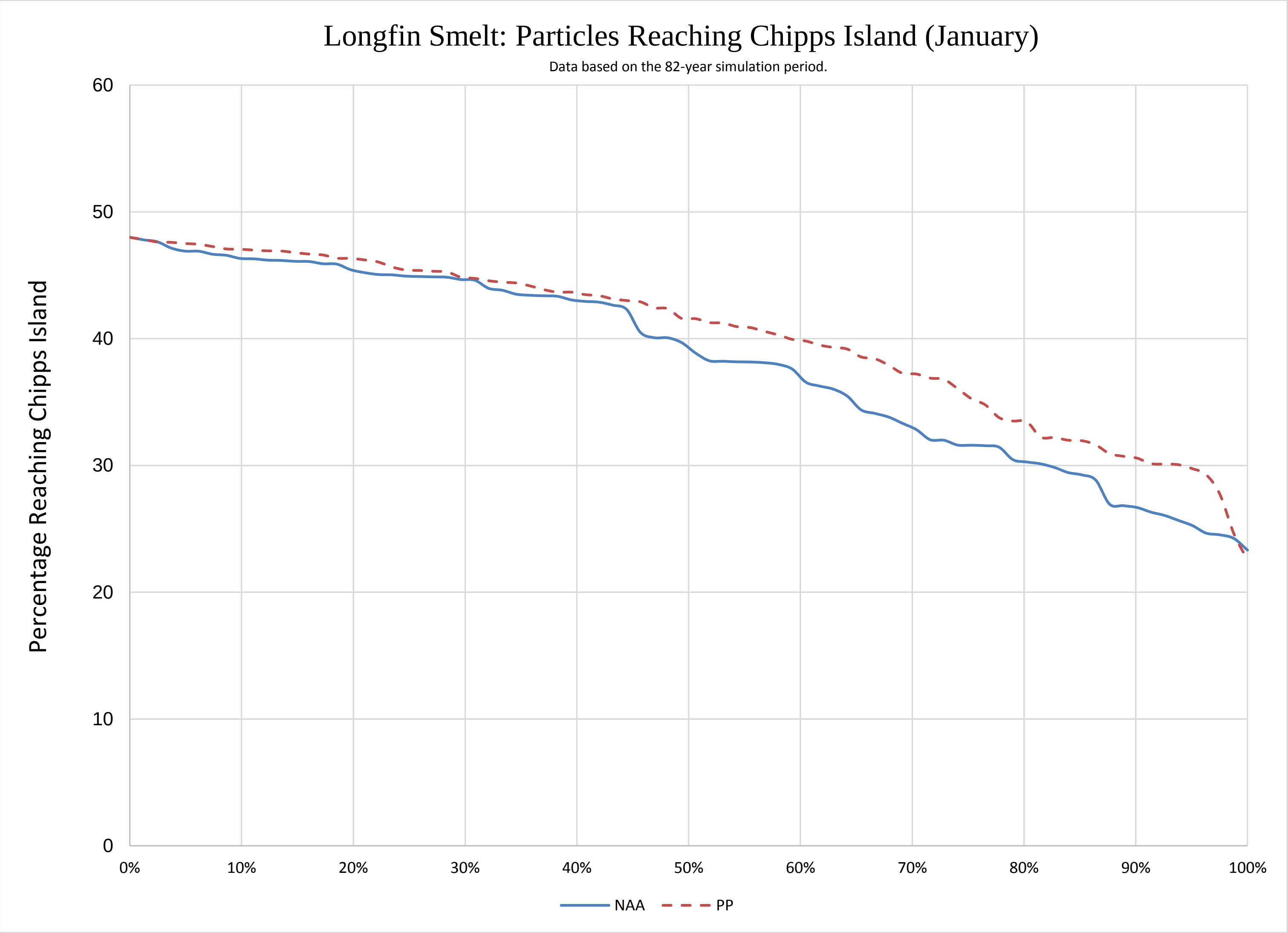


Figure 4.A-19. Box Plot of Particles Reaching Chipps Island in January from DSM2-PTM Modeling, Grouped by Water Year Type.



1
2 **Figure 4.A-20. Exceedance Plot of Particles Reaching Chipps Island in January from DSM2-PTM Modeling.**

3
4

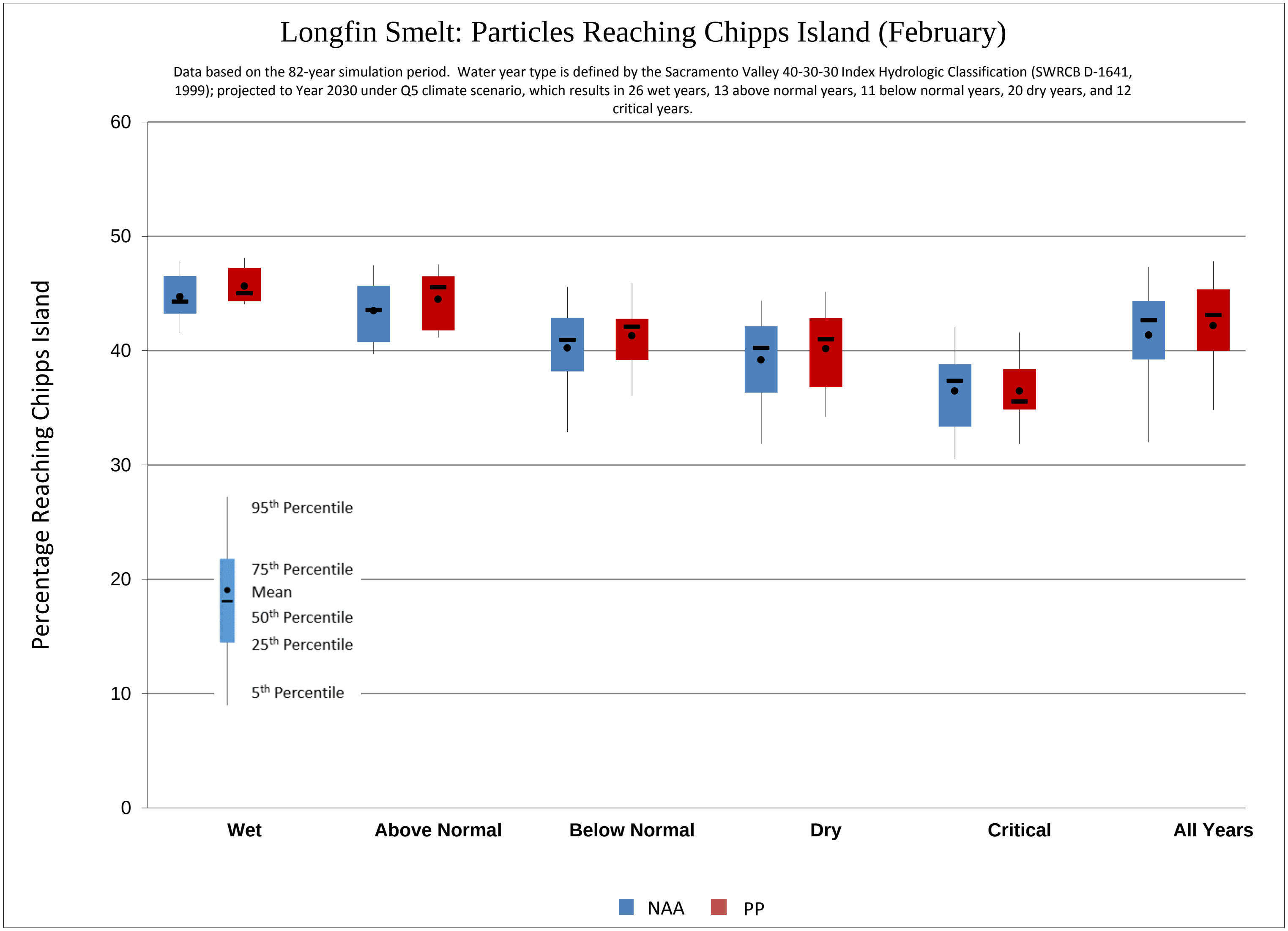


Figure 4.A-21. Box Plot of Particles Reaching Chipps Island in February from DSM2-PTM Modeling, Grouped by Water Year Type.

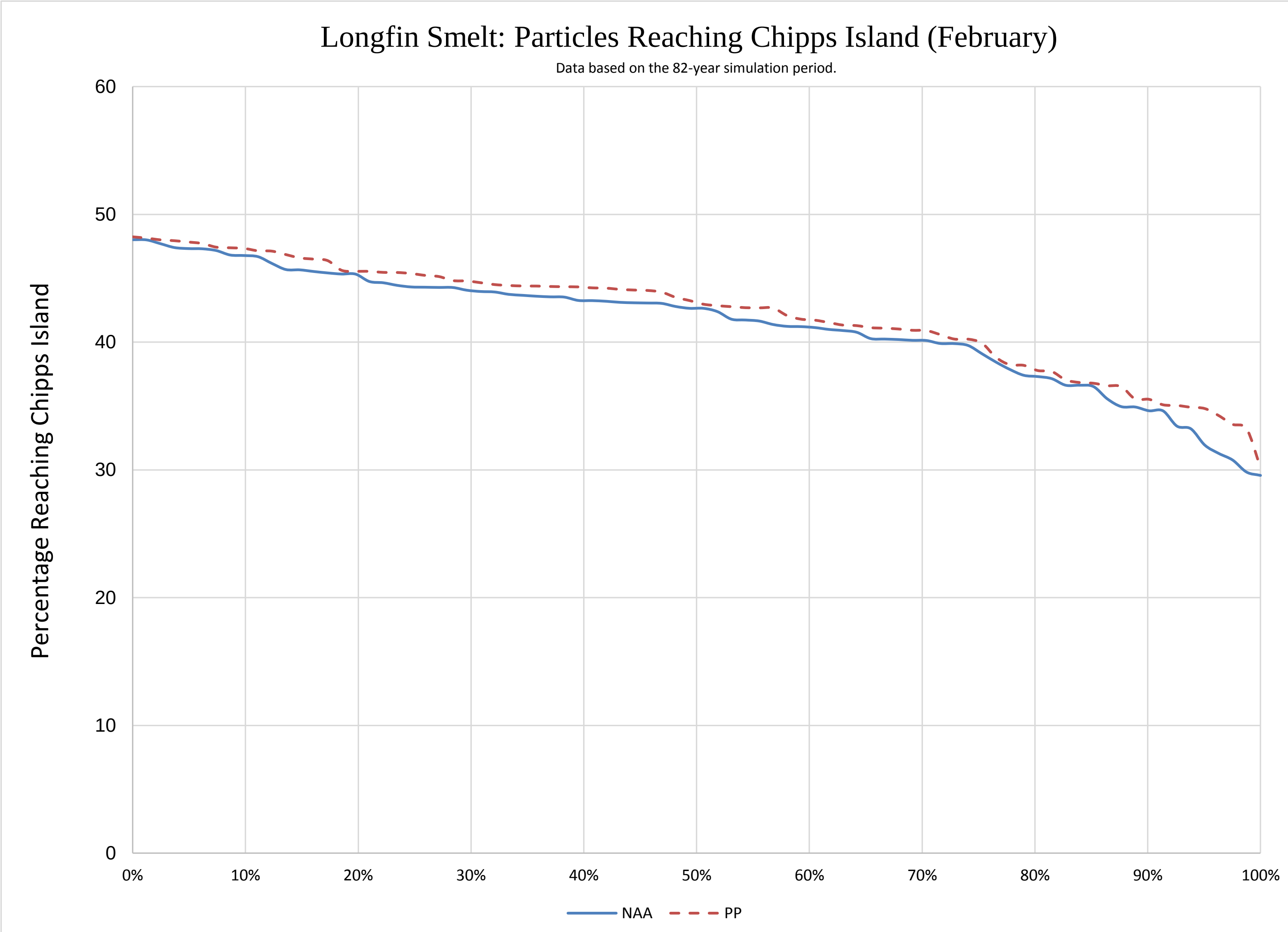


Figure 4.A-22. Exceedance Plot of Particles Reaching Chipps Island in February from DSM2-PTM Modeling.

