Appendix I, Old and Middle River Flow Management

Attachment I.6 Volumetric Influence Analysis

I.6.1 Model Overview

By estimating the fraction of Sacramento–San Joaquin Delta (Delta) inflow that is diverted by the CVP and SWP export facilities, the range of potential hydrodynamic influence can be estimated. Herein, hydrodynamic influence is measured as the percentage of delta inflow exported. Thus, an amount of influence is exerted on the natural hydrodynamics of the Delta through changes in export values within the alternatives during the months of December through June will be representative of Old and Middle River management actions. In practice, such actions are implemented to protect fish, water quality, and meet other requirements through the manipulation of export rates of the CVP and SWP. Through examining the total exports relative to the total delta inflow estimated through CALSIM3 modeling among different alternatives, an estimated range of hydrodynamic influence created under each alternative may be made.

I.6.2 Model Development

I.6.2.1 Methods

This analysis uses CALSIM 3 estimated monthly Delta inflow and combined total CVP and SWP exports to estimate the range of hydrodynamic influence during the OMR season under different alternatives. The percentage of Delta inflow (cfs) being exported (cfs) cumulatively by the facilities is assumed to represent the influence of operations on the hydrodynamics of the Delta. The analysis is limited to only December through June monthly means. The monthly means for Delta inflow (see Code and data repository for CALSIM 3 inputs), Jones Exports, Banks Exports for the SWP and Banks Exports for the CVP were assembled from CALSIM 3 outputs for each alternative. All export means were summed for each month of each year of each alternative. The sum of exports was then divided by the Delta inflow for the same month, year and alternative group and multiplied by 100 to result in a “percent delta inflow exported” (percent delta inflow) by the facilities for each month and year in each alternative. Data assembly and processing was done in R (4.2.0).

The percent delta inflow values were then summarized as means with standard deviation and grouped by month for each alternative (Table I.6-1, Table I.6-2). The full distribution of each alternative’s monthly percent delta inflow was grouped by water year type and alternative then illustrated as box plots (Figure I.6-1, Figure I.6-2) and as a kernel density estimates that assume an underlying smooth distribution (Figure I.6-5). Means, minimum and maximum values are also provided (Table I.6-4)

Separately, percent delta inflow values were summarized as the means with standard deviation and grouped by inflow bins and alternative (Table I.6-3). See Delta Export Zone of Influence (DEZOI) attachment for the description of inflow bin construction. The full distribution of each alternative's monthly percent delta inflow exported from all years was grouped by delta inflow bin and illustrated as box plots (Figure I.6-3, Figure I.6-4) and using the same grouping as a kernel density estimate that assumes an underlying smoothed distribution (Figure I.6-6). Means, minimum and maximum values are also provided (Table I.6-5)

I.6.2.2 Assumptions/Uncertainty

This analysis serves as a coarse resolution assessment of operations under different alternatives to provide context for the range of exports relative to patterns of Delta inflow. It is intended to be foundational to narrative used in more complex models that address daily or sub-daily hydrology and factors that affect fish entrainment risks.

These analyses do not attempt to quantify specific estimates of magnitude of the difference among smoothed kernel density estimates made for individual alternatives.

The conceptual model of this analysis assumes that as a larger percent of Delta inflow is exported, more of the habitat in the Delta will be under the influence of change in hydrodynamics. Furthermore, it assumes less hydrodynamic influence is better for listed fish species.

I.6.2.3 Code and data repository

Delta inflow was calculated within CalSim 3 using the following equation.

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goal set_DeltaInflowforNDOI {DeltaInflowforNDOI = C_SAC049!Sacramento River at Freeport B9-1840/11447650

        + R_SRWWTP_SAC048!Sacramento Regional Treatment Plant

        + SP_SAC066_YBP020!Sacramento Weir A0-2903

        + SP_SAC083_YBP037!Fremont Weir

        + C_CCH053 !Cache Creek at Rumsey

        + C_PTH007 !South Fork of Putah Creek

        + C_MOK034 !Mokelumne River at Woodbridge B0-2105/11325500

        + C_CSM035 !Cosumnes River at Michigan Bar B1-1150/11335000

        + C_CLV026 !Calaveras River at Bellota B0-2520/11310700

        + C_DSC016 !Dry Creek at Galt B0-2805/11329500

        + C_SDC001 !Stockton Diverting Canal B0-2580/11310990

        + C_FCS006 !French Camp Slough at French Camp B02805/11304600

        + C_MSH015 !Marsh Creek at Byron B8-9100/11337500

        + C_SJR070}!San Joaquin River flow at Vernalis B0-7020/11303500
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I.6.3 Results

The results are present as tables and visualizations of the observed distributions of percent delta inflow within each alternative, and they are grouped by water year type (Figure I.6-1, Figure I.6-2) or grouped by the inflow group (Figure I.6-3, Figure I.6-4). The subsequent Environmental Impact Statement (EIS; Table I.6-1 through Table I.6-5) and Biological Assessment (Table I.6-6 and Table I.6-7, Figure I.6-6 through Figure I.6-12) sections present summarized results for relevant alternatives or by Proposed Action components.

The EIS results include comparisons among the No Action Alternative (NAA) and all other management alternatives. The Biological Assessment results include results for the NAA, the EXP1 and EXP3 baseline alternatives, and the Proposed Action components. Results are summarized by water year type, inflow group and alternative.

I.6.3.1 Environmental Impact Statement Key Takeaways

When results were grouped by water year, the observed lowest (non-zero) mean percent Delta inflow was in Alt 3 and observed in an above normal year at 10%, the lowest minimum (non-zero) value was observed in Alt 3 in wet years at 0.35%, and the greatest maximum value of 65% was observed in all alternatives in wet, above normal, dry and critically dry year types except in Alt 3, Alt 4, EXP 1 and EXP3 (Table I.6-2). Zero values of EXP1 and EXP3 are not considered as lowest values because they do not include exports as defined in their models.

When results were grouped by inflow group, the observed lowest (non-zero) mean percent Delta inflow exported was in Alt 3 and observed in the hihi inflow group at 6.7%, the lowest minimum (non-zero) value was observed in Alt 3 in the hihi inflow group at 0.35%, the greatest maximum value of 65% was observed in all alternatives in the lolo, medmed, medlo, lohi inflow groups except in Alt 3, Alt 4, EXP 1 and EXP3 (Table I.6-3). Zero values of EXP1 and EXP3 are not considered as lowest values because they do not include exports as defined in their models.

In both groupings, the distribution of the percent delta inflow exported is explained in part by operational constraints of the CVP and SWP. No more than 65% of delta inflow may be exported at any time per D-1641 and in critically dry years operations to meet human health and safety are maximized to meet that need when delta inflow would be at its lowest.

By visualizing the distribution of percent delta inflow by each alternative as density plots, the frequency of specific observations can be used to qualitatively assess which alternatives have the most observations of low percent delta inflow. Means of the distributions are also represented as vertical lines to illustrate in both grouping methods the influence of the high percent delta inflow values since high percent delta inflow values were observed at low frequency in all distributions, but EXP1 and EXP3 (Figure I.6-6).

When grouped by water year type Alt 3 has the highest frequency of low percent delta inflow observations. Among the other alternatives there is great overlap in the distribution and variation among where the peaks in the distribution among the water types are observed.

When grouped by inflow group, more variation is introduced into the distributions as would be expected by increasing the number of categories. These distributions may also be influenced by the variability in the sample sizes among inflow groups (see ZOI attachment for details). Again Alt 3 does have a peak in its distribution that represents a higher frequency of lower percent delta inflow observations than other alternatives. The NA inflow group is also introduced because some of the observed values fall outside of the delta inflow group definitions.

Based on the assumptions described above, an alternative with the lowest frequency of high percent delta inflow would be hypothesized to exert the least influence over the natural hydrodynamics of the delta. Alt 3 has the highest frequency of low percent delta inflow and should exert the least influence among the alternatives within the context CALSIM 3 model parameters.

I.6.3.1.1 Tables

Table I.6-1. Monthly (December-June) mean percent delta inflow exported values and standard deviations for each Alternative by water year type and month.

