UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
West Coast Region
650 Capitol Mall, Suite 5-100
Sacramento, California 95814-4700

May 15, 2019

Mr. Jeff Rieker
Operations Manager
U.S. Bureau of Reclamation
Central Valley Operations Office
3310 El Camino Avenue, Suite 300
Sacramento, California 95821

Re: 2019 Final Sacramento River Temperature Management Plan

Dear Mr. Rieker:

Thank you for your April 16, 2019, letter transmitting the April forecast and temperature model runs, and the May 13, 2019, letter transmitting the 2019 Final Sacramento River Temperature Management Plan (SRTMP), pursuant to reasonable and prudent alternative (RPA) Actions I.2.3 and I.2.4, respectively, described in NOAA's National Marine Fisheries Service's (NMFS) biological opinion (issued June 4, 2009) on the long-term operations of the Central Valley Project and State Water Project (CVP/SWP Opinion) [1]. RPA Action I.2.3 requires updates of water delivery commitments based on monthly forecasts at least as conservative as the 90 percent probability of exceedance. The U.S. Bureau of Reclamation (Reclamation) is required to submit an SRTMP to NMFS for concurrence, and by May 15, Reclamation is required to submit a final Temperature Management Plan to meet the State Water Resources Control Board Order 90-5 requirements using the Sacramento River Temperature Task Group (SRTTG). The SRTMP is required to meet a daily average water temperature (DAT) not in excess of 56°F at a compliance location between Balls Ferry and Bend Bridge from May 15 through September 30 for protection of Sacramento River winter-run Chinook salmon (winter-run, *Oncorhynchus tshawytscha*), and not in excess of 56°F DAT at the same compliance location from October 1 through October 31 for protection of Central Valley spring-run Chinook salmon (*O. tshawytscha*), whenever possible. The objective of RPA Action I.2.4 is to manage the cold water storage within Shasta Reservoir and make cold water releases from Shasta Reservoir to provide suitable habitat temperatures for winter-run Chinook salmon, spring-run Chinook salmon, California Central Valley steelhead (*O. mykiss*), and the Southern distinct population segment of North American green sturgeon (*Acipenser medirostris*) in the Sacramento River between Keswick Dam and Bend Bridge, while retaining sufficient carryover storage to manage for next year's cohorts.

During and since the 2012-2016 drought, the cohort replacement rate for winter-run indicated an overall population decline (Figure 1). Juvenile winter-run from brood years 2014 and 2015 had

[1] The 2009 RPA was amended on April 7, 2011, and can be found at http://www.westcoast.fisheries.noaa.gov/publications/Central_Valley/Water%20Operations/Operations,%20Criteria%20and%20Plan/040711_ocap_opinion_2011_amendments.pdf.

very poor survival due to drought conditions and unfavorable temperatures on the spawning grounds. Adults returning in 2017 were the progeny from 2014. In 2014, Livingston Stone National Fish Hatchery tripled production to supplement anticipated poor survival of fish spawning in-river. Winter-run eggs that were spawned in-river suffered high mortality. Not surprisingly, as a result, brood year 2017 had a high proportion of hatchery returns. Despite the lower adult returns in 2017 (estimated to be 1,155), juvenile winter-run survival of the 2017 brood year was relatively high as a result of favorable hydrology, a large cold water pool in Shasta Reservoir, and the implementation of a pilot study to provide additional thermal protections for winter-run. This pilot study included a temperature target closer to actual redd locations and management of flows in the fall to minimize the potential for dewatering of winter-run redds. Likewise, adults in brood year 2018 had a high proportion of hatchery returns, as a result of twice the typical production of juvenile hatchery winter-run in 2015.