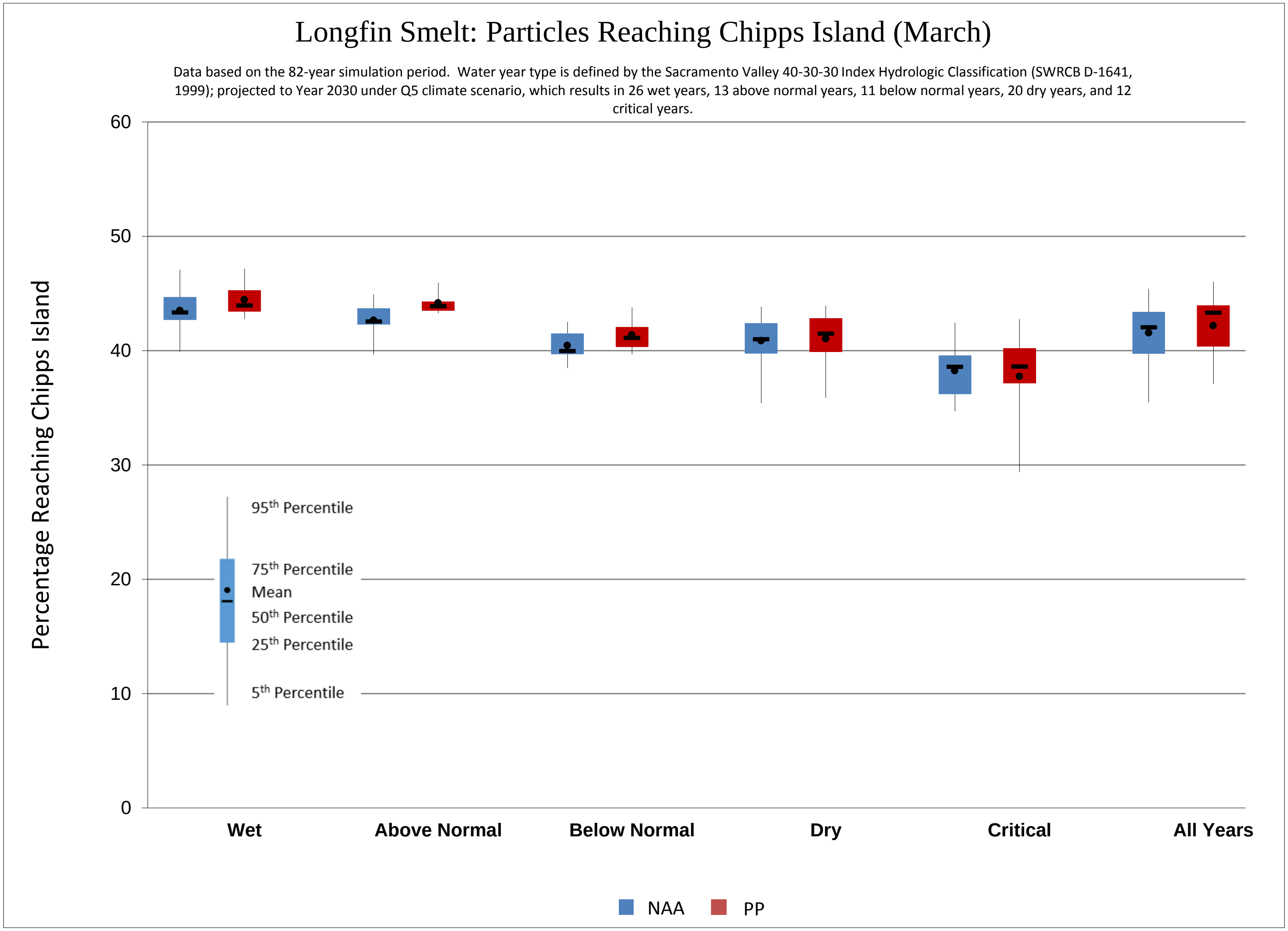


Figure 4.A-23. Box Plot of Particles Reaching Chipps Island in March from DSM2-PTM Modeling, Grouped by Water Year Type.

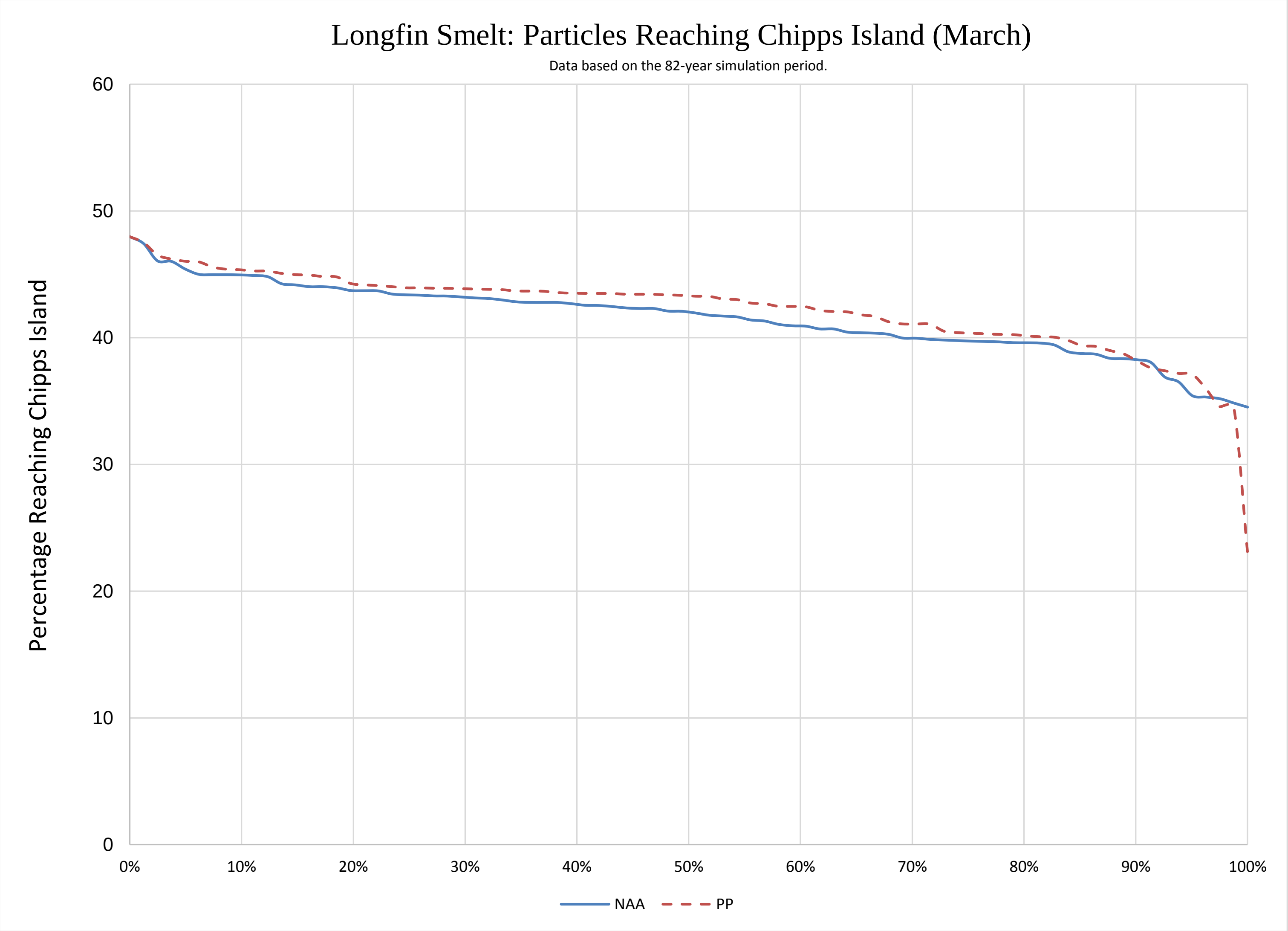


Figure 4.A-24. Exceedance Plot of Particles Reaching Chipps Island in March from DSM2-PTM Modeling.

Table 4.A-9. Mean Annual Percentage of Particles Reaching Chipps Island By Water Year Type, from DSM2-PTM Analysis of January-March 1922-2003.

Water Year Type	January			February			March		
	NAA	PP	PP vs. NAA[1]	NAA	PP	PP vs. NAA[1]	NAA	PP	PP vs. NAA[1]
Wet	44.74	45.78	1.04 (2%)	44.70	45.63	0.93 (2%)	43.50	44.46	0.96 (2%)
Above Normal	42.16	43.51	1.36 (3%)	43.48	44.48	1.01 (2%)	42.67	44.19	1.52 (4%)
Below Normal	34.86	38.65	3.79 (11%)	40.24	41.29	1.05 (3%)	40.45	41.38	0.93 (2%)
Dry	33.42	36.09	2.67 (8%)	39.19	40.17	0.99 (3%)	40.85	41.03	0.18 (0%)
Critical	30.51	32.44	1.93 (6%)	36.46	36.46	0.00 (0%)	38.24	37.74	-0.50 (-1%)

Note:
[1] Negative values indicate lower percentage of particles reaching Chipps Island under the proposed project (PP) than under the no action alternative (NAA).

4.A.1.5.4 Particles Remaining in the Modeling Domain

The percentage of particles remaining in the DSM2-PTM modeling domain after 45 days that were neither entrained nor left the domain generally was somewhat lower under the PP than the NAA in January (Figures 4.A-25 and 4.A-26), similar between PP and NAA in February (Figures 4.A-27 and 4.A-28), and generally similar in March (Figure 4.A-29), with the exception of a high percentage (>40%) remaining in the domain in one critical year under PP (Figure 4.A-30). Under both the NAA and PP, the mean percentage of particles remaining in the domain increased as water year types became drier (reflecting less outflow and water exports) and ranged from a mean of ~2–4% in wet years to ~12–17% in critical years (Table 4.A-10).