Water Year Type	Month	NAA Monthly Mean %	NAA SD	Alt1 Monthly Mean %	Alt1 SD	Alt2woTUCPwoVA Monthly Mean %	Alt2woTUCP woVA SD	Alt2woTUCPDeltaVA Monthly Mean %	Alt2woTUCP DeltaVA SD	Alt2woTUCPAllVA Monthly Mean %	Alt2woTUCP AllVA SD	Alt2wTUCPwoVA Monthly Mean %	Alt2wTUCP woVA SD	Alt3 Monthly Mean %	Alt3 SD	Alt4 Monthly Mean %	Alt4 SD	EXP1 Monthly Mean %	EXP1 SD	EXP3 Monthly Mean %	EXP3 SD
AN	12	38.0	18.6	43	15.85	38	18.5	38	18.3	37.7	18.3	38	18.6	16.6	12.3	35	17.3	0	0	0	0
AN	1	16.9	10.6	28	15.63	17	10.6	17	10.7	16.5	10.7	17	10.7	9.6	4.5	16	10.8	0	0	0	0
AN	2	12.9	5.7	19	9.68	13	5.4	13	5.4	12.9	5.5	13	5.4	10.2	4.6	14	6.1	0	0	0	0
AN	3	12.3	4.7	19	9.01	13	4.6	10	4.8	10.0	4.8	12	4.7	7.4	4.4	13	5.2	0	0	0	0
AN	4	13.4	4.2	19	4.92	18	5.2	10	2.7	9.5	2.6	18	5.2	5.3	2.6	18	5.2	0	0	0	0
AN	5	19.1	6.4	26	5.80	25	6.6	23	7.6	21.6	7.0	25	6.6	4.9	2.6	25	6.6	0	0	0	0
AN	6	30.9	3.2	35	0.63	28	3.5	29	3.3	29.1	3.1	28	3.5	18.8	10.1	28	3.5	0	0	0	0
BN	1	25.0	12.6	41	13.54	24	12.5	25	12.8	24.6	12.8	24	12.5	14.7	7.7	24	12.6	0	0	0	0
BN	2	23.3	6.8	30	9.38	22	6.4	22	6.4	22.2	6.4	22	6.2	13.4	6.8	24	6.8	0	0	0	0
BN	3	20.7	5.3	31	5.26	21	5.4	14	4.4	13.6	4.4	21	5.4	12.2	6.8	21	5.5	0	0	0	0
BN	4	16.5	4.4	22	4.31	20	4.2	16	4.3	14.6	3.7	20	4.2	7.7	2.4	20	4.2	0	0	0	0
BN	5	17.8	3.0	25	3.51	23	3.2	22	3.4	20.8	3.0	23	3.5	7.1	2.4	23	3.7	0	0	0	0
BN	6	32.1	2.0	33	6.03	29	2.1	29	2.1	30.1	2.3	29	1.9	16.7	7.0	29	1.9	0	0	0	0
BN	12	25.5	13.5	36	16.16	25	12.2	26	12.8	24.8	12.8	25	12.6	15.0	15.9	24	12.3	0	0	0	0
CD	1	33.7	14.1	47	14.13	31	12.1	31	15.3	31.5	14.9	30	13.4	24.5	10.8	33	14.1	0	0	0	0
CD	2	29.1	9.5	37	8.59	28	8.7	29	8.3	28.8	8.5	31	9.3	24.0	11.1	34	8.8	0	0	0	0

Water Year Type	Month	NAA Monthly Mean %	NAA SD	Alt1 Monthly Mean %	Alt1 SD	Alt2woTUCPwoVA Monthly Mean %	Alt2woTUCP woVA SD	Alt2woTUCPDeltaVA Monthly Mean %	Alt2woTUCP DeltaVA SD	Alt2woTUCPAllVA Monthly Mean %	Alt2woTUCP AllVA SD	Alt2wTUCPwoVA Monthly Mean %	Alt2wTUCP woVA SD	Alt3 Monthly Mean %	Alt3 SD	Alt4 Monthly Mean %	Alt4 SD	EXP1 Monthly Mean %	EXP1 SD	EXP3 Monthly Mean %	EXP3 SD
CD	3	29.3	5.4	26	8.06	23	7.9	22	7.3	22.4	7.4	28	6.2	17.5	8.2	29	6.0	0	0	0	0
CD	4	19.3	3.0	20	3.60	19	3.2	19	3.1	18.9	2.8	21	4.0	9.1	1.7	21	3.9	0	0	0	0
CD	5	21.3	2.5	23	4.79	22	4.4	22	4.4	21.4	4.4	23	3.2	9.6	1.5	22	3.8	0	0	0	0
CD	6	17.9	6.4	19	7.35	17	7.1	17	6.9	16.1	7.0	17	6.4	10.6	4.0	16	6.0	0	0	0	0
CD	12	36.3	10.4	42	18.25	40	11.9	39	12.1	36.0	12.2	36	9.5	11.5	10.9	32	12.3	0	0	0	0
D	1	35.6	9.8	50	9.64	33	10.1	33	10.1	33.2	10.1	33	10.0	17.9	9.1	36	10.2	0	0	0	0
D	2	23.3	9.4	32	8.61	22	8.9	21	8.9	22.2	9.1	22	8.9	16.4	8.8	24	8.9	0	0	0	0
D	3	25.0	6.7	32	4.84	25	6.9	19	6.4	19.1	6.3	25	6.9	18.2	9.0	25	6.8	0	0	0	0
D	4	16.8	3.2	21	3.88	19	3.4	15	4.8	14.3	4.5	19	3.4	6.1	1.5	19	3.3	0	0	0	0
D	5	18.2	3.7	24	4.84	21	5.6	20	6.3	18.5	6.2	21	5.6	7.2	1.6	21	5.6	0	0	0	0
D	6	30.5	2.5	31	3.53	28	2.1	28	2.4	27.7	2.5	28	2.1	9.2	4.6	28	1.8	0	0	0	0
D	12	22.0	11.0	37	16.91	22	11.4	22	11.4	22.3	10.7	23	11.2	13.3	9.4	22	11.3	0	0	0	0
W	1	11.7	5.7	18	13.00	11	5.2	11	5.3	11.4	5.4	11	5.2	9.4	6.4	11	5.2	0	0	0	0
W	2	9.9	4.9	13	8.09	10	5.2	10	5.3	10.3	5.3	10	5.2	6.2	4.0	11	5.5	0	0	0	0
W	3	11.8	6.6	15	9.60	12	6.8	12	6.8	11.9	6.8	12	6.8	4.8	3.2	13	7.4	0	0	0	0
W	4	13.2	4.7	16	7.20	16	7.1	14	6.8	13.5	6.7	16	7.1	3.8	2.7	16	7.0	0	0	0	0
W	5	18.5	5.5	23	6.41	24	6.3	24	6.4	23.6	6.3	24	6.3	3.7	2.8	23	6.3	0	0	0	0
W	6	30.9	4.4	33	4.11	30	4.2	30	4.2	30.3	4.2	30	4.2	26.0	8.5	30	4.3	0	0	0	0
W	12	36.7	20.5	42	18.22	37	20.3	36	19.9	36.0	19.9	37	20.2	19.9	13.1	33	18.1	0	0	0	0

AN = Above Normal; BN = Below Normal; CD = Critically Dry; D = Dry; W = Wet; SD = Standard Deviation.

Table I.6-2. Monthly (December-June mean percent delta inflow exported values and percent difference from NAA for each Alternative by water year type.

Water Year Type	Month	NAA Monthly Mean %	Alt1 Monthly Mean %	Alt1 % Diff	Alt2wTUCPwoVA Monthly Mean %	Alt2wTUCPwoVA % Diff	Alt2woTUCPwoVA Monthly Mean %	Alt2woTUCPwoVA % Diff	Alt2woTUCPDeltaVA Monthly Mean %	Alt2woTUCPDeltaVA % Diff	Alt2woTUCPAllVA Monthly Mean %	Alt2woTUCPAllVA % Diff	Alt3 Monthly Mean %	Alt3 % Diff	Alt4 Monthly Mean %	Alt4 % Diff	EXP1 Monthly Mean %	EXP1 % Diff	EXP3 Monthly Mean %	EXP3 % Diff
AN	12	38.0	43	13.0	38	0.20	38	0.099	38	-0.843	37.7	-0.8781	16.6	-56	35	-7.672	0	-100	0	-100
AN	1	16.9	28	66.2	17	-2.19	17	-2.101	17	-2.237	16.5	-2.6677	9.6	-44	16	-3.911	0	-100	0	-100
AN	2	12.9	19	48.7	13	0.73	13	0.254	13	0.396	12.9	0.0045	10.2	-21	14	9.308	0	-100	0	-100
AN	3	12.3	19	57.5	12	1.63	13	2.929	10	-18.861	10.0	-18.1755	7.4	-40	13	6.255	0	-100	0	-100
AN	4	13.4	19	39.7	18	33.58	18	33.536	10	-25.509	9.5	-29.4360	5.3	-61	18	33.669	0	-100	0	-100
AN	5	19.1	26	35.8	25	29.33	25	29.341	23	21.733	21.6	12.8968	4.9	-74	25	29.716	0	-100	0	-100
AN	6	30.9	35	12.1	28	-7.94	28	-7.936	29	-7.162	29.1	-5.6840	18.8	-39	28	-7.909	0	-100	0	-100
BN	1	25.0	41	63.2	24	-2.62	24	-2.394	25	-1.402	24.6	-1.5022	14.7	-41	24	-2.753	0	-100	0	-100
BN	2	23.3	30	27.8	22	-4.86	22	-4.827	22	-4.884	22.2	-4.9142	13.4	-43	24	4.326	0	-100	0	-100
BN	3	20.7	31	48.3	21	-0.69	21	-0.635	14	-34.297	13.6	-34.4377	12.2	-41	21	-0.182	0	-100	0	-100
BN	4	16.5	22	32.1	20	23.15	20	23.199	16	-2.828	14.6	-11.3564	7.7	-53	20	23.580	0	-100	0	-100
BN	5	17.8	25	38.1	23	30.27	23	27.882	22	26.233	20.8	16.9508	7.1	-60	23	31.866	0	-100	0	-100
BN	6	32.1	33	2.1	29	-9.20	29	-8.440	29	-8.544	30.1	-6.2555	16.7	-48	29	-9.121	0	-100	0	-100
BN	12	25.5	36	42.7	25	-0.57	25	-2.836	26	1.620	24.8	-2.8011	15.0	-41	24	-6.003	0	-100	0	-100
CD	1	33.7	47	39.5	30	-10.71	31	-9.346	31	-8.219	31.5	-6.3893	24.5	-27	33	-2.710	0	-100	0	-100
CD	2	29.1	37	27.1	31	7.44	28	-2.348	29	-0.532	28.8	-0.8812	24.0	-17	34	18.326	0	-100	0	-100
CD	3	29.3	26	-10.3	28	-4.75	23	-22.013	22	-23.331	22.4	-23.5150	17.5	-40	29	-1.156	0	-100	0	-100
CD	4	19.3	20	3.1	21	6.55	19	0.592	19	0.069	18.9	-2.1414	9.1	-53	21	7.028	0	-100	0	-100
CD	5	21.3	23	8.4	23	6.11	22	4.889	22	4.999	21.4	0.4520	9.6	-55	22	3.114	0	-100	0	-100