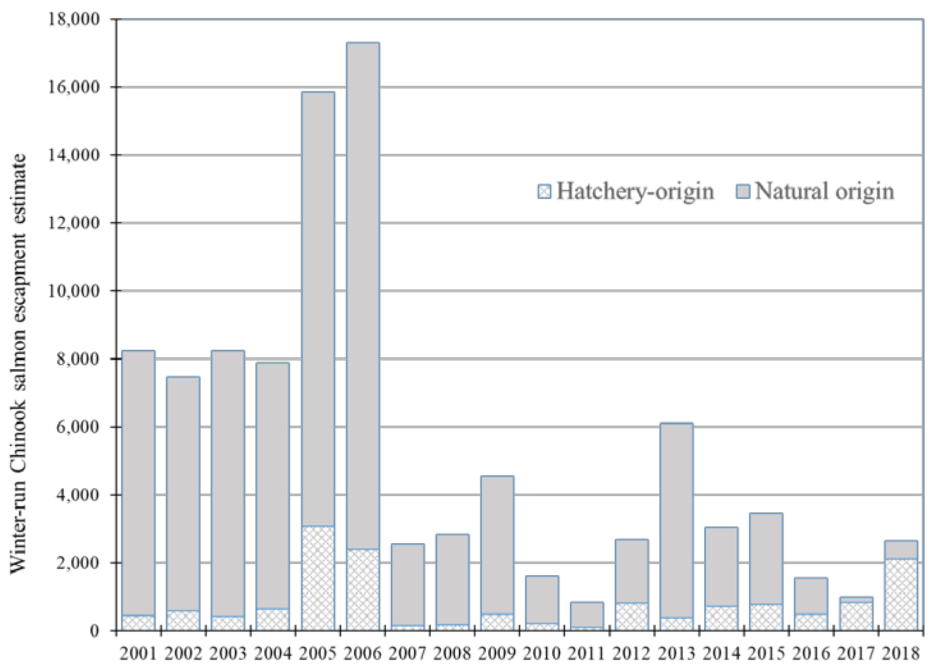

Figure 1. Winter-run Chinook salmon escapement from 2001-2018, with proportion hatchery origin and natural origin.

Reclamation has implemented pilot operations beginning in 2016 to determine the operational feasibility of colder water temperature criteria at the CCR California Data Exchange Center temperature gage station just upstream of the confluence of Clear Creek, a more upstream location closer to actual redd locations. In 2016, Reclamation operated to 55.0°F 7-day average of the daily maximum (7DADM) temperatures at CCR; in 2017, Reclamation operated to 53.0°F DAT at CCR; and in 2018, Reclamation operated to 53.5°F DAT at CCR (Figure 2). The pilot operations also included management of flows in the fall to minimize the potential for dewatering of winter-run redds.

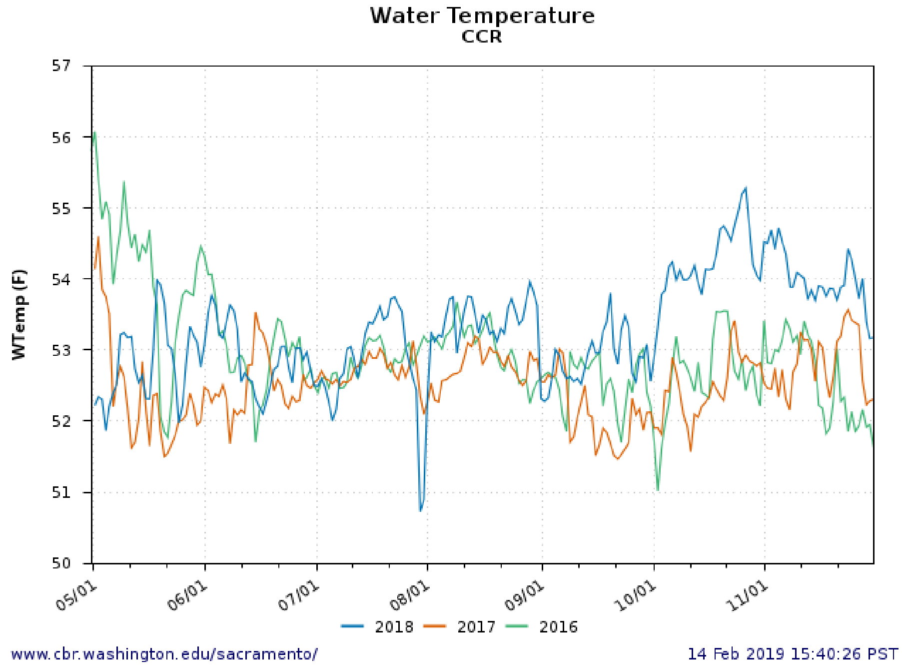

Figure 2. Water temperatures at the CCR California Data Exchange Center gaging station in 2016-2018. Source: www.cbr.washington.edu/sacramento/.

On April 16, 2019, Reclamation provided NMFS with updated CVP operational outlooks at the 50 percent and 90 percent exceedance hydrologic forecasts for April, and associated temperature modeling results using the 90 percent exceedance hydrologic forecast and 25 percent meteorological conditions, and a Shasta Reservoir profile from April 9, 2019.