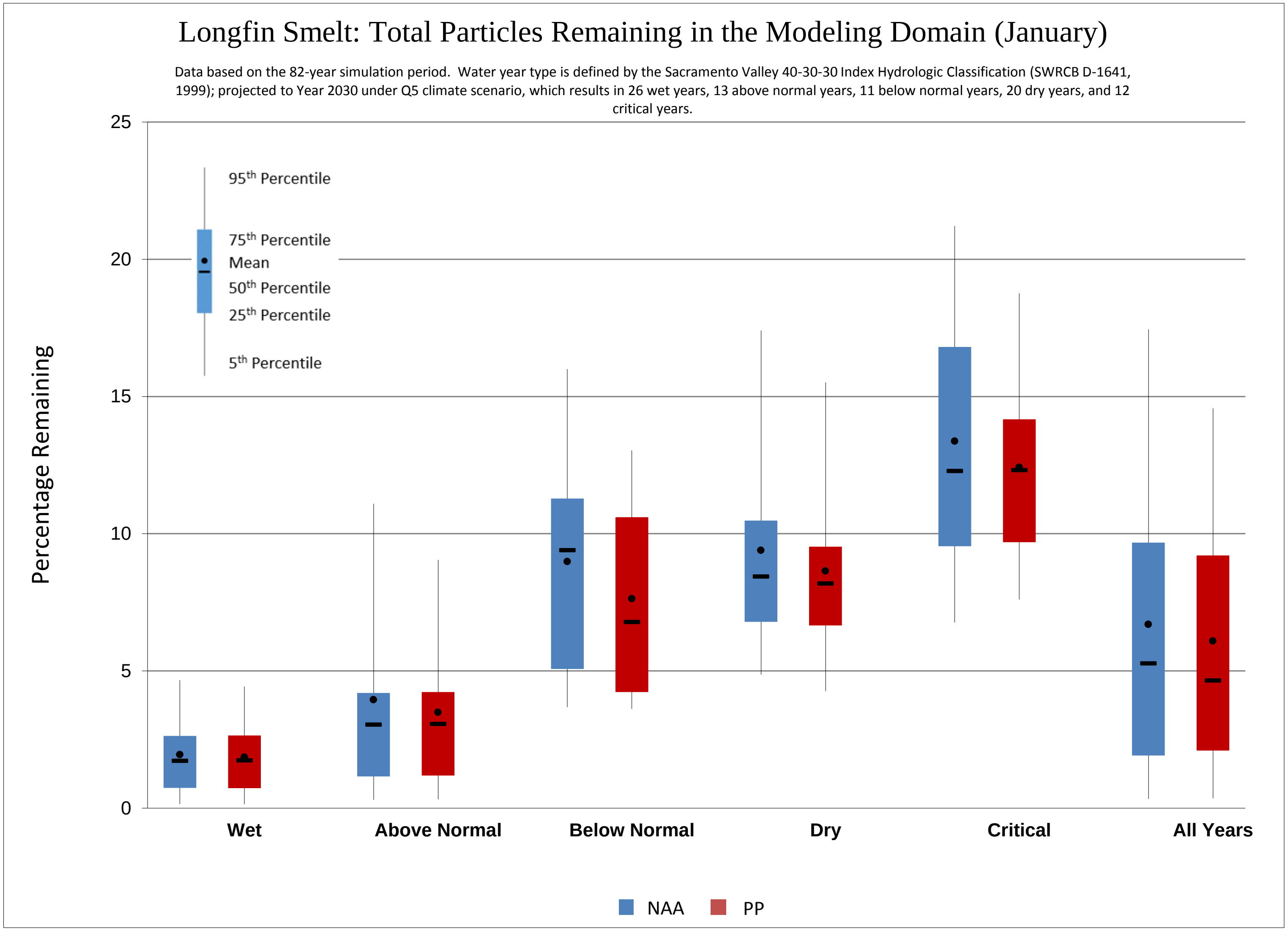


Figure 4.A-25. Box Plot of Particles Remaining the Modeling Domain in January from DSM2-PTM Modeling, Grouped by Water Year Type.

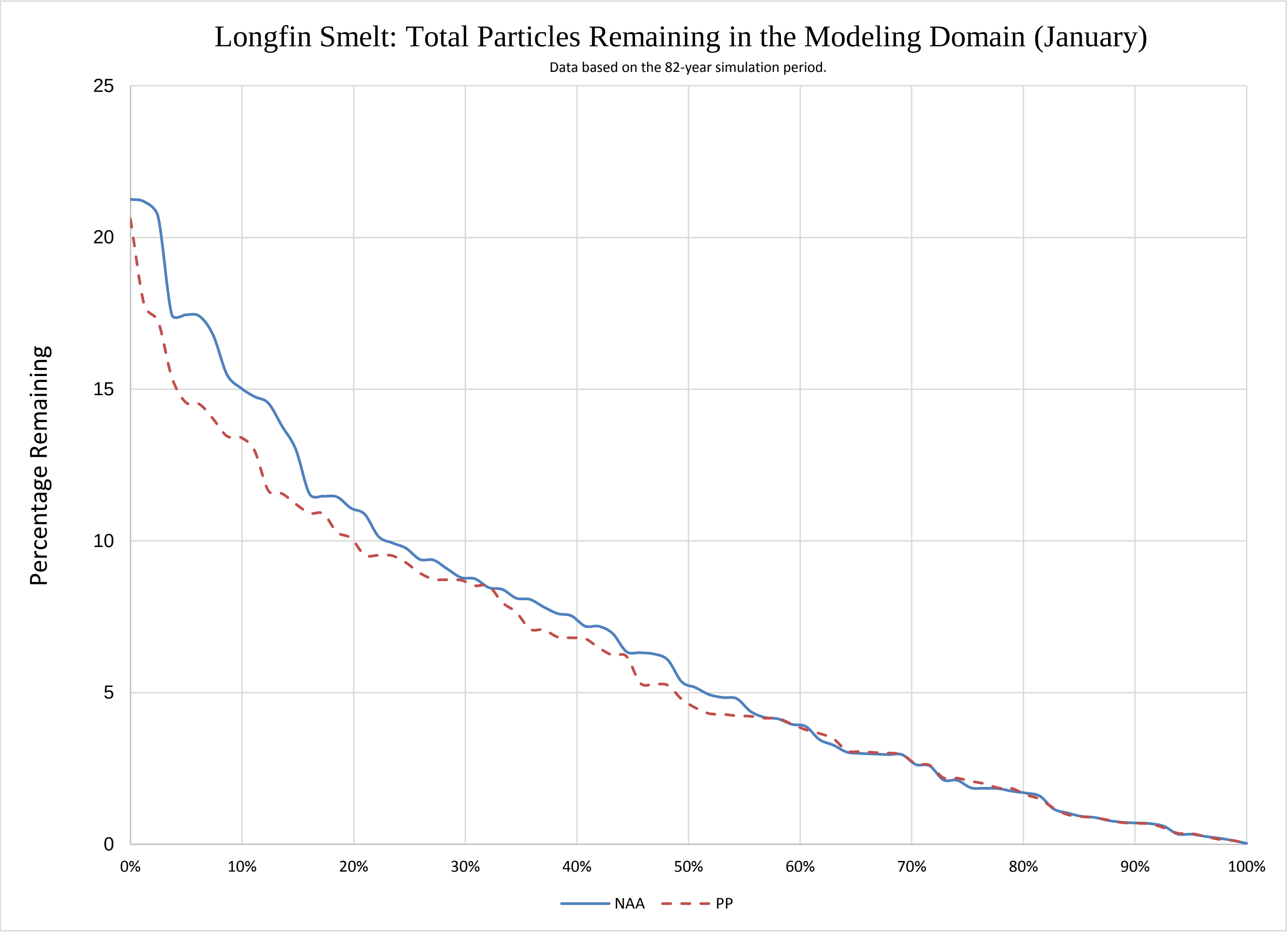


Figure 4.A-26. Exceedance Plot of Particles Remaining the Modeling Domain in January from DSM2-PTM Modeling.

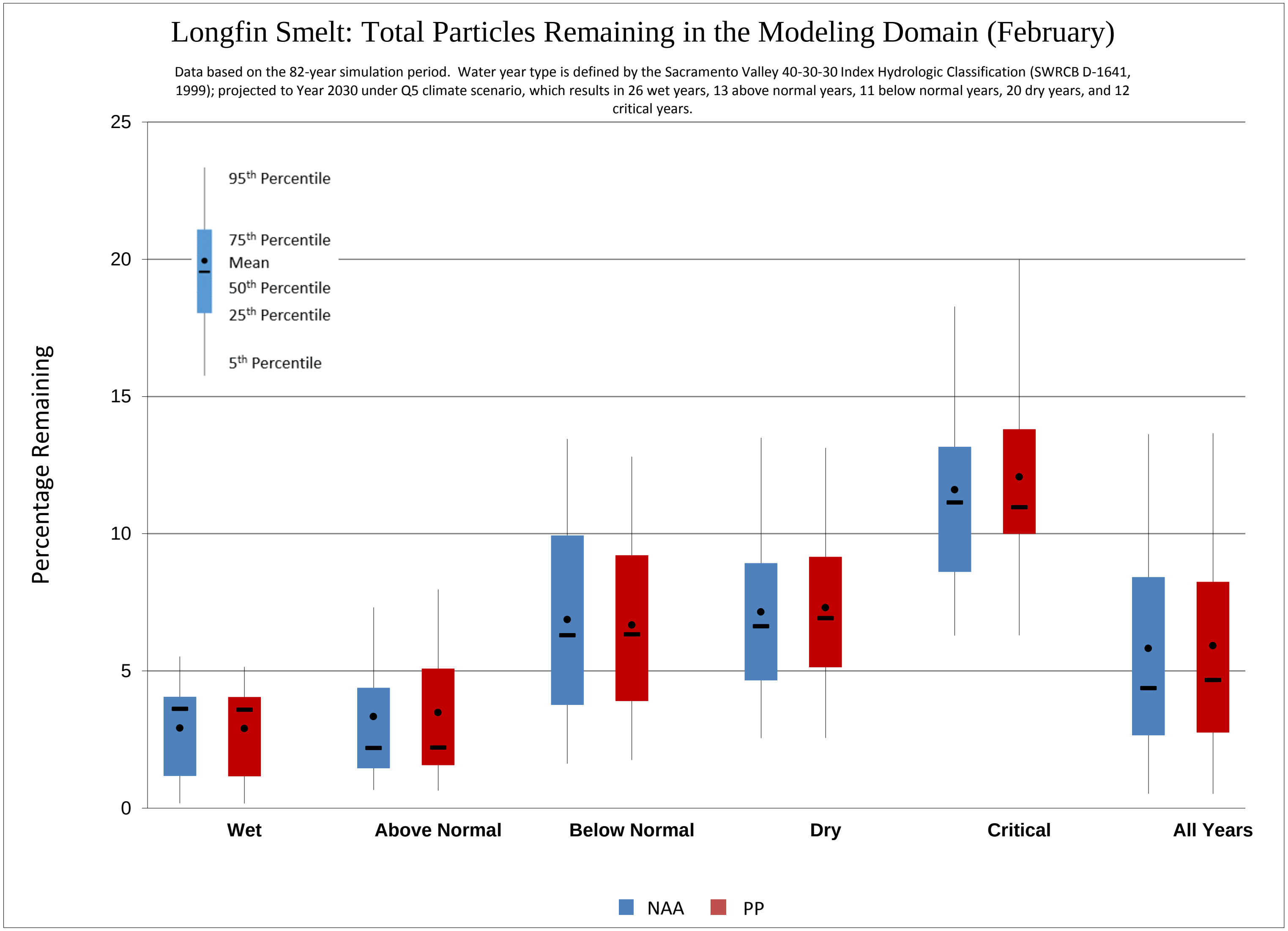


Figure 4.A-27. Box Plot of Particles Remaining the Modeling Domain in February from DSM2-PTM Modeling, Grouped by Water Year Type.