Water Year Type	Month	NAA Monthly Mean %	Alt1 Monthly Mean %	Alt1 % Diff	Alt2wTUCPwoVA Monthly Mean %	Alt2wTUCPwoVA % Diff	Alt2woTUCPwoVA Monthly Mean %	Alt2woTUCPwoVA % Diff	Alt2woTUCPDeltaVA Monthly Mean %	Alt2woTUCPDeltaVA % Diff	Alt2woTUCPAllVA Monthly Mean %	Alt2woTUCPAllVA % Diff	Alt3 Monthly Mean %	Alt3 % Diff	Alt4 Monthly Mean %	Alt4 % Diff	EXP1 Monthly Mean %	EXP1 % Diff	EXP3 Monthly Mean %	EXP3 % Diff
CD	6	17.9	19	4.1	17	-4.86	17	-7.611	17	-7.081	16.1	-10.2008	10.6	-41	16	-8.884	0	-100	0	-100
CD	12	36.3	42	15.4	36	-0.83	40	9.009	39	7.022	36.0	-0.8505	11.5	-68	32	-10.734	0	-100	0	-100
D	1	35.6	50	39.8	33	-7.87	33	-7.919	33	-6.694	33.2	-6.7645	17.9	-50	36	-0.029	0	-100	0	-100
D	2	23.3	32	37.1	22	-7.33	22	-7.272	21	-7.847	22.2	-4.9755	16.4	-30	24	3.650	0	-100	0	-100
D	3	25.0	32	29.0	25	-1.32	25	-1.363	19	-23.008	19.1	-23.4760	18.2	-27	25	-0.382	0	-100	0	-100
D	4	16.8	21	22.2	19	13.19	19	13.095	15	-8.831	14.3	-15.2592	6.1	-64	19	13.585	0	-100	0	-100
D	5	18.2	24	30.0	21	16.78	21	16.753	20	7.852	18.5	1.4406	7.2	-61	21	16.956	0	-100	0	-100
D	6	30.5	31	2.5	28	-8.70	28	-8.734	28	-9.939	27.7	-9.1789	9.2	-70	28	-8.059	0	-100	0	-100
D	12	22.0	37	68.1	23	4.23	22	0.694	22	0.680	22.3	1.0947	13.3	-39	22	-1.648	0	-100	0	-100
W	1	11.7	18	57.7	11	-3.05	11	-3.110	11	-2.352	11.4	-2.3383	9.4	-19	11	-5.272	0	-100	0	-100
W	2	9.9	13	32.4	10	3.43	10	3.379	10	3.866	10.3	3.8753	6.2	-38	11	7.195	0	-100	0	-100
W	3	11.8	15	28.5	12	5.79	12	5.678	12	0.799	11.9	0.9373	4.8	-60	13	13.092	0	-100	0	-100
W	4	13.2	16	18.1	16	19.43	16	19.640	14	3.513	13.5	2.4140	3.8	-71	16	19.434	0	-100	0	-100
W	5	18.5	23	26.9	24	28.04	24	27.918	24	28.265	23.6	27.5001	3.7	-80	23	26.963	0	-100	0	-100
W	6	30.9	33	5.5	30	-2.34	30	-2.357	30	-2.261	30.3	-1.9933	26.0	-16	30	-3.047	0	-100	0	-100
W	12	36.7	42	13.2	37	-0.14	37	-0.120	36	-1.712	36.0	-1.7374	19.9	-46	33	-8.999	0	-100	0	-100

AN = Above Normal; BN = Below Normal; CD = Critically Dry; D = Dry; W = Wet; % Diff = Percent Difference.

The full distribution of each alternatives monthly percent delta inflow was grouped by month and alternative and illustrated as box plots (Figure I.6-3, Figure I.6-4) and as a kernel density estimate that assumes an underlying smoothe distribution (Figure I.6-6).

Table I.6-3. Mean percent delta inflow exported values and percent difference from NAA for each Alternative by inflow group.

Inflow Group	NAA	Alt1	Alt1 % Diff	Alt2wTUCP woVA	Alt2wTUCP woVA % Diff	Alt2woTUCP woVA	Alt2woTUCP woVA % Diff	Alt2woTUCP DeltaVA	Alt2woTUCP DeltaVA % Diff	Alt2woTUCP AllVA	Alt2woTUCP AllVA % Diff	Alt3	Alt3 % Diff	Alt4	Alt4 % Diff
hihi	12	14.6	24.9	12	6.32	12	6.4	12	0.67	12	1.18	6.7	-42.5	13	8.36
hilo	16	29.6	90.6	16	0.98	16	1.1	16	2.09	16	1.18	11.2	-27.5	15	-0.71
himed	14	24.5	79.6	14	2.23	14	2.5	13	-3.19	13	-3.98	10.0	-26.4	14	2.56
lohi	29	32.1	12.1	32	11.56	31	8.8	31	7.22	31	9.11	26.1	-8.8	31	8.63
lolo	29	32.6	10.6	29	-1.10	29	-2.9	29	-1.32	28	-3.78	15.4	-47.6	30	0.37
lomed	26	28.3	8.2	27	2.72	26	1.2	24	-6.92	24	-6.95	14.9	-42.9	28	5.63
medhi	21	28.6	33.2	26	20.13	26	19.7	23	8.85	24	10.11	10.0	-53.4	26	20.33
medlo	32	43.5	35.4	31	-2.95	31	-2.7	31	-2.84	32	-0.99	15.1	-53.0	30	-6.56
medmed	25	34.7	40.8	25	2.49	25	1.9	22	-9.79	22	-12.11	11.1	-54.9	25	3.13
NA	NA	9.6	NA	33	NA	NA	NA	NA	NA	NA	NA	9.2	NA	NA	NA

% Diff = Percent Difference.

Table I.6-4. Percent delta inflow mean, minimum observed value and maximum observed value for each alternative in every water year type.

Alternative	Water Year	Mean	Min	Max
Alt1	W	23	1.69	65
Alt1	AN	27	3.90	59
Alt1	BN	31	9.21	63
Alt1	CD	30	7.47	65
Alt1	D	32	10.44	65
Alt2wTUCPwoVA	W	20	1.72	65
Alt2wTUCPwoVA	AN	22	6.79	65
Alt2wTUCPwoVA	BN	24	8.17	50
Alt2wTUCPwoVA	CD	26	9.01	52
Alt2wTUCPwoVA	D	24	4.04	47
Alt2woTUCPAllVA	W	20	1.72	65
Alt2woTUCPAllVA	AN	20	5.15	65
Alt2woTUCPAllVA	BN	22	6.30	51
Alt2woTUCPAllVA	CD	25	8.26	65
Alt2woTUCPAllVA	D	22	4.77	47
Alt2woTUCPDeltaVA	W	20	1.72	65
Alt2woTUCPDeltaVA	AN	20	5.60	65
Alt2woTUCPDeltaVA	BN	22	6.71	50
Alt2woTUCPDeltaVA	CD	26	7.99	65
Alt2woTUCPDeltaVA	D	23	3.59	47
Alt2woTUCPwoVA	W	20	1.72	65
Alt2woTUCPwoVA	AN	22	6.79	65
Alt2woTUCPwoVA	BN	23	8.52	50
Alt2woTUCPwoVA	CD	26	8.20	54
Alt2woTUCPwoVA	D	24	3.62	47
Alt3	W	11	0.35	54
Alt3	AN	10	1.53	41
Alt3	BN	12	1.47	54
Alt3	CD	15	2.63	46
Alt3	D	13	1.96	38
Alt4	W	20	1.72	57
Alt4	AN	22	6.34	59

Alternative	Water Year	Mean	Min	Max
Alt4	BN	24	8.36	47
Alt4	CD	27	8.49	57
Alt4	D	25	3.67	52
EXP1	W	0	0.00	0
EXP1	AN	0	0.00	0
EXP1	BN	0	0.00	0
EXP1	CD	0	0.00	0
EXP1	D	0	0.00	0
EXP3	W	0	0.00	0
EXP3	AN	0	0.00	0
EXP3	BN	0	0.00	0
EXP3	CD	0	0.00	0
EXP3	D	0	0.00	0
NAA	W	19	1.72	65
NAA	AN	21	6.32	65
NAA	BN	23	7.59	52
NAA	CD	27	12.42	65
NAA	D	25	3.59	50

AN = Above Normal; BN = Below Normal; CD = Critically Dry; D = Dry; W = Wet.