On April 25, 2019, Reclamation convened an SRTTG meeting to share the modeling results and discuss formulating the development of the 2019 Sacramento River Temperature Management Plan. Among the handouts were the updated CVP operational outlooks at the 50 percent and 90 percent exceedance hydrologic forecasts for April, and associated temperature modeling results using the 90 percent exceedance hydrologic forecast and 25 percent meteorological conditions, and a Shasta Reservoir profile from April 9, 2019.

On May 13, 2019, Reclamation submitted its SRTMP to NMFS and requested concurrence that it was consistent with RPA Action I.2.4 in NMFS' CVP/SWP Opinion. Reclamation's transmittal included the same CVP operational outlooks at the 50 percent and 90 percent exceedance hydrologic forecasts for April, but the associated temperature modeling results using the 90 percent exceedance hydrologic forecast and 25 percent meteorological conditions utilized an updated Shasta Reservoir profile from April 23, 2019 (enclosure 1). In summary, Reclamation's plan consists of:

- A 56°F DAT temperature compliance point at Balls Ferry from May 15 through October 31.

- An evaluation study that will target 53.5°F DAT at CCR during the same time frame. This acts as a surrogate location for the most downstream winter-run redd.

- Reclamation will monitor the cold-water-pool projections and compare to actual performance. The primary "off-ramp" criterion is defined as a deficient cold-water-pool volume less than 49°F which deviates more than 10 percent projected. If the "off-ramp" conditions are met and/or other indicators warrant, as discussed by the SRTTG, then the evaluation study will conclude and operations will revert to the compliance location at Balls Ferry using 56°F DAT metric for the remainder of the season to protect fall temperatures.

- Ongoing modeling results will be completed for each monthly SRTTG meeting, and more often as necessary (potentially as frequently as every 2 weeks, or upon NMFS request).

- As in past years, Reclamation will work with NMFS and the other members of the SRTTG during fall operations to address the potential for redd dewatering.

<u>Summary and Expectations</u>

The following are NMFS' summary conclusions and expectations based on Reclamation's proposed SRTMP:

- NMFS has reviewed Reclamation's proposed SRTMP. Within the range of hydrologic and meteorological scenarios modeled, the SRTMP is expected to provide generally suitable water temperatures for incubating winter-run eggs and fry in brood year 2019. The NMFS-Southwest Fisheries Science Center (SWFSC) ran the four scenarios through the temperature-dependent egg mortality model. Results are provided in enclosure 2, and summarized in Table 1.

Table 1.a. Temperature-dependent egg mortality using outputs from the HEC-5Q model.

April 2019 Hydrological Exceedance Forecast	Meteorological Exceedance Forecast	Percent Temperature-Dependent Egg Mortality-Mean	Percent Temperature-Dependent Egg Mortality-Median	Percent Temperature-Dependent Egg Mortality- 95% Confidence Intervals
50%	25%	8.51%	1.26%	0.08 – 52.15%
50%	50%	8.35%	0.38%	0.08 – 53.46%
90%	25%	8.11%	0.69%	0.08 – 51.49%
90%	50%	9.48%	0.88%	0.08 – 55.18%

Table 1.b. Temperature-dependent egg mortality using outputs from the River Assessment Forecast Temperature model.

April 2019 Hydrological Exceedance Forecast	Meteorological Exceedance Forecast	Percent Temperature-Dependent Egg Mortality-Mean	Percent Temperature-Dependent Egg Mortality-Median	Percent Temperature-Dependent Egg Mortality- 95% Confidence Intervals
50%	25%	9.17%	1.5%	0.08 – 53.6%
50%	50%	10.69%	1.7%	0.08 – 57.35%
90%	25%	9.57%	1.88%	0.08 – 54.37%
90%	50%	9.42%	0.88%	0.08 – 55.6%

- NMFS expects temperature modeling to be conducted and results distributed to the SRTTG prior to their monthly meeting, as frequently as every 2 weeks, and upon NMFS' request.

- If the "off-ramp" conditions are met, or other indicators warrant, then the evaluation study will conclude and operations will revert to the temperature compliance location at Balls Ferry using 56.0°F DAT metric for the remainder of the season.

- Reclamation will operate in a manner to avoid any exceedance of 56.0°F DAT at Balls Ferry, and Reclamation will promptly implement steps to reduce the temperature to the compliance criterion to deal with any unforeseen transitions to periods of high air temperatures.

- NMFS expects the timing for reductions in flows in September and October will be scheduled in coordination with the fish agencies to reduce the risk of dewatering existing winter-run or spring-run Chinook salmon redds, and to discourage, to the extent possible, the spawning of fall-run Chinook salmon redds in areas that could be dewatered when Keswick releases are reduced further later in the year.