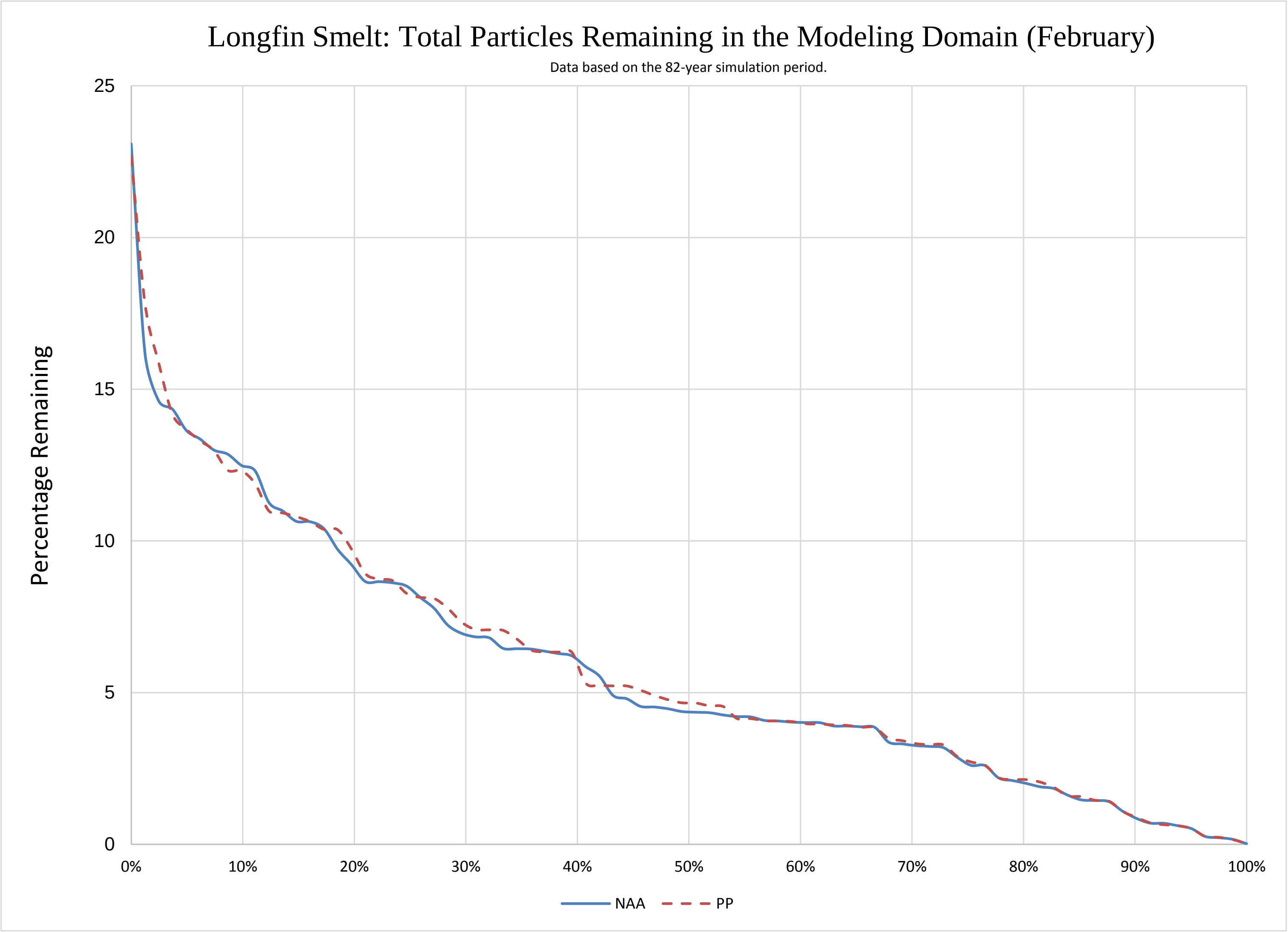


Figure 4.A-28. Exceedance Plot of Particles Remaining the Modeling Domain in February from DSM2-PTM Modeling.

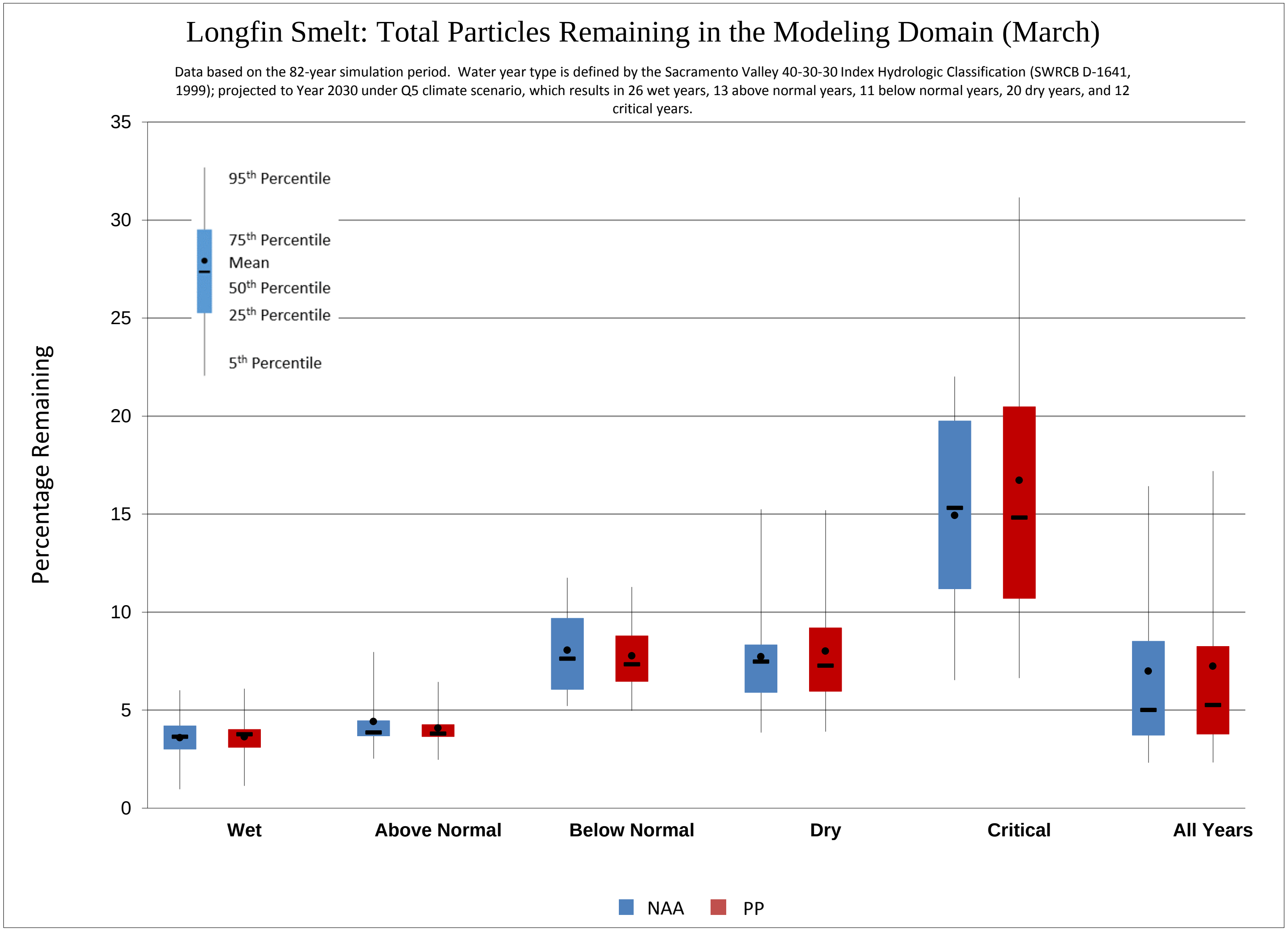


Figure 4.A-29. Box Plot of Particles Remaining the Modeling Domain in March from DSM2-PTM Modeling, Grouped by Water Year Type.

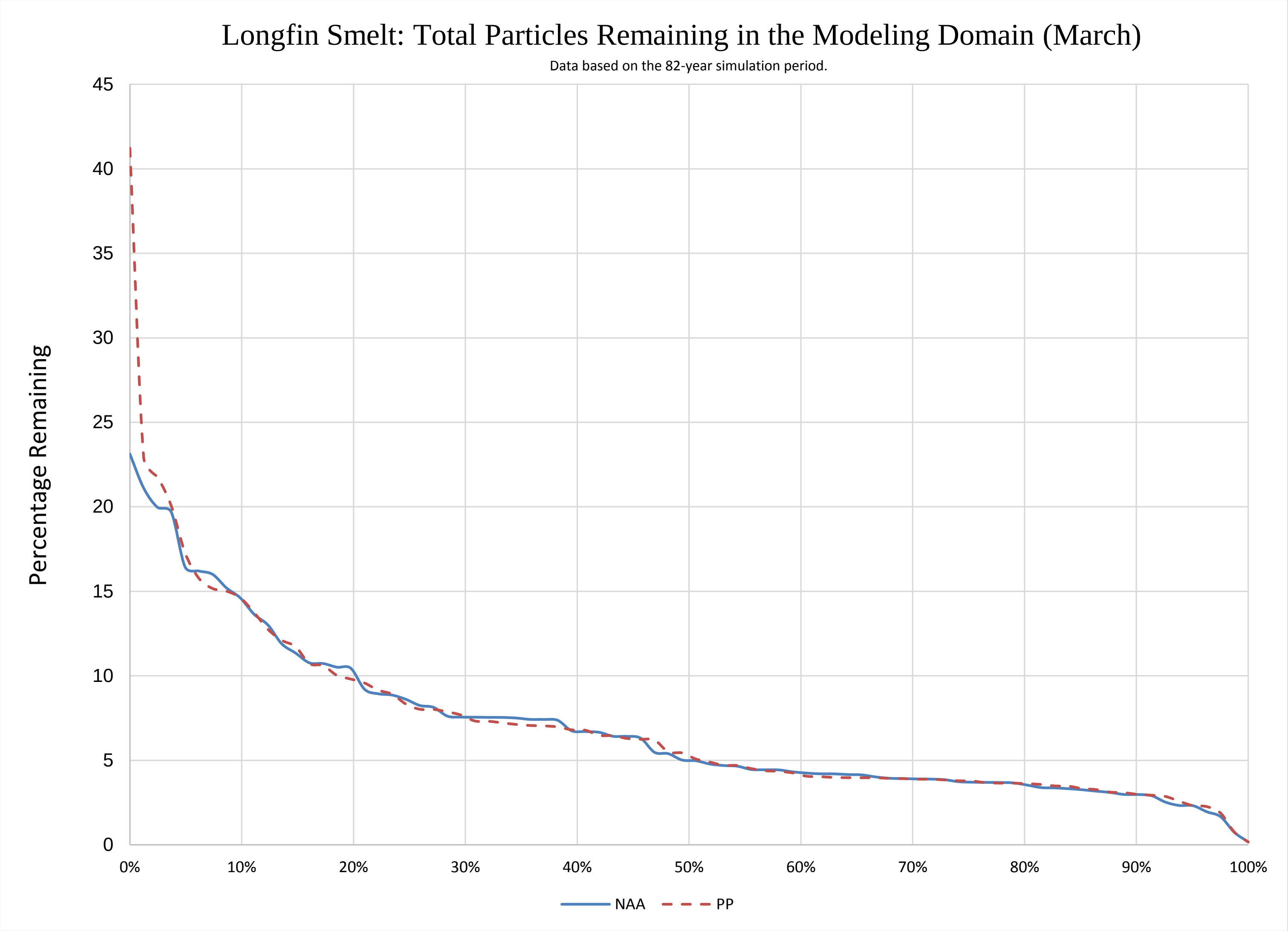


Figure 4.A-30. Exceedance Plot of Particles Remaining the Modeling Domain in March from DSM2-PTM Modeling.