Table I.6-5. Percent delta inflow mean, minimum observed value and maximum observed value for each alternative in each inflow group.

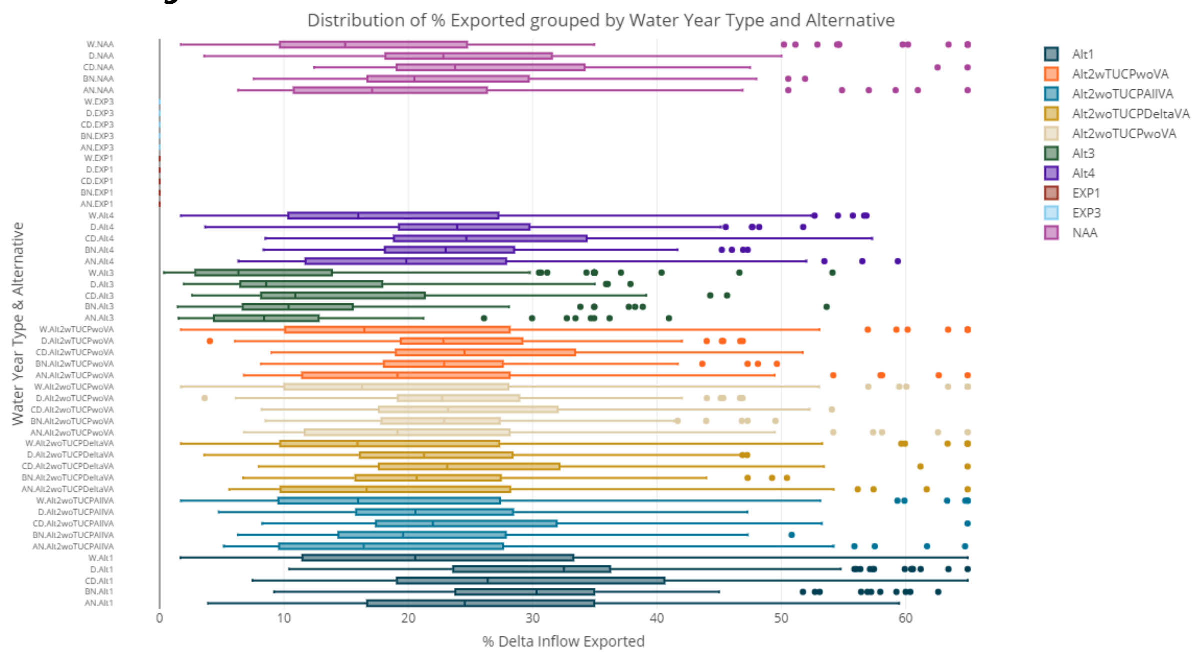
Alternative	Inflow Group	Mean	Min	Max
Alt1	NA	9.6	9.63	9.6
Alt1	hihi	14.6	1.69	35.0
Alt1	hilo	29.6	10.44	41.3
Alt1	himed	24.5	5.77	41.3
Alt1	lohi	32.1	18.50	64.8
Alt1	lolo	32.6	7.47	64.7
Alt1	lomed	28.3	10.05	57.1
Alt1	medhi	28.6	16.49	45.2
Alt1	medlo	43.5	13.89	65.0
Alt1	medmed	34.7	12.13	65.0

Alternative	Inflow Group	Mean	Min	Max
Alt2wTUCPwoVA	NA	32.5	32.53	32.5
Alt2wTUCPwoVA	hihi	12.4	1.72	23.2
Alt2wTUCPwoVA	hilo	15.7	6.06	23.7
Alt2wTUCPwoVA	himed	13.9	3.72	24.8
Alt2wTUCPwoVA	lohi	32.0	23.34	48.1
Alt2wTUCPwoVA	lolo	29.1	4.04	65.0
Alt2wTUCPwoVA	lomed	26.9	12.20	47.3
Alt2wTUCPwoVA	medhi	25.8	15.03	33.7
Alt2wTUCPwoVA	medlo	31.2	11.64	65.0
Alt2wTUCPwoVA	medmed	25.3	14.28	65.0
Alt2woTUCPAllVA	hihi	11.8	1.72	23.2
Alt2woTUCPAllVA	hilo	15.7	6.00	23.6
Alt2woTUCPAllVA	himed	13.1	3.72	24.8
Alt2woTUCPAllVA	lohi	31.3	9.43	65.0
Alt2woTUCPAllVA	lolo	28.4	8.26	64.8
Alt2woTUCPAllVA	lomed	24.3	9.75	47.3
Alt2woTUCPAllVA	medhi	23.6	7.50	33.7
Alt2woTUCPAllVA	medlo	31.8	8.53	63.3
Alt2woTUCPAllVA	medmed	21.7	5.15	65.0
Alt2woTUCPDeltaVA	hihi	11.8	1.72	23.2
Alt2woTUCPDeltaVA	hilo	15.8	6.02	23.7
Alt2woTUCPDeltaVA	himed	13.2	3.71	24.8
Alt2woTUCPDeltaVA	lohi	30.7	9.16	65.0
Alt2woTUCPDeltaVA	lolo	29.1	3.59	65.0
Alt2woTUCPDeltaVA	lomed	24.3	10.11	47.3
Alt2woTUCPDeltaVA	medhi	23.4	8.12	33.7
Alt2woTUCPDeltaVA	medlo	31.2	8.21	63.4
Alt2woTUCPDeltaVA	medmed	22.2	5.66	65.0
Alt2woTUCPwoVA	hihi	12.5	1.72	23.2
Alt2woTUCPwoVA	hilo	15.7	6.12	24.0
Alt2woTUCPwoVA	himed	13.9	3.72	24.8
Alt2woTUCPwoVA	lohi	31.2	18.29	44.4
Alt2woTUCPwoVA	lolo	28.6	3.62	65.0
Alt2woTUCPwoVA	lomed	26.5	9.67	47.3

Alternative	Inflow Group	Mean	Min	Max
Alt2woTUCPwoVA	medhi	25.7	15.04	33.7
Alt2woTUCPwoVA	medlo	31.2	8.20	65.0
Alt2woTUCPwoVA	medmed	25.1	10.40	65.0
Alt3	NA	9.2	7.47	12.9
Alt3	hihi	6.7	0.35	24.3
Alt3	hilo	11.2	1.47	24.2
Alt3	himed	10.0	1.53	25.3
Alt3	lohi	26.1	6.51	35.0
Alt3	lolo	15.4	5.42	53.6
Alt3	lomed	14.9	5.68	54.1
Alt3	medhi	10.0	1.69	35.0
Alt3	medlo	15.1	3.42	39.1
Alt3	medmed	11.1	3.53	35.0
Alt4	hihi	12.7	1.72	23.4
Alt4	hilo	15.4	5.32	20.9
Alt4	himed	14.0	3.96	26.5
Alt4	lohi	31.1	23.34	35.0
Alt4	lolo	29.6	3.67	59.4
Alt4	lomed	27.6	12.15	56.9
Alt4	medhi	25.8	15.09	34.8
Alt4	medlo	30.0	15.61	52.0
Alt4	medmed	25.4	14.61	50.5
EXP1	NA	0.0	0.00	0.0
EXP1	hihi	0.0	0.00	0.0
EXP1	hilo	0.0	0.00	0.0
EXP1	himed	0.0	0.00	0.0
EXP1	lohi	0.0	0.00	0.0
EXP1	lolo	0.0	0.00	0.0
EXP1	lomed	0.0	0.00	0.0
EXP1	medhi	0.0	0.00	0.0
EXP1	medlo	0.0	0.00	0.0
EXP1	medmed	0.0	0.00	0.0
EXP3	NA	0.0	0.00	0.0
EXP3	hihi	0.0	0.00	0.0