- NMFS expects Reclamation to implement the following monthly average Keswick release schedule (in cubic feet per second). Should Reclamation need to change the monthly average Keswick release schedule, NMFS expects close coordination between our agencies to ensure that the habitat needs (i.e., cold water, stable flows) of winter-run continue to be met. In addition, NMFS will work with Reclamation on real-time management during the temperature management season.

Table 2. Keswick monthly average release schedule (in cubic feet per second).

Exceedance	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb
90%	8,500	10,500	12,000	12,000	9,000	7,000	5,000	4,500	4,000	4,000
50%	8,500	10,000	11,500	13,000	9,500	7,000	6,000	5,000	8,000	8,000

In conclusion, NMFS concurs that Reclamation's proposed SRTMP is consistent with RPA Action I.2.4. We are making this finding based on Reclamation's May 13, 2019, letter and enclosures, our understanding of the water temperature needs of winter-run, and our conclusion that the potential effects of implementing the Sacramento River temperature management plan in water year 2019 were considered in the underlying analysis of the CVP/SWP Opinion. Furthermore, the best available scientific and commercial data indicate that implementation of the Sacramento River temperature management plan will not exceed levels of take anticipated for implementation of the RPA specified in the CVP/SWP Opinion.

We look forward to continued close coordination with you and your staff throughout this water year.

If you have any questions regarding this letter, contact Garwin Yip at garwinyip@noaa.gov, or 916-930-3611, or me at maria.rea@noaa.gov or (916) 930-3600.

Sincerely,

Maria Rea
Assistant Regional Administrator

Enclosures:

1. Reclamation's April CVP operations outlooks and associated temperature modeling results in support of its Sacramento River Temperature Management Plan

2. NMFS-SWFSC's temperature-dependent egg mortality model results from the scenarios provided in Reclamation's Sacramento River Temperature Management Plan

cc: Copy to file: ARN #151422SWR2006SA00268

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Enclosure 1

Estimated CVP Operations 90% Exceedance
65% Ag, 90% M

Storages

Federal End of the Month Storage/Elevation (TAF/Feet)

			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Trinity		**1932**	**2061**	**2153**	**2176**	**2059**	**1906**	**1786**	**1754**	**1735**	**1744**	**1776**	**1861**	**1938**
	Elev.		2345	2351	2353	2345	2334	2326	2323	2322	2322	2325	2331	2337
Whiskeytown		**216**	**238**	**238**	**238**	**238**	**238**	**238**	**206**	**206**	**206**	**206**	**206**	**206**
	Elev.		1209	1209	1209	1209	1209	1209	1199	1199	1199	1199	1199	1199
Shasta		**4028**	**4235**	**4328**	**4082**	**3653**	**3192**	**2896**	**2719**	**2684**	**2737**	**2888**	**3193**	**3622**
	Elev.		1056	1059	1051	1035	1016	1003	995	993	996	1003	1016	1033
Folsom		**735**	**871**	**932**	**966**	**852**	**667**	**611**	**522**	**443**	**382**	**383**	**444**	**593**
	Elev.		456	462	465	454	436	430	419	409	400	400	409	428
New Melones		**2001**	**1890**	**1931**	**1961**	**1897**	**1824**	**1780**	**1731**	**1736**	**1744**	**1748**	**1755**	**1689**
	Elev.		1042	1046	1049	1043	1036	1032	1027	1027	1028	1029	1029	1023
San Luis		**965**	**830**	**591**	**419**	**190**	**59**	**49**	**-44**	**66**	**278**	**431**	**525**	**651**
	Elev.		519	481	451	432	423	411	381	397	435	460	473	487
Total			10125	10172	9843	8889	7886	7360	6888	6869	7091	7432	7983	8698

Monthly River Releases (TAF/cfs)

		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Trinity	TAF	136	197	133	66	53	52	23	18	18	18	17	18
	cfs	**2,286**	**3,204**	**2,235**	**1,073**	**857**	**870**	**373**	**300**	**300**	**300**	**300**	**300**
Clear Creek	TAF	13	13	17	9	9	9	12	12	12	12	11	12
	cfs	**218**	**216**	**288**	**150**	**150**	**150**	**200**	**200**	**200**	**200**	**200**	**200**
Sacramento	TAF	892	523	625	738	738	535	430	297	277	246	222	246
	cfs	**15000**	**8500**	**10500**	**12000**	**12000**	**9000**	**7000**	**5000**	**4500**	**4000**	**4000**	**4000**
American	TAF	446	369	238	223	286	149	123	119	123	111	100	92
	cfs	**7500**	**6000**	**4000**	**3634**	**4653**	**2500**	**2000**	**2000**	**2000**	**1800**	**1800**	**1500**
Stanislaus	TAF	222	123	65	26	25	24	52	18	18	22	20	101
	cfs	**3734**	**2001**	**1100**	**429**	**400**	**400**	**842**	**300**	**300**	**358**	**364**	**1648**