Table 4.A-10. Mean Annual Percentage of Particles Remaining in the Modeling Domain By Water Year Type, from DSM2-PTM Analysis of January-March 1922-2003.

Water Year Type	January			February			March		
	NAA	PP	PP vs. NAA[1]	NAA	PP	PP vs. NAA[1]	NAA	PP	PP vs. NAA[1]
Wet	1.95	1.86	-0.09 (-5%)	2.92	2.90	-0.02 (-1%)	3.59	3.63	0.04 (1%)
Above Normal	3.95	3.49	-0.46 (-12%)	3.33	3.48	0.15 (5%)	4.41	4.08	-0.33 (-8%)
Below Normal	8.98	7.63	-1.35 (-15%)	6.87	6.67	-0.19 (-3%)	8.05	7.77	-0.29 (-4%)
Dry	9.39	8.64	-0.75 (-8%)	7.15	7.30	0.16 (2%)	7.72	8.01	0.29 (4%)
Critical	13.37	12.42	-0.94 (-7%)	11.59	12.07	0.47 (4%)	14.93	16.72	1.80 (12%)

Note:
[1] Negative values indicated lower percentage of particles remaining in the modeling domain under the proposed project (PP) than under the no action alternative (NAA).

4.A.1.6 Salvage-Old and Middle River Flow Regression

Grimaldo et al. (2009: their Figure 7B) found a significant relationship between juvenile Longfin Smelt salvage in April and May as a function of mean April–May Old and Middle River flows. In order to assess potential differences in salvage between NAA and PP, the regression of Grimaldo et al. (2009) was recreated in order to be able to fully account for sources of error in the predictions; this allowed calculation of prediction intervals from CalSim-derived estimates of Old and Middle River flows for NAA and PP scenarios, as recommended by Simenstad et al. (2016).

4.A.1.7 Methods

Longfin Smelt salvage data for April and May 1993–2005 were obtained from the DFW salvage monitoring website[9]. Consistent with Grimaldo et al. (2009), a record of 616 Longfin Smelt salvaged on April 7, 1998, was assumed to be in error, and was converted to zero for the analysis. Old and Middle River flow data were provided by Smith (pers. comm.). Following Grimaldo et al. (2009), $\log_{10}$(total salvage) was regressed against mean April–May Old and Middle River flow (converted to cubic meters/second). The resulting regression equation was very similar to that obtained by Grimaldo et al. (2009):

Log_{10}(April–May total Longfin Smelt salvage) = 2.5454 (± 0.2072 SE) – 0.0100 (± 0.0020 SE)*(Mean April–May Old and Middle River flow); $r^2 = 0.70$, 12 degrees of freedom.

For the comparison of NAA and PP scenarios, CalSim data outputs[10] were used to calculate mean April–May Old and Middle River flows for each year of the 1922–2003 simulation. The salvage-Old and Middle River flow regression calculated as above was used to estimate salvage for the NAA and PP scenarios. The log-transformed salvage estimates were back-transformed to a linear scale for comparison of NAA and PP. In order to illustrate the variability in predictions from the salvage-Old and Middle River flow regression, annual estimates were made for the mean and upper and lower 95% prediction limits of the salvage estimates, as recommended by Simenstad et al. (2016). Means and predictions limits giving negative estimates of salvage were converted to zero before statistical summary. Statistical analyses were conducted with PROC GLM and PROC PLM in SAS/STAT software, Version 9.4 of the SAS System for Windows.[11]

4.A.1.8 Results

Predicted salvage from the salvage-Old and Middle River flow regressions generally was less under the PP in wetter years and greater under the PP in drier years (Table 4.A-11 and Figure 4.A-31). The mean salvage in wet and above normal years was within 14-15% less under PP,

9 http://www.dfg.ca.gov/delta/apps/salvage/SalvageExportChart.aspx?Species=1&SampleDate=1%2f22%2f2016&Facility=1, accessed January 1, 2016, and August 17, 2016 (salvage for Longfin Smelt at both facilities was selected).

10 CalSim modeling methods and results for the NAA and PP are presented in ICF International (2016: Appendix 5.A *CalSim II Modeling and Results*).

11 Copyright 2002–2010, SAS Institute Inc. SAS and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA

similar (3% greater under PP) in dry years, and nearly 30% greater under PP in below normal years (Table 4.A-11).

The 95% prediction intervals for the annual estimates of salvage were very wide in some cases (Figures 4.A-32 and 4.A-33). There were no years where the 95% prediction intervals of the salvage estimates did not overlap between the NAA and PP scenarios (Figure 4.A-4). Predicted differences in relative abundance between NAA and PP scenarios were small compared to the predictive ability of the regressions. As noted in the independent review panel report for the working draft BA, it is possible that the true annual values could lie near the bottom boundary of the prediction interval for PP and near the top boundary of the prediction interval for NAA (Simenstad et al. 2016). This would result in greater differences than suggested by the comparison of annual mean values. By the same rationale, it is also possible that the true annual values could lie near the top boundary of the prediction intervals for both PA and NAA, in which case the differences would be more similar to the differences between means. However, given the mean estimates of greater salvage under the PP in drier years, it is worthwhile exploring the mechanisms in terms of the underlying modeling assumptions for operations which drive these results.

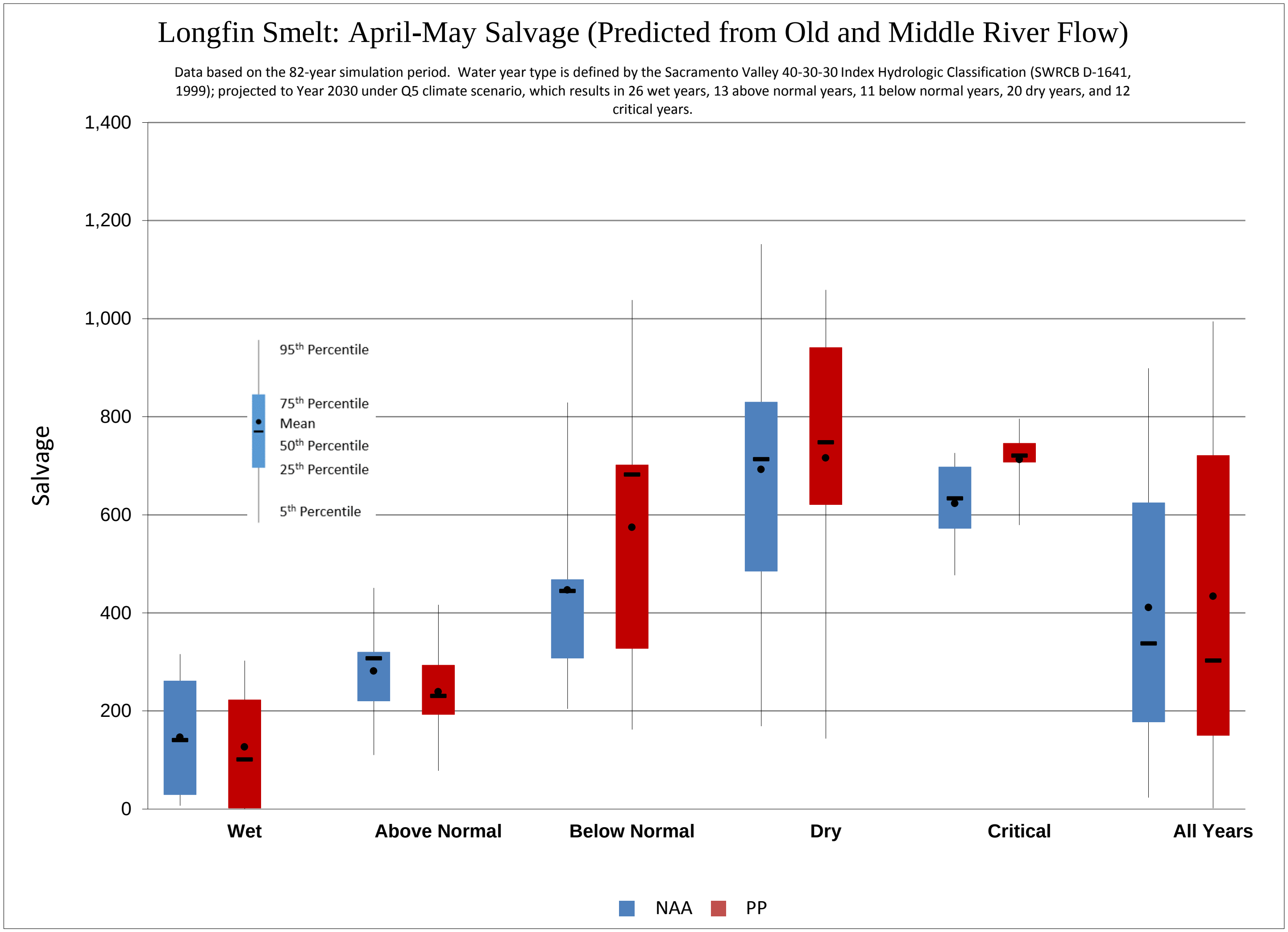
In April, south Delta exports under the PP were lower than under the NAA in 69 of 82 CalSim-simulated years from 1922 to 2003 (Figure 4.A-34). In the 13 years for which April south Delta exports were greater under the PP, the differences were very low in nine years (mean difference = 12 cfs; maximum difference = 62 cfs), slightly greater but relatively low in two years (132 cfs in 1939 and 237 cfs in 1934), and more substantial in two years (1,045 cfs in 1960 and 1,107 cfs in 1987). However, Old and Middle River flows under the PP in April were lower in 44 of 82 years (Figure 4.A-35), although never below the -2,000 cfs minimum criterion described in ICF International (2016: Table 5.A-11 in Appendix 5.A *CalSim II Modeling and Results*). Insight into the reason for the patterns comes from comparison of the differences between PP and NAA for flows at the Head of Old River (HOR flows) with the differences between PP and NAA for Old and Middle River flows (Figure 4.A-36). This shows that there were 22 years in which the difference in Old and Middle River flows was greater than the difference in HOR flows under the PP; in 20 of these 22 years, the differences between HOR flows and Old and Middle River flows were small (242 cfs or less; mean = 50 cfs). This indicates that the differences in Old and Middle River flows between PP and NAA were largely a result of the operation of the HOR gate, which reduced the amount of San Joaquin River flow entering Old River and therefore resulted in less Old and Middle River flow under the PP, depending on south Delta exports. In April 1960 and 1987, the difference between PP and NAA in Old and Middle River flows was approximately 1,000 cfs greater than the difference between PP and NAA in HOR flows. This indicates that in these two years, the primary driver on the difference in Old and Middle River flows between NAA and PP was a factor other than HOR gate operations; this factor likely reflected the different assumptions for the San Luis rule curve between NAA and PP. This emphasizes that HOR gate operations are an important consideration for entrainment of Longfin Smelt and other listed fishes.