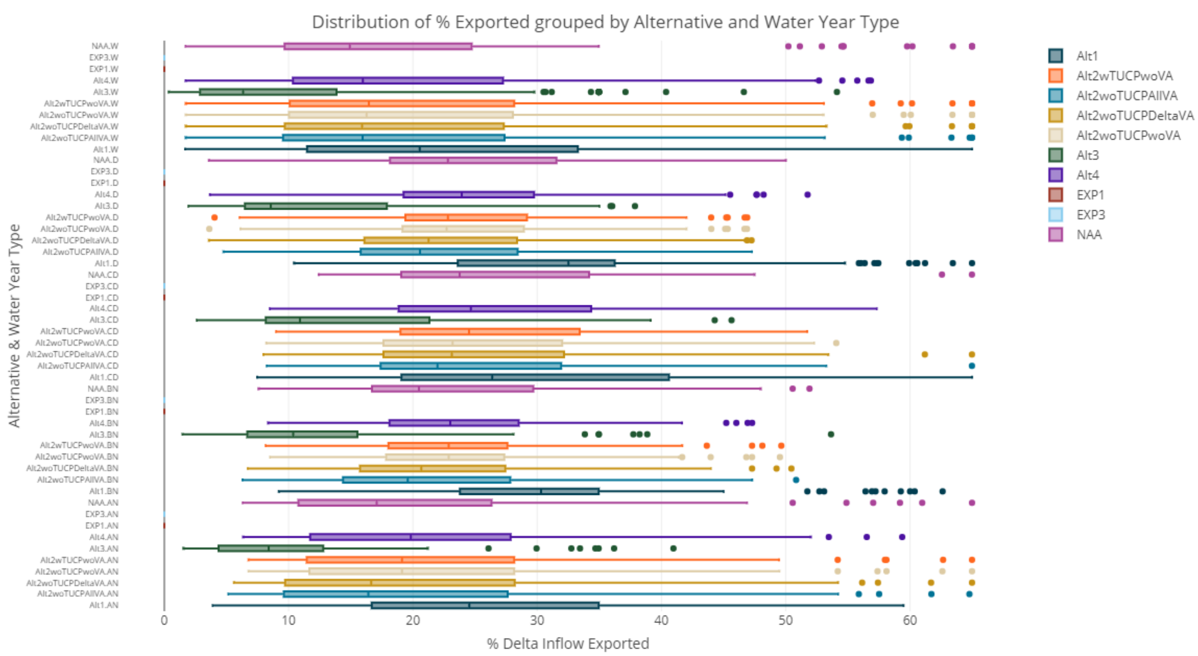
Alternative	Inflow Group	Mean	Min	Max
EXP3	hilo	0.0	0.00	0.0
EXP3	himed	0.0	0.00	0.0
EXP3	lohi	0.0	0.00	0.0
EXP3	lolo	0.0	0.00	0.0
EXP3	lomed	0.0	0.00	0.0
EXP3	medhi	0.0	0.00	0.0
EXP3	medlo	0.0	0.00	0.0
EXP3	medmed	0.0	0.00	0.0
NAA	hihi	11.7	1.72	23.3
NAA	hilo	15.5	6.20	21.9
NAA	himed	13.6	3.69	24.7
NAA	lohi	28.7	18.35	65.0
NAA	lolo	29.5	3.59	65.0
NAA	lomed	26.1	12.25	47.3
NAA	medhi	21.5	7.59	34.0
NAA	medlo	32.1	14.28	63.5
NAA	medmed	24.6	11.35	65.0

I.6.3.1.2 Figures



W = Wet; AN = Above Normal; BN = Below Normal; CD = Critically Dry; D = Dry.

Figure I.6-1. Box plots of percent delta inflow exported grouped by water year type and alternative.



W = Wet; AN = Above Normal; BN = Below Normal; CD = Critically Dry; D = Dry.

Figure I.6-2. Box plots of percent delta inflow exported grouped by alternative and water year type.

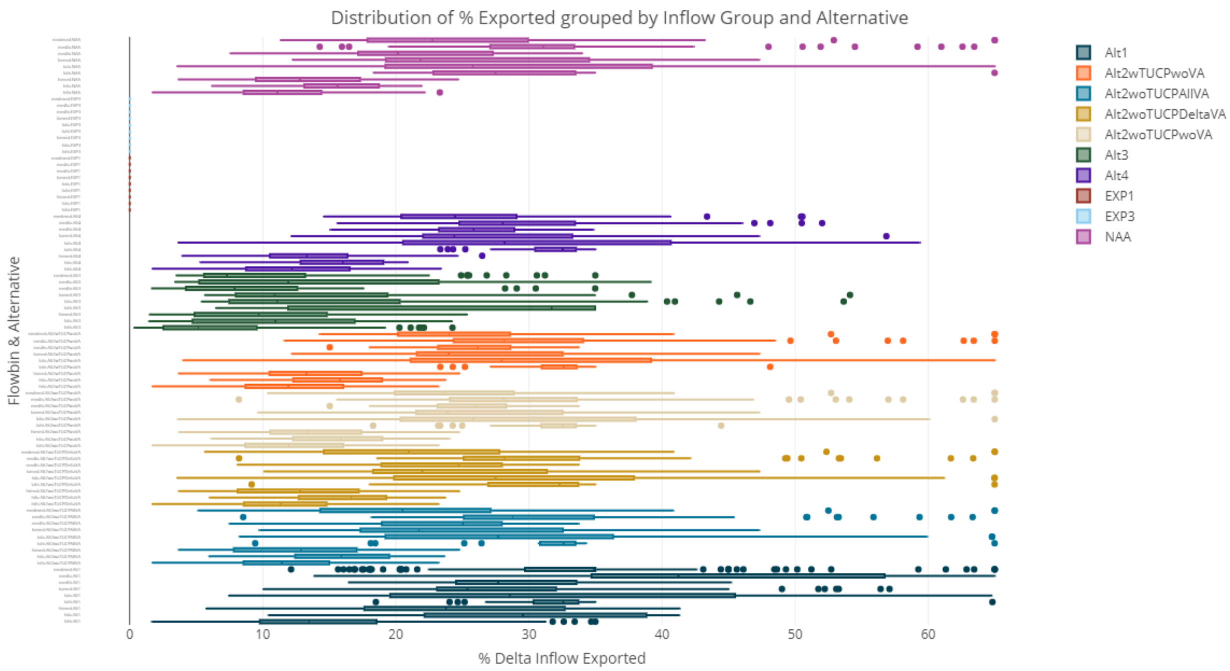


Figure I.6-3. Box plot of the full distribution of the each alternatives' percent delta inflow exported from all years grouped by inflow group and alternative.

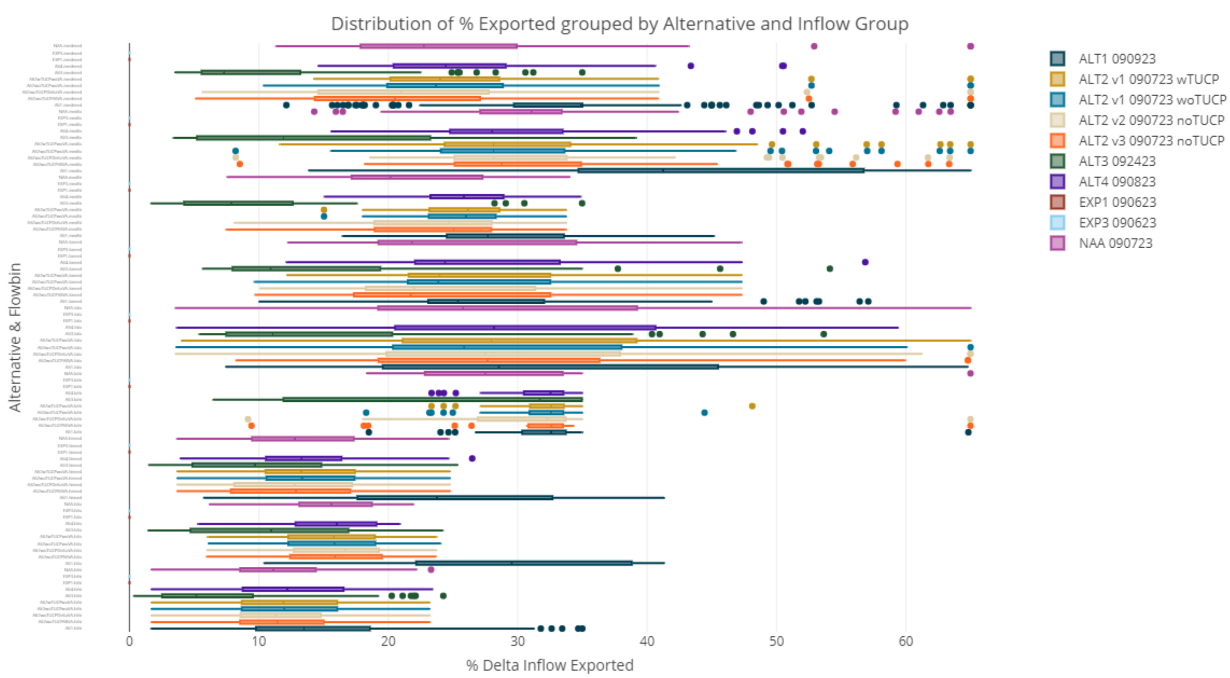
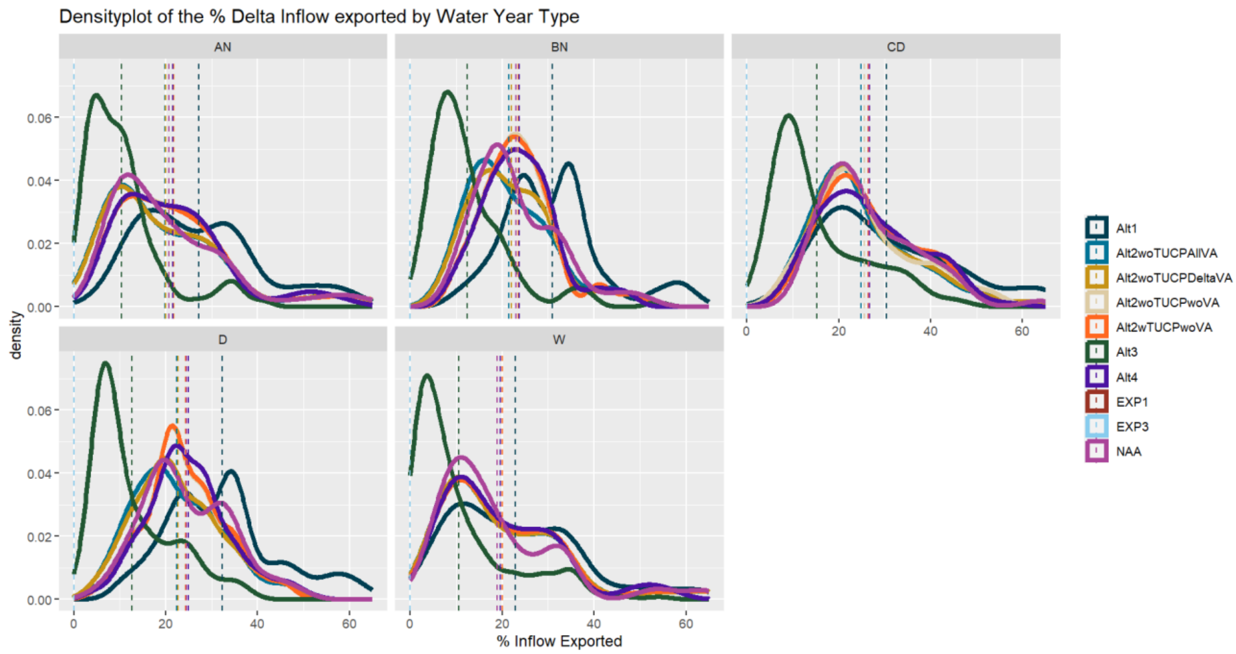
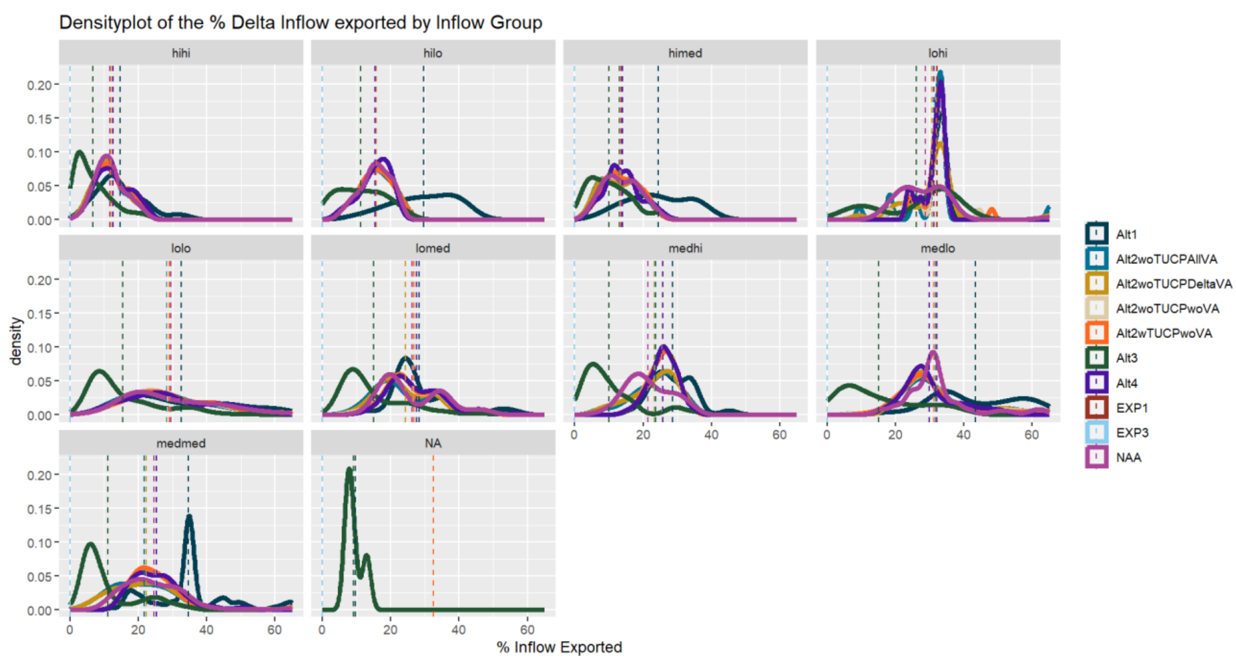