Trinity Diversions (TAF)

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Carr PP	30	17	45	100	101	70	18	21	12	3	2	35
Spring Crk. PP	**10**	**10**	**30**	**90**	**90**	**60**	**40**	**15**	**12**	**10**	**20**	**50**

Delta Summary (TAF)

		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Tracy		77	61	255	268	268	229	60	187	270	220	200	258
USBR Banks		0	0	0	26	26	26	0	0	0	0	0	0
Contra Costa		12.7	12.7	9.8	11.1	12.7	14.0	16.8	18.4	18.3	14.0	14.0	12.7
Total USBR		89	74	265	305	307	269	77	205	288	234	214	271
COA Balance		0	0	0	0	0	0	0	0	0	0	0	0
Old/Middle River Std.													
Old/Middle R. calc.		1,505	929	-5,149	-8,463	-8,050	-5,134	-1,656	-5,003	-6,611	-4,903	-5,045	-5,033
Computed DOI		62817	27134	12305	8004	10004	13784	12282	5850	6946	11891	11545	13941
Excess Outflow		35384	7694	303	0	0	773	878	0	2440	5889	144	2538
% Export/Inflow		3%	6%	32%	48%	43%	29%	13%	47%	54%	36%	37%	34%
% Export/Inflow std.		35%	35%	35%	65%	65%	65%	65%	65%	65%	65%	45%	35%

Hydrology

	Trinity	Shasta	Folsom	New Melones
Water Year Inflow (TAF)	1506	6,804	3,598	1483
Year to Date + Forecasted — % of mean	125%	123%	132%	140%

CVP actual operations do not follow any forecasted operation or outlook; actual operations are based on real-time conditions.
CVP operational forecasts or outlooks represent general system-wide dynamics and do not necessarily address specific watershed/tributary details.
CVP releases or export values represent monthly averages.
CVP Operations are updated monthly as new hydrology information is made available December through May.

4/12/2019

Estimated CVP Operations 50% Exceedance

Storages

Federal End of the Month Storage/Elevation (TAF/Feet)

			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Trinity		**1932**	**2070**	**2227**	**2269**	**2158**	**2012**	**1875**	**1849**	**1836**	**1863**	**1927**	**2037**	**2121**
	Elev.		2346	2356	2359	2352	2342	2332	2330	2329	2331	2336	2343	2349
Whiskeytown		**216**	**238**	**238**	**238**	**238**	**238**	**238**	**206**	**206**	**206**	**206**	**206**	**206**
	Elev.		1209	1209	1209	1209	1209	1209	1199	1199	1199	1199	1199	1199
Shasta		**4028**	**4235**	**4448**	**4301**	**3947**	**3464**	**3198**	**3036**	**2995**	**3081**	**3195**	**3513**	**3773**
	Elev.		1056	1063	1058	1046	1027	1016	1009	1008	1011	1016	1029	1039
Folsom		**735**	**841**	**927**	**938**	**904**	**715**	**704**	**625**	**595**	**584**	**581**	**593**	**750**
	Elev.		453	461	462	459	441	440	431	428	427	426	428	444
New Melones		**2001**	**1898**	**1998**	**2090**	**2034**	**1980**	**1945**	**1901**	**1912**	**1929**	**1954**	**2000**	**1969**
	Elev.		1043	1052	1060	1055	1050	1047	1043	1044	1046	1048	1052	1049
San Luis		**965**	**868**	**644**	**451**	**212**	**74**	**91**	**85**	**118**	**317**	**481**	**601**	**724**
	Elev.		520	481	452	434	415	425	407	399	434	462	475	488
Total			10150	10482	10288	9492	8482	8052	7701	7662	7980	8344	8949	9543

Monthly River Releases (TAF/cfs)