In May, south Delta exports under the PP were greater than under the NAA in only three years, and the differences in these years were low (9 cfs in 1924, 112 cfs in 1929, and 2 cfs in 2002) (Figure 4.A-37). However, Old and Middle River flows under the PP were less than under the NAA in 33 of 82 years (Figure 4.A-38). This again reflects the influence of the HOR gate, as illustrated by the comparison of the difference between HOR flow and the difference between Old and Middle River flows for the PP and NAA (Figure 4.A-39): of the 31 years in which Old and Middle River flows were lower under the PP than NAA, the difference between Old and Middle River flows was greater than the difference in HOR flows in 8 years, and the differences were small (129 cfs; mean = 39 cfs). Thus, the difference in OMR flows in May appears to be almost entirely driven by HOR gate operations, and again emphasizes that this is an important consideration for entrainment of Longfin Smelt and other listed fishes. As described in Section 4.2.6.3.3 *Head of Old River Gate Operations* in Chapter 4, real-time operations under the PP would be undertaken to limit the potential for take, particularly with respect to the consideration of Longfin Smelt distribution, OMR flows, and other factors (including HOR gate operations).

Table 4.A-11. Mean Annual Longfin Smelt April–May Salvage, Estimated from Regression Based on Old and Middle River Flows, Grouped by Water Year Type.

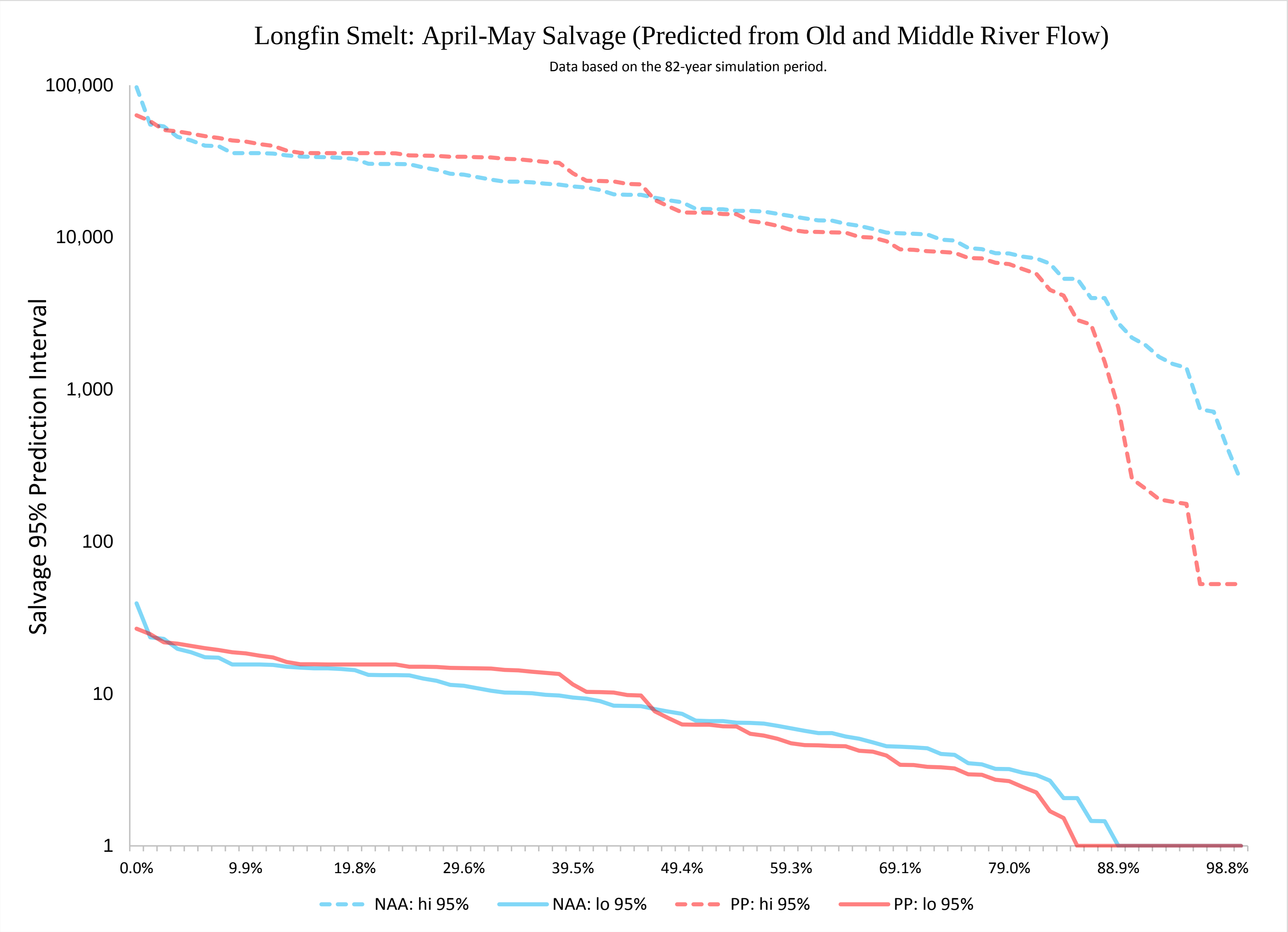
Water Year Type	NAA	PP	PP vs. NAA[1]
Wet	146	126	-20 (-14%)
Above Normal	281	239	-43 (-15%)
Below Normal	446	574	128 (29%)
Dry	693	716	23 (3%)
Critical	623	712	90 (14%)

[1]Positive values indicate greater salvage under the proposed project (PP) than under the no action alternative (NAA).



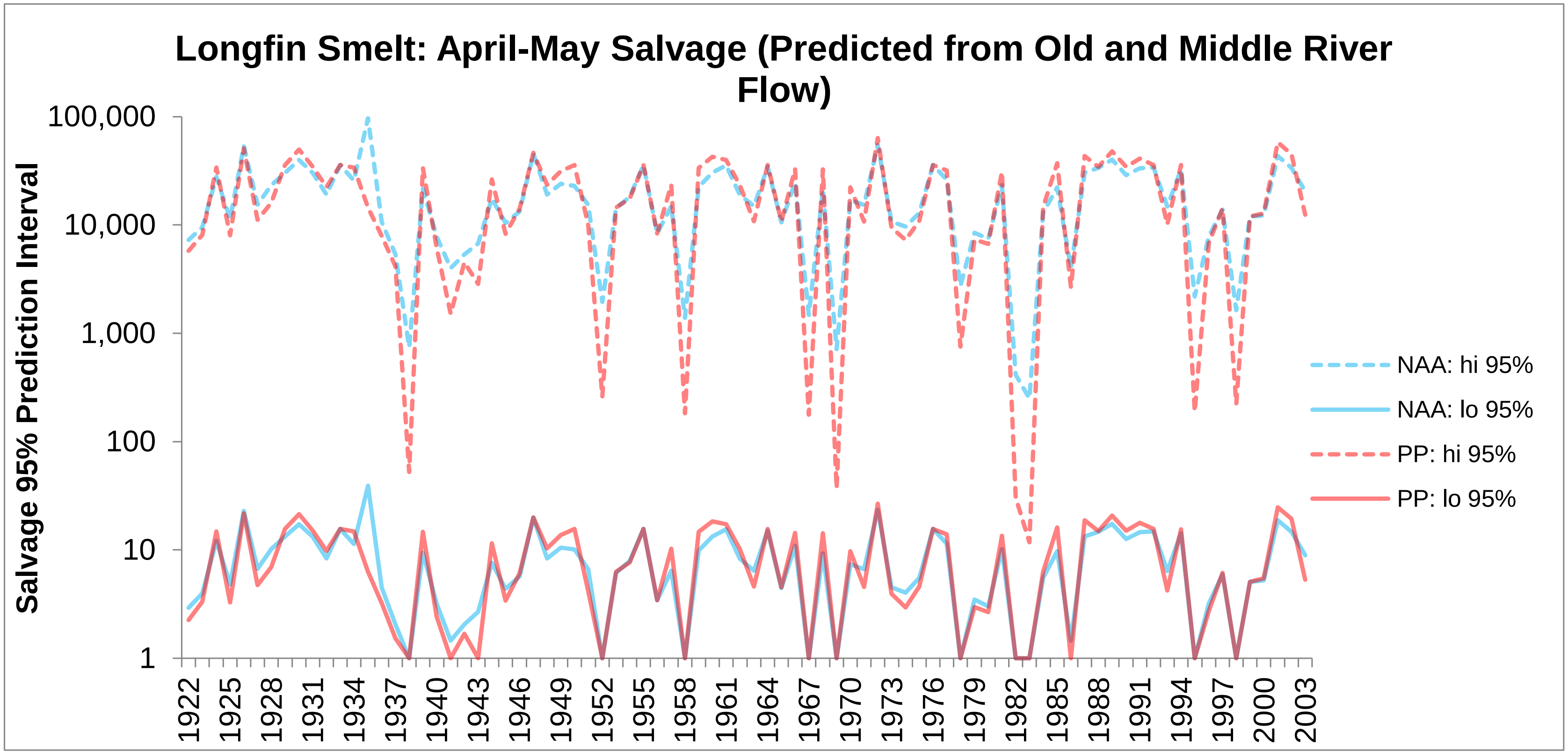
Note: Plot only includes mean responses and does not consider model uncertainty.

Figure 4.A-31. Box Plot of Longfin Smelt April–May Salvage, from the Regression Including Mean Old and Middle River Flows, Grouped by Water Year Type.



Note: Data are sorted by mean estimate, with only 95% prediction intervals shown. Zero estimates are converted to 1 in this plot to allow plotting on a log scale.

Figure 4.A-32. Exceedance Plot of Longfin Smelt April–May Salvage, from the Regression Including Mean Old and Middle River Flows.



Note: Zero estimates are converted to 1 in this plot to allow plotting on a log scale.

Figure 4.A-33. Time Series of 95% Prediction Interval Longfin Smelt April–May Salvage, from the Regression Including Mean Old and Middle River Flows.