Figure I.6-4. Box plot of the full distribution of the each alternatives' percent delta inflow exported from all years grouped by alternative and inflow group.



Each kernel density distribution is based on the default bandwidth specified in ggplot2 (geom_density).

Figure I.6-5. Kernel density estimate of each alternative's monthly percent delta inflow grouped by water year type.



Each kernel density distribution is based on the default bandwidth specified in ggplot2 (geom_density).

Figure I.6-6. Kernel density estimate of percent delta inflow exported for all years grouped by delta inflow groups.

I.6.3.2 Biological Assessment Key Takeaways

When results were grouped by water year the observed lowest mean (non-zero) percent Delta inflow exported was observed in NAA in a wet years year at 19%, the lowest minimum (non-zero) value was observed in NAA and all Proposed Action components in wet years at 1.7%, the greatest maximum value of 65% was observed in all alternatives in wet, above normal, and critically dry year types except in EXP1 and EXP3 (Table I.6-6). Zero values of EXP1 and EXP3 are not considered as lowest values because they do not include exports as defined in their models.

When results were grouped by inflow group the observed lowest mean (non-zero) percent Delta inflow exported was in NAA, Alt2woTUCPAllVA, Alt2woTUCPDeltaVA, and Alt2woTUCPwoVA in the hihi inflow group at 12 %, the lowest minimum (non-zero) value was observed in Alt2woTUCPAllVA, Alt2woTUCPDeltaVA, Alt2woTUCPwoVA, and NAA in hihi inflow group at 1.7 %, the greatest maximum value of 65% was observed in all alternatives in the lolo, medmed, medlo, lohi inflow groups, except in EXP 1 and EXP3 (Table I.6-7). Zero values of EXP1 and EXP3 are not considered as lowest values because they do not include exports as defined in their models.

In both groupings, the distribution of the percent delta inflow exported is explained by operational constraints of the CVP and SWP. No more than 65% of delta inflow may be exported at any time per D-1641 and in critically dry years operations to meet human health and safety are maximized to meet that need when delta inflow would be at its lowest.

By visualizing the distribution of percent delta inflow by each alternative as density plots, the frequency of specific observations can be used to illustrate which alternatives have the most observations of low percent delta inflow. Means of the distributions are also represented as vertical lines to illustrate in both grouping methods the influence of the high percent delta inflow values observed at low frequency in all distributions but EXP1 and EXP3 (Figure I.6-11, Figure I.6-12).

When grouped by water year type Alt2woTUCPwoVA has a higher frequency peak of slightly above 20% percent delta inflow in below normal and dry years relative to the other alternatives. In wet and above normal years, the NAA has the highest frequency peak near 10% of percent delta inflow. Within critically dry years all alternatives overlap in frequency near 20% and it is difficult to separate which frequency is greatest.

When grouped by inflow group, overlap in the distributions among these alternatives increases in most inflow groups. These distributions may also be influenced by the variability in the sample sizes among inflow groups (see ZOI attachment for details). Inflow groups with high Sacramento River flows have a large amount of overlap in their distribution among the alternatives. A similar pattern occurs in the lolo and lomed groupings, however medmed, and medhi have distinctly high frequencies between 20% and 30% in Alt2woTUCPwoVA. The group medlo has a peak in the frequency near 30% in the NAA. The lohi group is unlike any other group by having its highest peak in Alt2woTUCPAllVA, but this is likely driven by the sample size. The NA group is introduced because of some of the observed values falling outside of the delta inflow group definitions.

Based on the assumptions described above an alternative with the lowest frequency of high percent delta inflow would exert the least influence over the natural hydrodynamics of the delta. Among the alternatives in this analysis it is difficult to describe which alternative has the lowest frequency of high percent delta inflow since among both water year type and inflow group some alternatives perform better in some but never all circumstances at this coarse scale investigation.

I.6.3.2.1 Tables

Table I.6-6. Percent delta inflow mean, minimum observed value and maximum observed value for each alternative in every water year type.

Alternative	Water Year	Mean	Min	Max
Alt2wTUCPwoVA	AN	22	6.8	65
Alt2wTUCPwoVA	BN	24	8.2	50
Alt2wTUCPwoVA	CD	26	9.0	52
Alt2wTUCPwoVA	D	24	4.0	47
Alt2wTUCPwoVA	W	20	1.7	65
Alt2woTUCPAllVA	AN	20	5.2	65
Alt2woTUCPAllVA	BN	22	6.3	51
Alt2woTUCPAllVA	CD	25	8.3	65
Alt2woTUCPAllVA	D	22	4.8	47
Alt2woTUCPAllVA	W	20	1.7	65
Alt2woTUCPDeltaVA	AN	20	5.6	65
Alt2woTUCPDeltaVA	BN	22	6.7	50
Alt2woTUCPDeltaVA	CD	26	8.0	65
Alt2woTUCPDeltaVA	D	23	3.6	47
Alt2woTUCPDeltaVA	W	20	1.7	65
Alt2woTUCPwoVA	AN	22	6.8	65
Alt2woTUCPwoVA	BN	23	8.5	50
Alt2woTUCPwoVA	CD	26	8.2	54
Alt2woTUCPwoVA	D	24	3.6	47
Alt2woTUCPwoVA	W	20	1.7	65
EXP1	AN	0	0.0	0
EXP1	BN	0	0.0	0
EXP1	CD	0	0.0	0
EXP1	D	0	0.0	0
EXP1	W	0	0.0	0
EXP3	AN	0	0.0	0

Alternative	Water Year	Mean	Min	Max
EXP3	BN	0	0.0	0
EXP3	CD	0	0.0	0
EXP3	D	0	0.0	0
EXP3	W	0	0.0	0
NAA	AN	21	6.3	65
NAA	BN	23	7.6	52
NAA	CD	27	12.4	65
NAA	D	25	3.6	50
NAA	W	19	1.7	65

AN = Above Normal; BN = Below Normal; CD = Critically Dry; D = Dry; W = Wet.