		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Trinity	TAF	136	197	133	66	53	52	23	18	18	18	17	18
	cfs	**2,286**	**3,204**	**2,235**	**1,073**	**857**	**870**	**373**	**300**	**300**	**300**	**300**	**300**
Clear Creek	TAF	13	13	17	9	9	9	12	12	12	15	11	12
	cfs	**218**	**216**	**288**	**150**	**150**	**150**	**200**	**200**	**200**	**240**	**200**	**200**
Sacramento	TAF	892	523	595	707	799	565	430	357	307	492	444	615
	cfs	**15000**	**8500**	**10000**	**11500**	**13000**	**9500**	**7000**	**6000**	**5000**	**8000**	**8000**	**10000**
American	TAF	476	553	357	184	297	119	154	119	123	154	250	154
	cfs	**8000**	**9000**	**6000**	**3000**	**4835**	**2000**	**2500**	**2000**	**2000**	**2500**	**4500**	**2500**
Stanislaus	TAF	222	123	65	61	25	24	52	18	18	22	20	101
	cfs	**3734**	**2001**	**1100**	**1000**	**400**	**400**	**842**	**300**	**300**	**358**	**364**	**1648**

Trinity Diversions (TAF)

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Carr PP	21	9	41	99	100	89	13	25	12	0	2	45
Spring Crk. PP	**10**	**10**	**30**	**90**	**90**	**80**	**35**	**20**	**15**	**20**	**35**	**70**

Delta Summary (TAF)

		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Tracy		122	86	258	270	268	258	149	114	260	235	230	260
USBR Banks		0	0	0	31	31	31	0	0	0	0	0	0
Contra Costa		12.7	12.7	9.8	11.1	12.7	14.0	16.8	18.4	18.3	14.0	14.0	12.7
Total USBR		134	99	268	312	312	303	166	132	278	249	244	273
COA Balance		0	0	0	0	0	0	0	0	0	0	0	0
Old/Middle River Std.													
Old/Middle R. calc.		2,773	1,589	-5,753	-8,895	-7,687	-8,189	-3,006	-2,805	-6,532	-4,971	-4,975	-5,068
Computed DOI		72500	41921	17566	8313	12998	12271	12819	11397	10183	20415	26853	32307
Excess Outflow		45066	16153	1412	309	0	874	1415	0	5677	14413	15453	20903
% Export/Inflow		4%	5%	29%	49%	37%	42%	22%	23%	45%	25%	21%	19%
% Export/Inflow std.		35%	35%	35%	65%	65%	65%	65%	65%	65%	65%	45%	35%

Hydrology

	Trinity	Shasta	Folsom	New Melones
Water Year Inflow (TAF)	1592	7,119	3,967	1661
Year to Date + Forecasted % of mean	132%	129%	146%	157%

CVP actual operations do not follow any forecasted operation or outlook; actual operations are based on real-time conditions.
CVP operational forecasts or outlooks represent general system-wide dynamics and do not necessarily address specific watershed/tributary details.
CVP releases or export values represent monthly averages.
CVP Operations are updated monthly as new hydrology information is made available December through May.

4/16/2019

April 24, 2019

Upper Sacramento River – April 2019 Preliminary Temperature Analysis

Summary of Temperature Results by Month (Monthly Average Temperature °F)

Location (°F DAT)	APR	MAY	JUN	JUL	AUG	SEP*	OCT*
April 90%-Exceedance Outlook – 25% L3MTO Meteorology							
Keswick Dam KWK	53.1	52.7	52.4	52.8	53.0	See Figures 1 and 5	See Figures 1 and 5
Sac. R. abv Clear Creek CCR	53.4	53.4	53.1	53.3	53.4	See Figures 1 and 6	See Figures 1 and 6
Balls Ferry BSF	55.6	57.2	55.9	55.5	55.1	See Figures 1 and 7	See Figures 1 and 7
April 90%-Exceedance Outlook – 50% L3MTO Meteorology							
Keswick Dam KWK	52.8	52.5	52.7	52.9	52.8	See Figures 2 and 5	See Figures 2 and 5
Sac. R. abv Clear Creek CCR	52.7	53.1	53.1	53.5	53.2	See Figures 2 and 6	See Figures 2 and 6
Balls Ferry BSF	53.7	56.3	55.3	55.6	54.8	See Figures 2 and 7	See Figures 2 and 7

Location (°F DAT)	APR	MAY	JUN	JUL	AUG	SEP*	OCT*
April 50%-Exceedance Outlook – 25% L3MTO Meteorology							
Keswick Dam KWK	53.4	52.7	52.4	52.9	52.9	See Figures 3 and 5	See Figures 3 and 5
Sac. R. abv Clear Creek CCR	53.9	53.4	53.0	53.5	53.3	See Figures 3 and 6	See Figures 3 and 6
Balls Ferry BSF	56.3	57.2	56.0	55.7	54.8	See Figures 3 and 7	See Figures 3 and 7
April 50%-Exceedance Outlook – 50% L3MTO Meteorology							
Keswick Dam KWK	53.1	52.8	52.4	52.9	53.0	See Figures 4 and 5	See Figures 4 and 5
Sac. R. abv Clear Creek CCR	53.0	53.4	52.9	53.5	53.3	See Figures 4 and 6	See Figures 4 and 6
Balls Ferry BSF	54.0	56.6	55.2	55.7	54.8	See Figures 4 and 7	See Figures 4 and 7