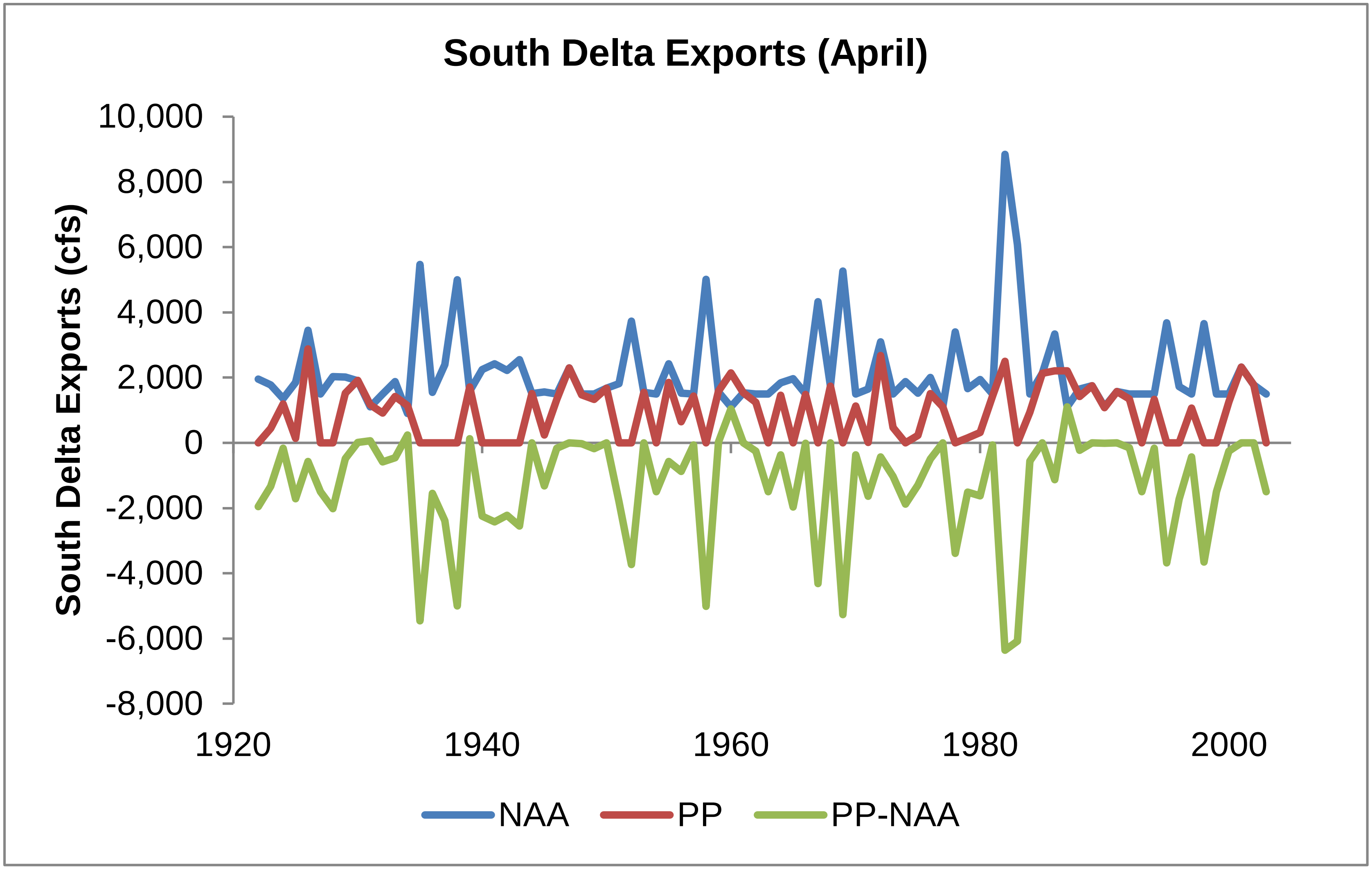


Figure 4.A-34. CalSim-II Modeling Results for South Delta Exports under No Action Alternative (NAA) and Proposed Project (PP) and Difference Between NAA and PP, April.

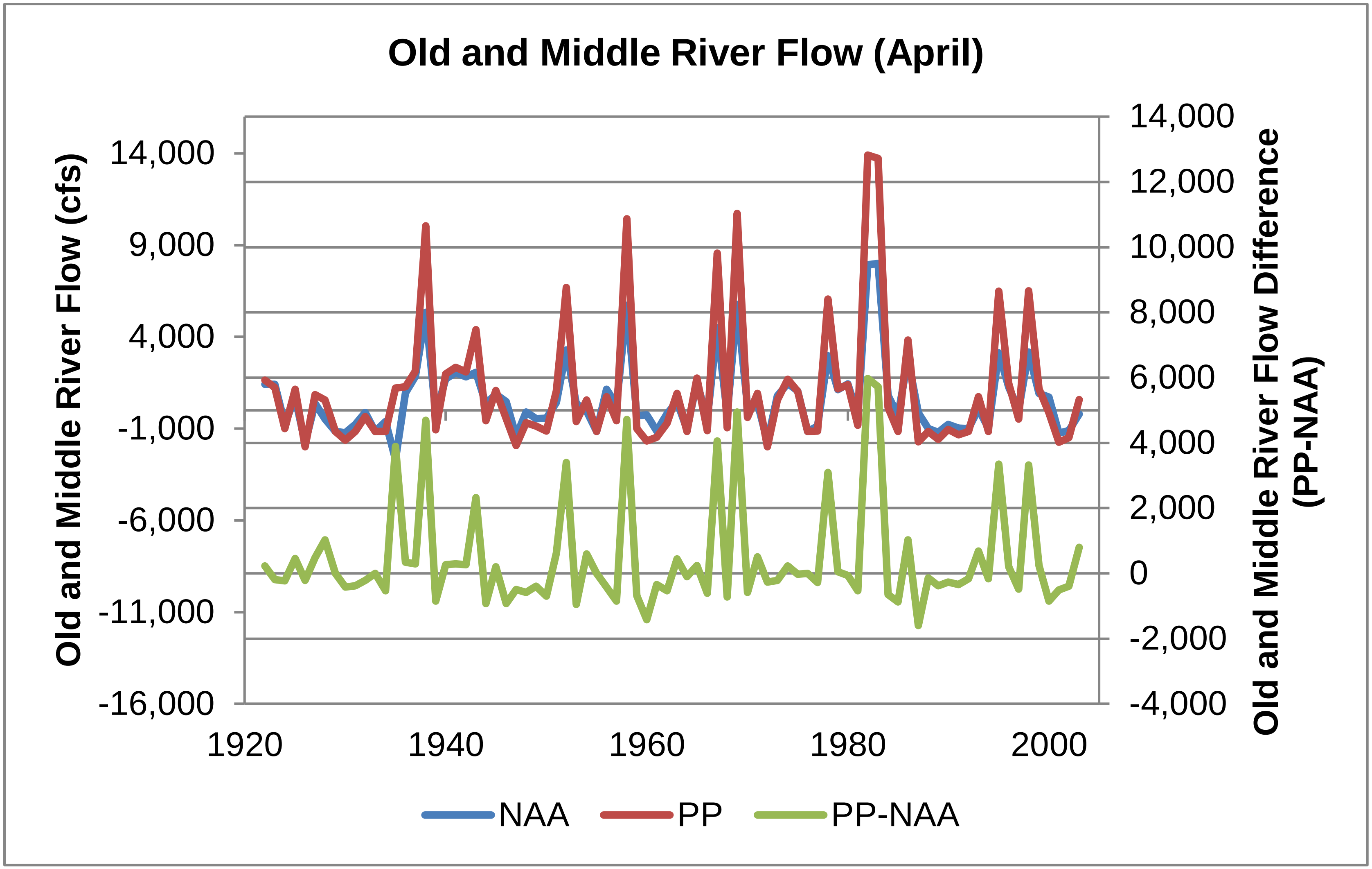


Figure 4.A-35. CalSim-II Modeling Results for Old and Middle River Flows under No Action Alternative (NAA) and Proposed Project (PP) and Difference Between NAA and PP, April.

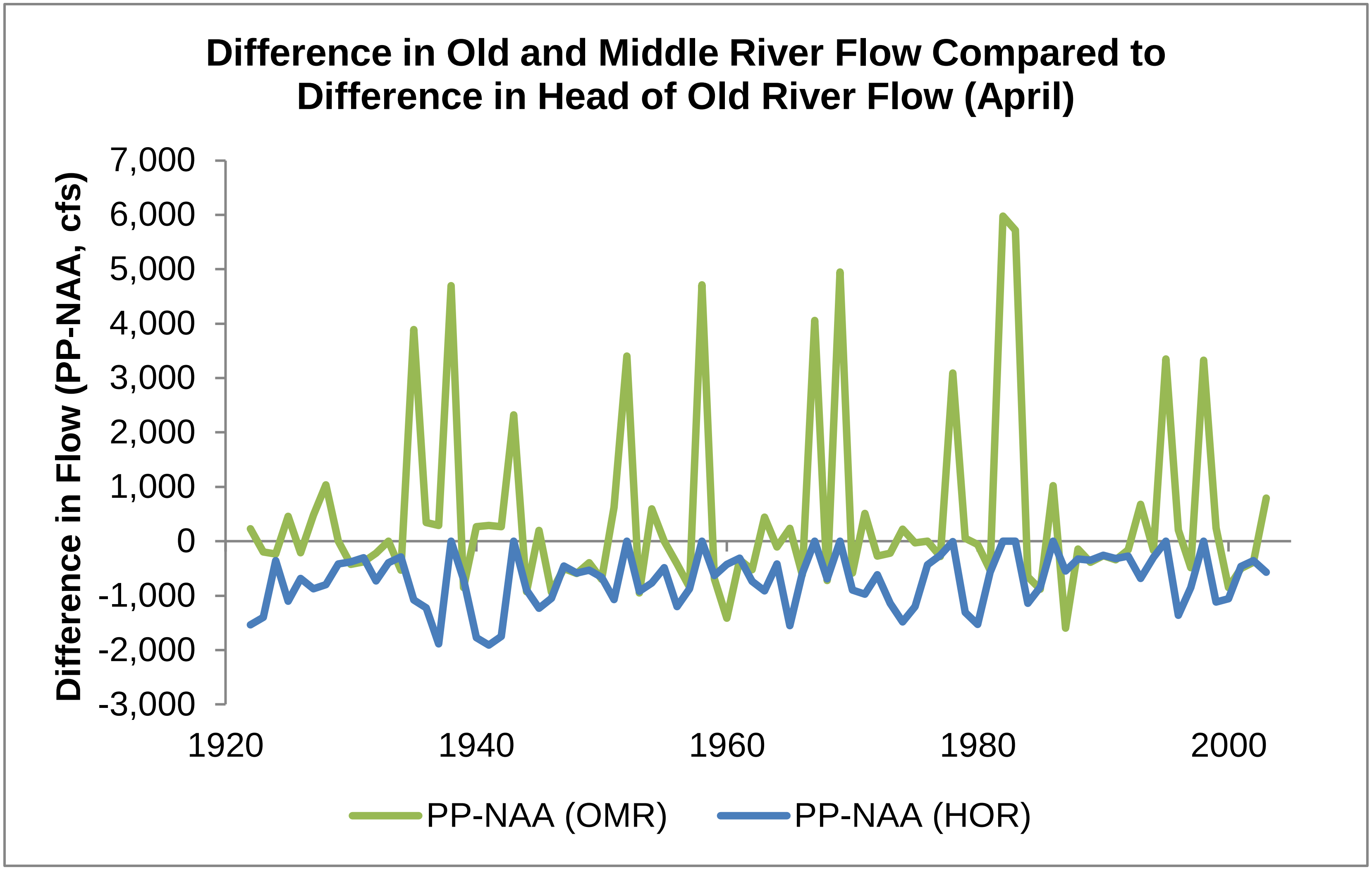


Figure 4.A-36. CalSim-II Modeling Results for Difference Between No Action Alternative (NAA) and Proposed Project (PP) for Head of Old River (HOR) Flows and Old and Middle River (OMR) Flows, April.