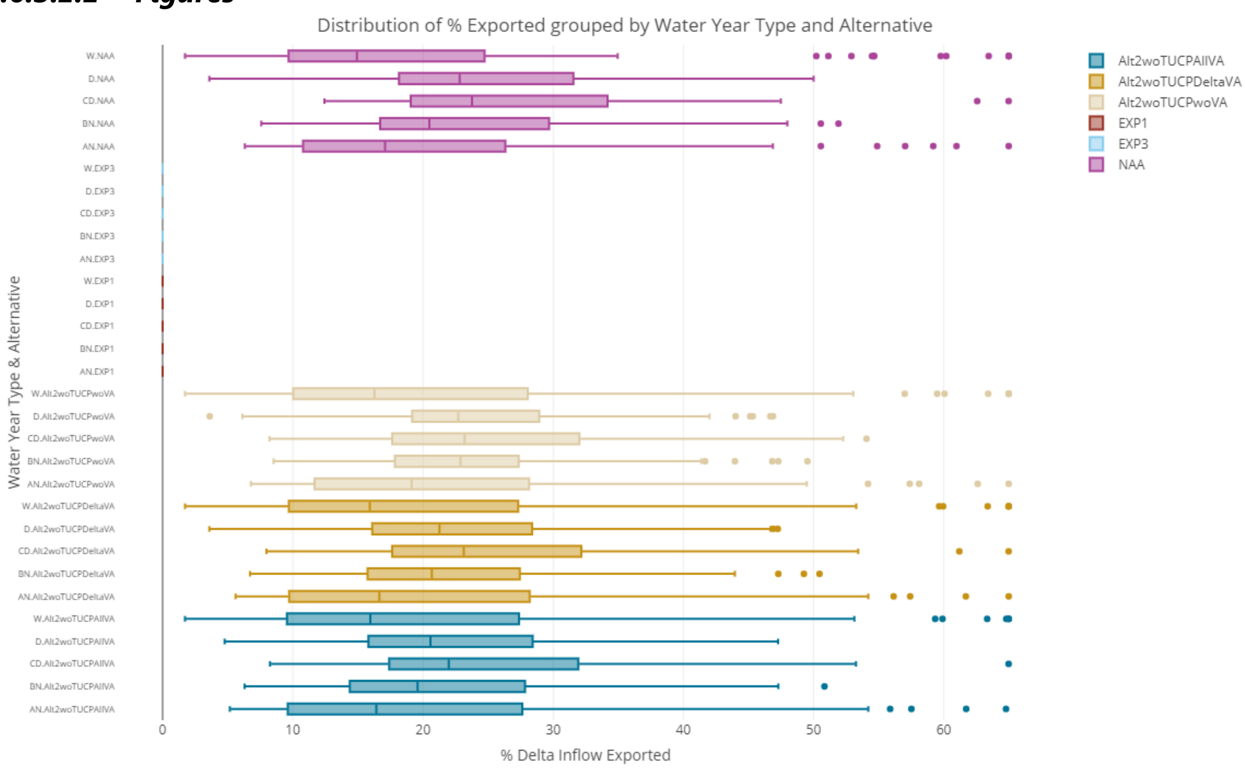
Table I.6-7. Percent delta inflow mean, minimum observed value and maximum observed value for each alternative in each inflow group.

Alternative	Inflow Group	Mean	Min	Max
Alt2wTUCPwoVA	hihi	12	1.7	23
Alt2wTUCPwoVA	hilo	16	6.1	24
Alt2wTUCPwoVA	himed	14	3.7	25
Alt2wTUCPwoVA	lohi	32	23.3	48
Alt2wTUCPwoVA	lolo	29	4.0	65
Alt2wTUCPwoVA	lomed	27	12.2	47
Alt2wTUCPwoVA	medhi	26	15.0	34
Alt2wTUCPwoVA	medlo	31	11.6	65
Alt2wTUCPwoVA	medmed	25	14.3	65
Alt2wTUCPwoVA	NA	33	32.5	33
Alt2woTUCPAllVA	hihi	12	1.7	23
Alt2woTUCPAllVA	hilo	16	6.0	24
Alt2woTUCPAllVA	himed	13	3.7	25
Alt2woTUCPAllVA	lohi	31	9.4	65
Alt2woTUCPAllVA	lolo	28	8.3	65
Alt2woTUCPAllVA	lomed	24	9.8	47
Alt2woTUCPAllVA	medhi	24	7.5	34
Alt2woTUCPAllVA	medlo	32	8.5	63
Alt2woTUCPAllVA	medmed	22	5.2	65

Alternative	Inflow Group	Mean	Min	Max
Alt2woTUCPDeltaVA	hihi	12	1.7	23
Alt2woTUCPDeltaVA	hilo	16	6.0	24
Alt2woTUCPDeltaVA	himed	13	3.7	25
Alt2woTUCPDeltaVA	lohi	31	9.2	65
Alt2woTUCPDeltaVA	lolo	29	3.6	65
Alt2woTUCPDeltaVA	lomed	24	10.1	47
Alt2woTUCPDeltaVA	medhi	23	8.1	34
Alt2woTUCPDeltaVA	medlo	31	8.2	63
Alt2woTUCPDeltaVA	medmed	22	5.7	65
Alt2woTUCPwoVA	hihi	12	1.7	23
Alt2woTUCPwoVA	hilo	16	6.1	24
Alt2woTUCPwoVA	himed	14	3.7	25
Alt2woTUCPwoVA	lohi	31	18.3	44
Alt2woTUCPwoVA	lolo	29	3.6	65
Alt2woTUCPwoVA	lomed	26	9.7	47
Alt2woTUCPwoVA	medhi	26	15.0	34
Alt2woTUCPwoVA	medlo	31	8.2	65
Alt2woTUCPwoVA	medmed	25	10.4	65
EXP1	hihi	0	0.0	0
EXP1	hilo	0	0.0	0
EXP1	himed	0	0.0	0
EXP1	lohi	0	0.0	0
EXP1	lolo	0	0.0	0
EXP1	lomed	0	0.0	0
EXP1	medhi	0	0.0	0
EXP1	medlo	0	0.0	0
EXP1	medmed	0	0.0	0
EXP1	NA	0	0.0	0
EXP3	hihi	0	0.0	0
EXP3	hilo	0	0.0	0
EXP3	himed	0	0.0	0
EXP3	lohi	0	0.0	0
EXP3	lolo	0	0.0	0
EXP3	lomed	0	0.0	0

Alternative	Inflow Group	Mean	Min	Max
EXP3	medhi	0	0.0	0
EXP3	medlo	0	0.0	0
EXP3	medmed	0	0.0	0
EXP3	NA	0	0.0	0
NAA	hihi	12	1.7	23
NAA	hilo	16	6.2	22
NAA	himed	14	3.7	25
NAA	lohi	29	18.3	65
NAA	lolo	29	3.6	65
NAA	lomed	26	12.3	47
NAA	medhi	21	7.6	34
NAA	medlo	32	14.3	63
NAA	medmed	25	11.4	65

I.6.3.2.2 Figures



W = Wet; AN = Above Normal; BN = Below Normal; CD = Critically Dry; D = Dry.

Figure I.6-7. Box plots of percent delta inflow exported grouped by water year type and alternative.

W = Wet; AN = Above Normal; BN = Below Normal; CD = Critically Dry; D = Dry.

Figure I.6-8. Box plots of percent delta inflow exported grouped by alternative and water year type.

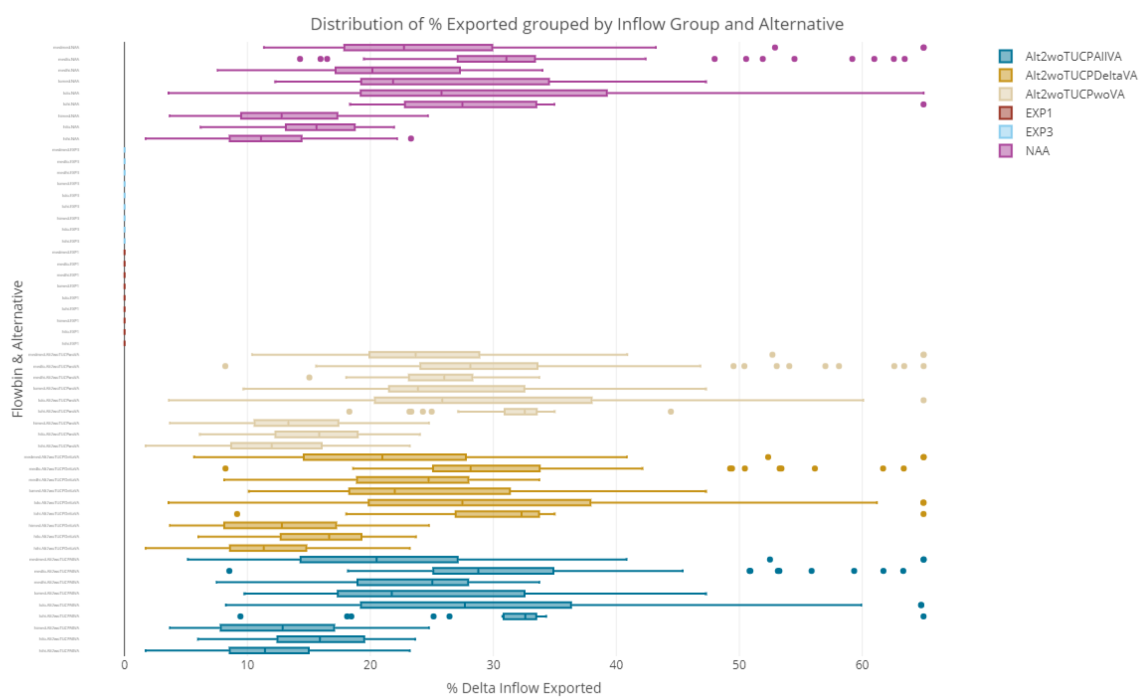


Figure I.6-9. Box plot of the full distribution of each alternatives' percent delta inflow exported from all years grouped by inflow group and alternative.