Model Run	End of September Cold Water Pool <56°F (TAF)	First Side Gate	Full Side Gates
90% Hydro, 25% Met	716	9/22	11/1
90% Hydro, 50% Met	903	10/3	11/28
50% Hydro, 25% Met	707	9/20	10/31
50% Hydro, 50% Met	944	10/5	11/27

Model Run Date April 24, 2019

* The HEC5Q model output is displayed above for the months April through August. Based on past analysis, the temperature model does not perform well in late September and October. One factor is that the modeled release temperatures are cooler than has historically been achieved when all release is through the side gates (lowest gates), especially when there's a large temperature gradient between the pressure relief gates (PRG) and the side gates.

For the months of September and October, ranges in possible outcomes are illustrated with the Fall Temperature Index (graphics above Figures 5-7). This relationship is an end of September Lake Shasta Volume less than 56°F and likely downstream temperature performance for the early fall months. Estimated temperatures for September and October may fall into a range indicated within the Fall Temperature Index (graphical chart), illustrating historical performance. However, this range should be viewed as an element of uncertainty based on past performance, not a simulation or projection of temperature management operations or results.

Temperature Analysis Results:
Modeling runs explore Sacramento River compliance performance above Clear Creek confluence and Balls Ferry locations by varying hydrology and meteorology. The temperature results for the Sacramento River between Keswick Dam and Balls Ferry are shown in Figures 1 through 4. The relationship between end-of-September lake volume below 56°F and a downstream Sacramento River compliance location through fall is based on the Figures 5-7.

Temperature Model Inputs, Assumptions, Limitations and Uncertainty:
1. The latest available profiles for Shasta, Trinity, and Whiskeytown were taken on April 23, April 10, and April 9, respectively. Model results are sensitive to initial reservoir temperature conditions and the model performs best under highly stratified conditions. The April 2019 temperature profile does not yet exhibit conditions for ideal model computations (still nearly isothermal conditions). The model performs well after the reservoir stratifies, typically in late spring (i.e. end of April). The concern this year is assuming over or under estimations with variable hydrologic and meteorological conditions and not capturing the stratification with sufficient

detail to project into the future with confidence.
2. Guidance on forecasted flows from the creeks (e.g., Cow, Cottonwood, Battle, etc.) between Keswick Dam and Bend Bridge are not available beyond 5 days. Creek flows developed from the historical record that most closely reflects current conditions were used for all model runs. The resulting creek flows cause significant additional warming in the upper Sacramento River during spring.
3. Operation is based on the April 2019 Operation Outlooks (monthly flows, reservoir release, and end-of-month reservoir storage) for the 90%- and 50%-exceedances, with minor modifications to accommodate for flood management. Trinity Lake inflows are updated with the CNRFC 90% runoff exceedance for the 90% and DWR Bulletin 120 for the 50% runoff exceedance studies.
4. Although mean daily flows and releases are temperature model inputs, they are based on the mean monthly values from the operation outlooks. Mean daily flow patterns are user defined and are generalized representations. It is important to note that these outlooks do not suggest a certain actual future outcome, but rather the statistical likelihood of an event occurring, including, but not limited to, projected storage and releases. Thus, the outlooks do not provide exact end of month storages or flow rates but general projections that will likely fall within the range of uncertainty based on the different hydrologic runoff conditions between the 90% and 50% runoff exceedance hydrology.
5. Cottonwood Creek flows, Keswick to Bend Bridge local flows, and ACID diversions are mean daily synthesized flows based on the available historical record for a 1922-2002 study period. Side-flows were adjusted to a 25% historical exceedance for both the 90% and 50% runoff exceedance studies.
6. Meteorological inputs represent historical (1985 – 2017) monthly mean equilibrium temperature exceedance at 25% and 50% patterned after like months on a 6-hour time-step (for months prior to April). Assumed inflows temperature remain static inputs and do not vary with the assumed meteorology. Tools to use local three-month-temperature outlooks, driven by the NOAA NWS Climate Prediction Center (CPC) are used beginning in April.
7. Meteorology, as well as the flow volume and pattern, significantly influences reservoir inflow temperatures and downstream tributary temperatures; and consequently, the development of the cold-water pool during winter and early spring, which is still uncertain prior to the end of April.
8. Modified model coefficients more closely represent actual Keswick Dam temperatures. As a result, temperature predictions downstream of Keswick Dam are likely to be warmer than actual.
9. The model is specifically being applied to generate the most accurate results at the Sacramento River above Clear Creek confluence location.