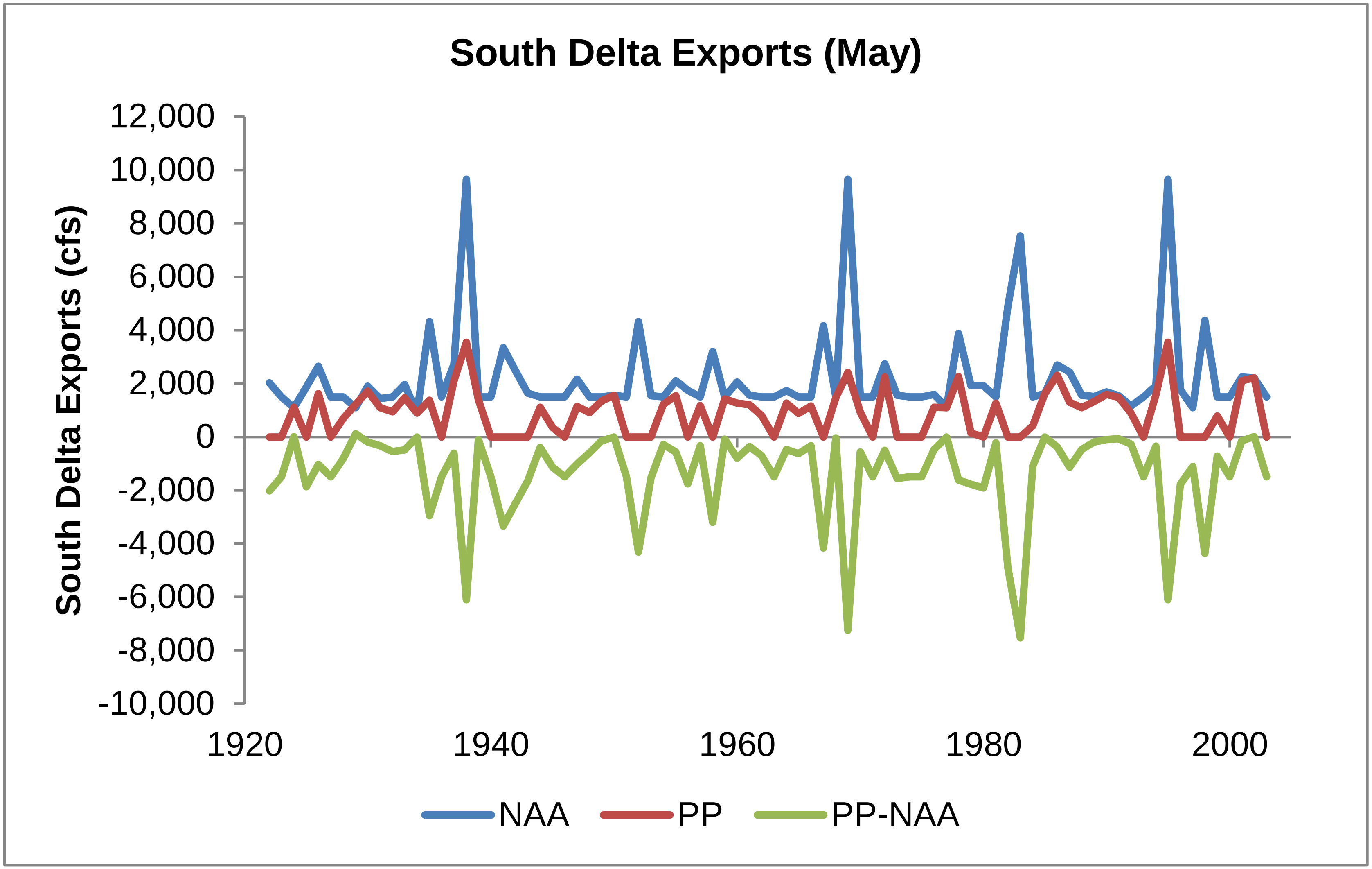


Figure 4.A-37. CalSim-II Modeling Results for South Delta Exports under No Action Alternative (NAA) and Proposed Project (PP) and Difference Between NAA and PP, May.

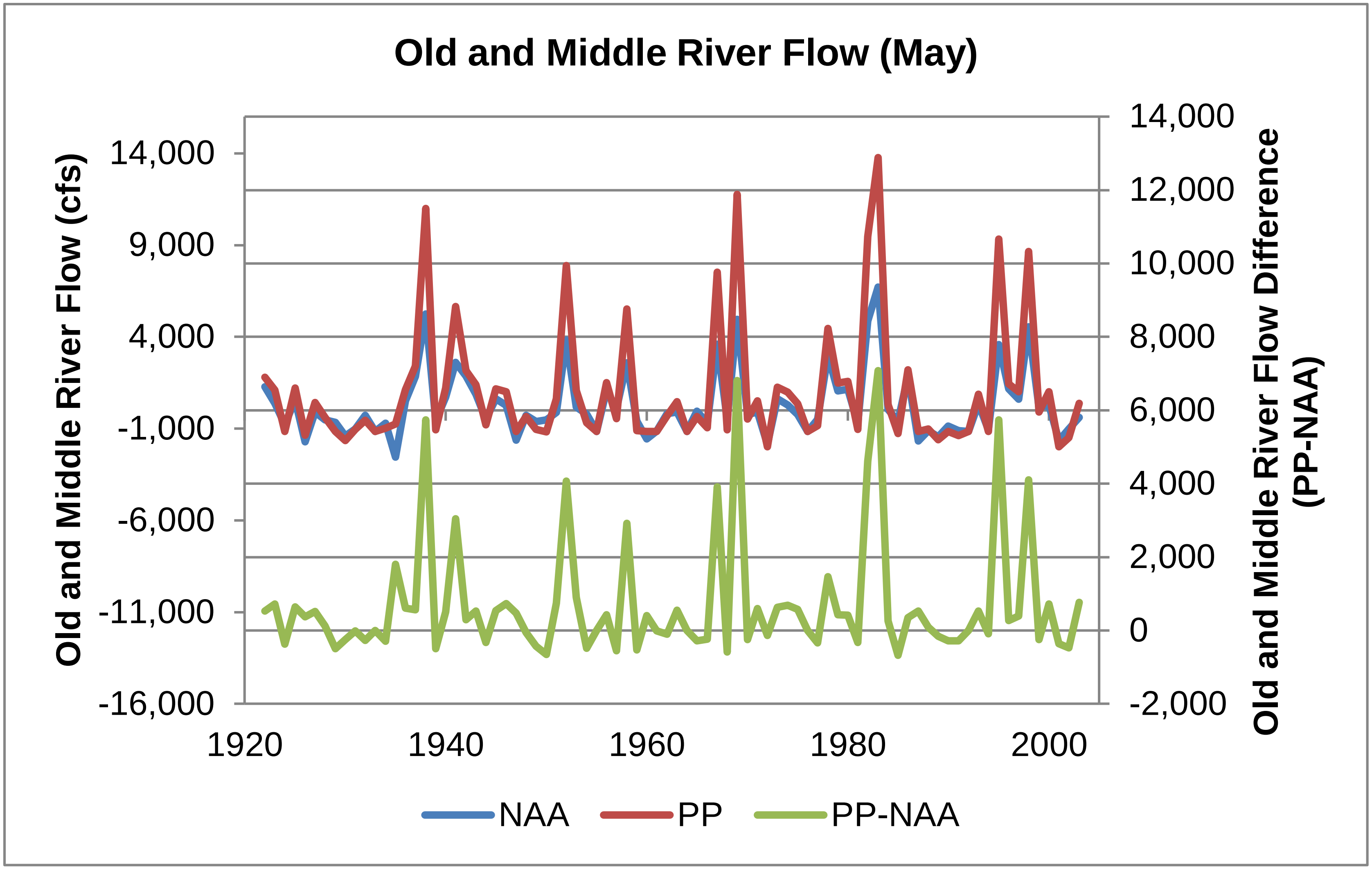


Figure 4.A-38. CalSim-II Modeling Results for Old and Middle River Flows under No Action Alternative (NAA) and Proposed Project (PP) and Difference Between NAA and PP, May.

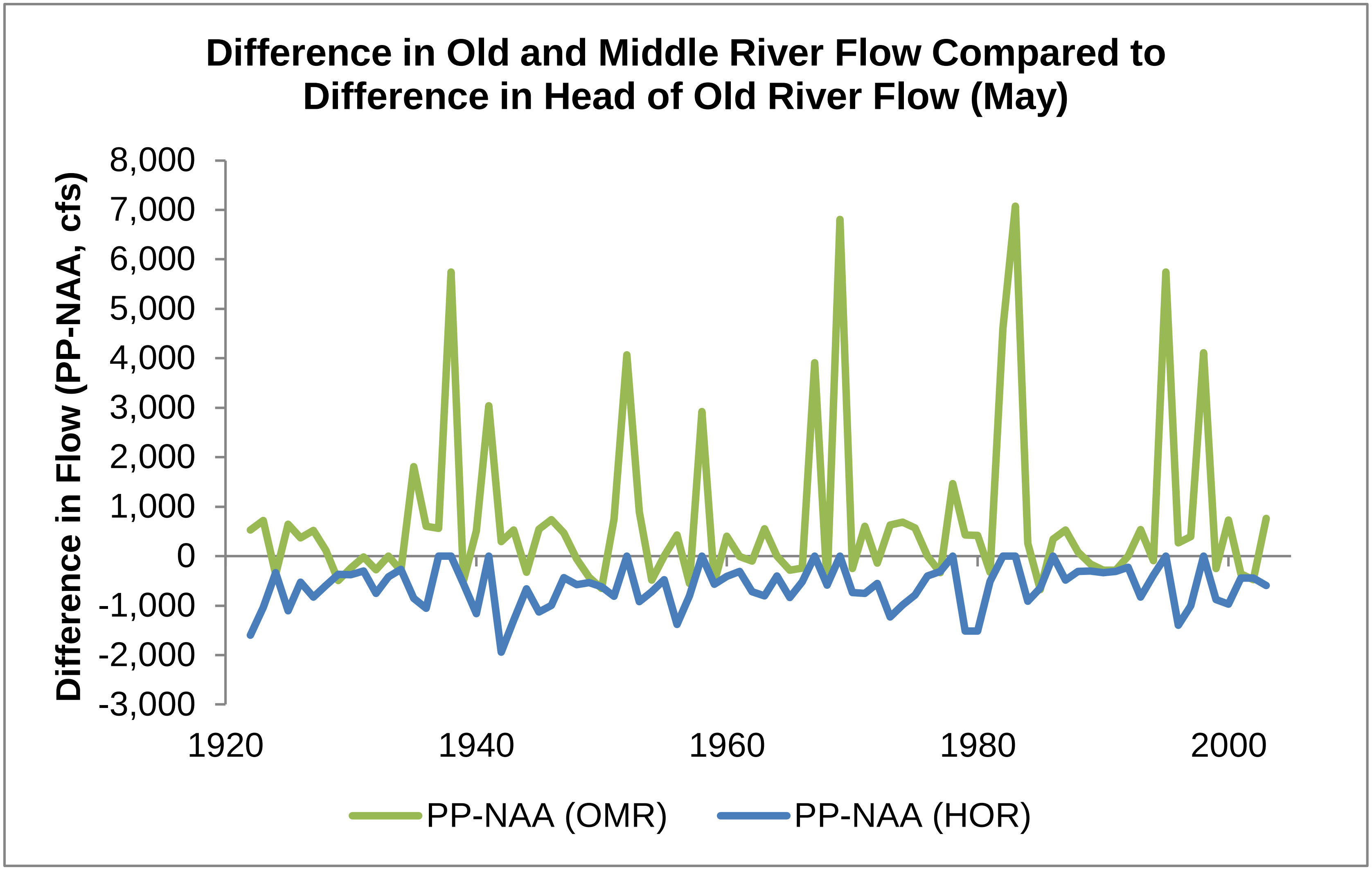


Figure 4.A-39. CalSim-II Modeling Results for Difference Between No Action Alternative (NAA) and Proposed Project (PP) for Head of Old River (HOR) Flows and Old and Middle River (OMR) Flows, May.

4.A.1.9 References

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4.A.1.9.1 Attachments

4.A.1.9.1.1 Raw DSM2-PTM Outputs

Raw DSM2-PTM analysis outputs are provided in the workbook < Appendix_4A_Attachment.xlsx>. The ‘notes’ sheet of that workbook provides explanation of the workbook contents.