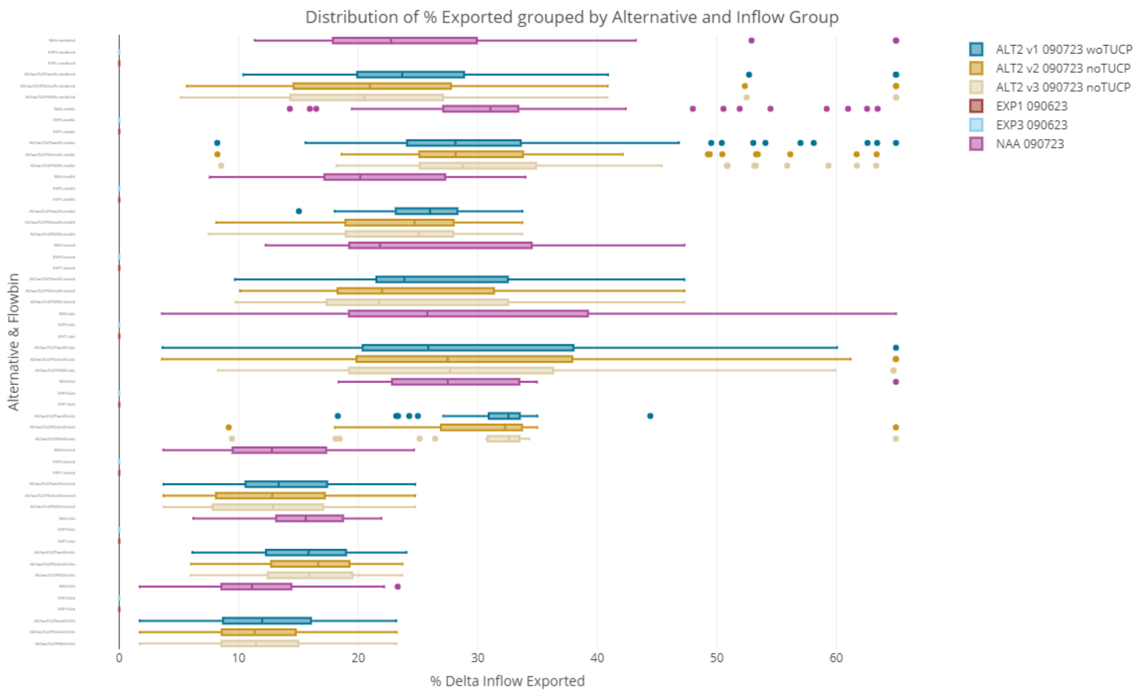
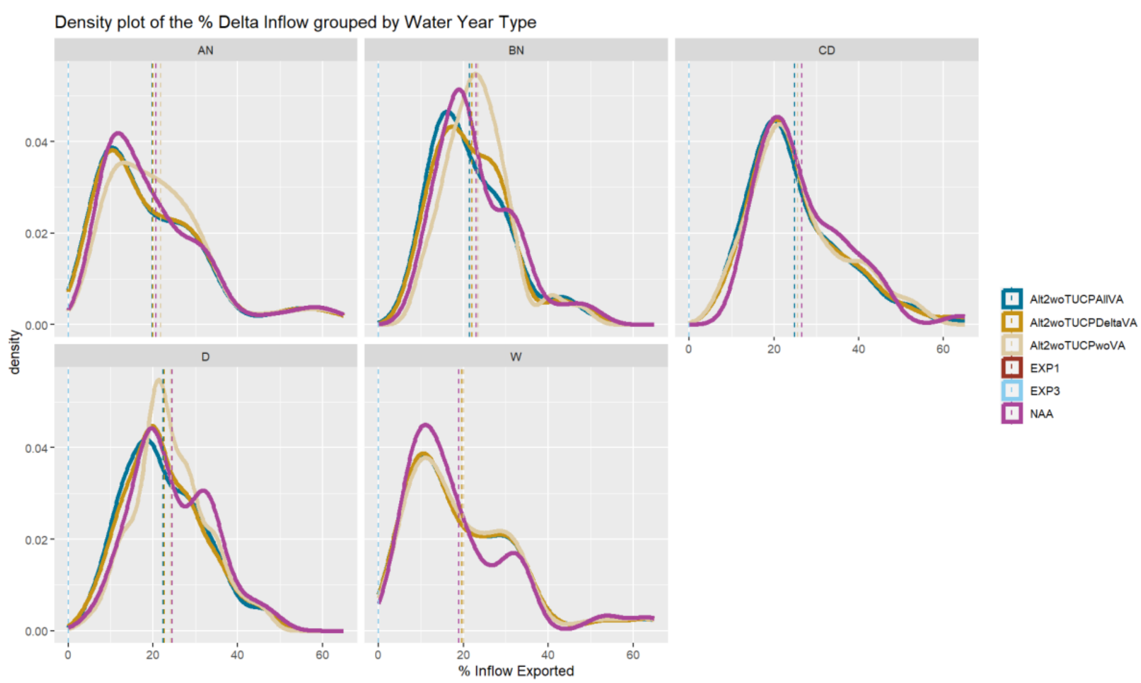
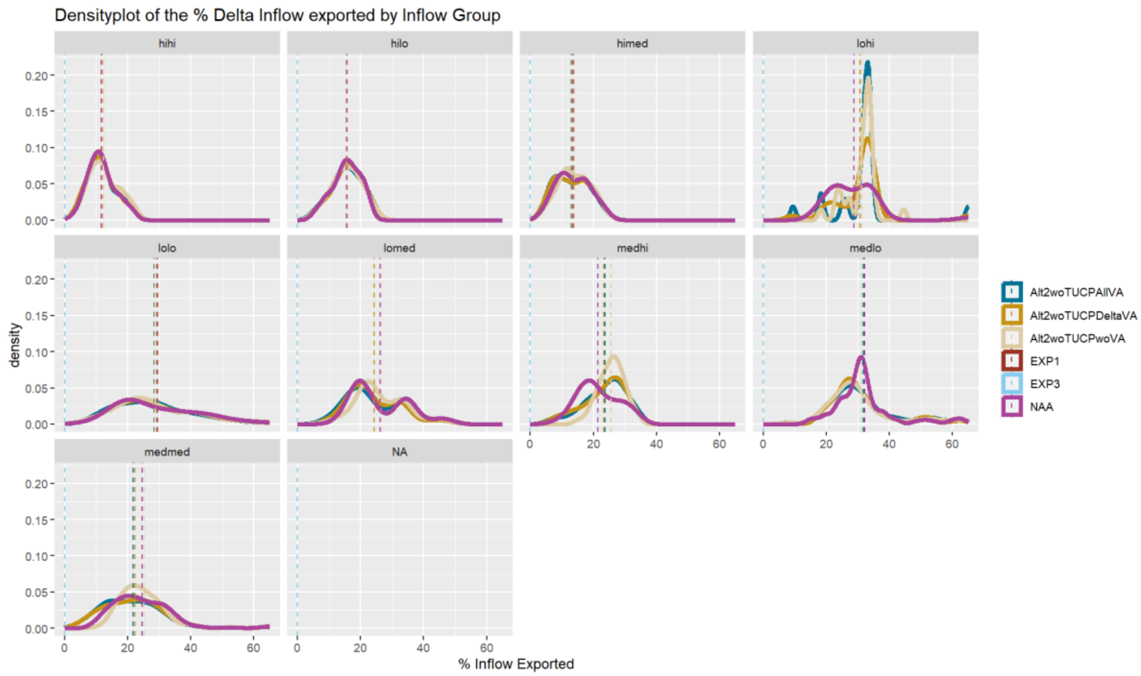


Figure I.6-10. Box plot of the full distribution of each alternatives' percent delta inflow exported from all years grouped by alternative and inflow group.



Each kernel density distribution is based on the default bandwidth specified in ggplot2 (geom_density).

Figure I.6-11. Kernel density estimate of each alternative's monthly percent delta inflow grouped by water year type.



Each kernel density distribution is based on the default bandwidth specified in ggplot2 (geom_density).

Figure I.6-12. Kernel density estimate of percent delta inflow exported for all years grouped by delta inflow groups.