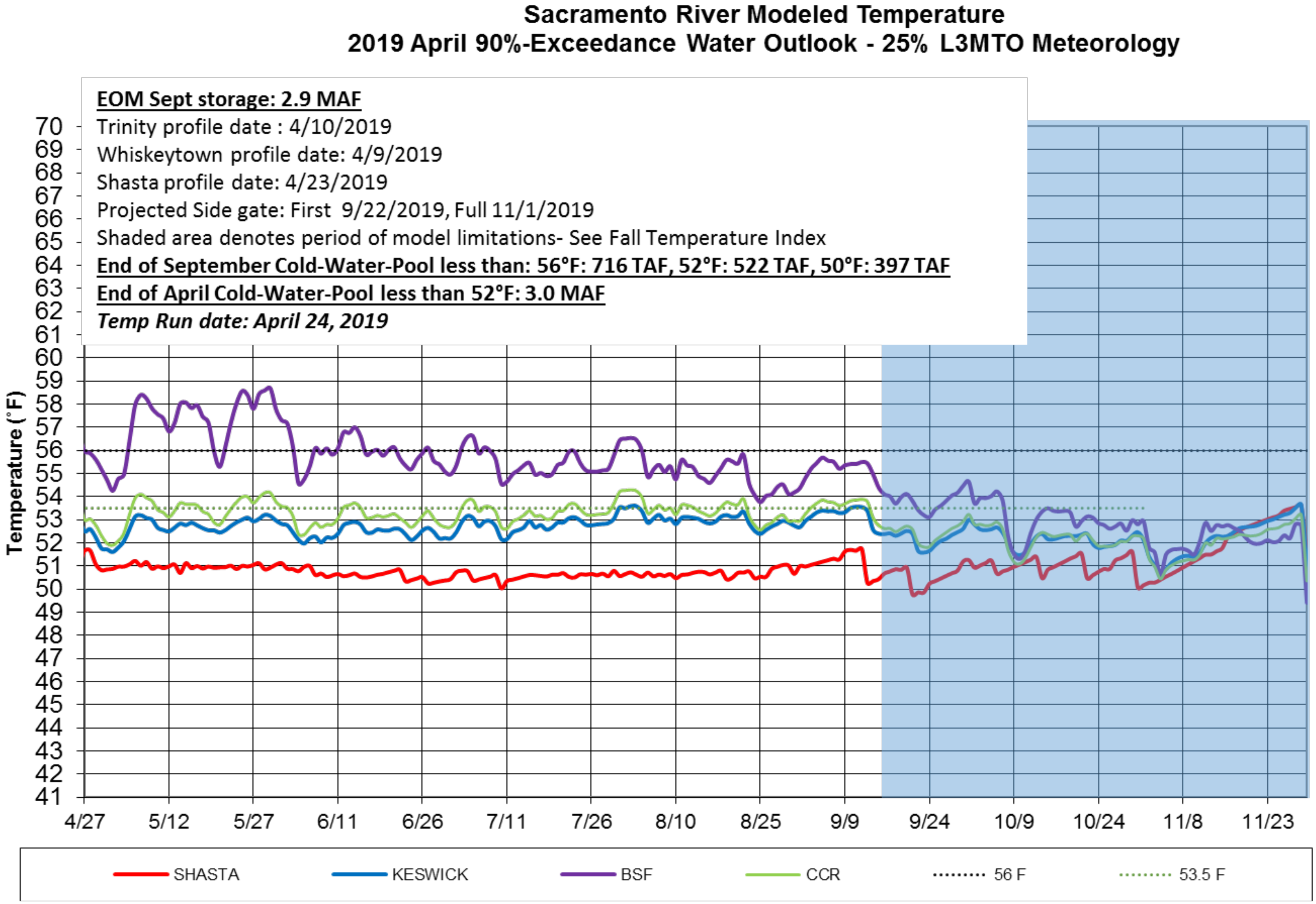

Figure 1. April 2019 simulated Sacramento River temperatures 90% runoff exceedance hydrology and 25% L3MTO meteorology.

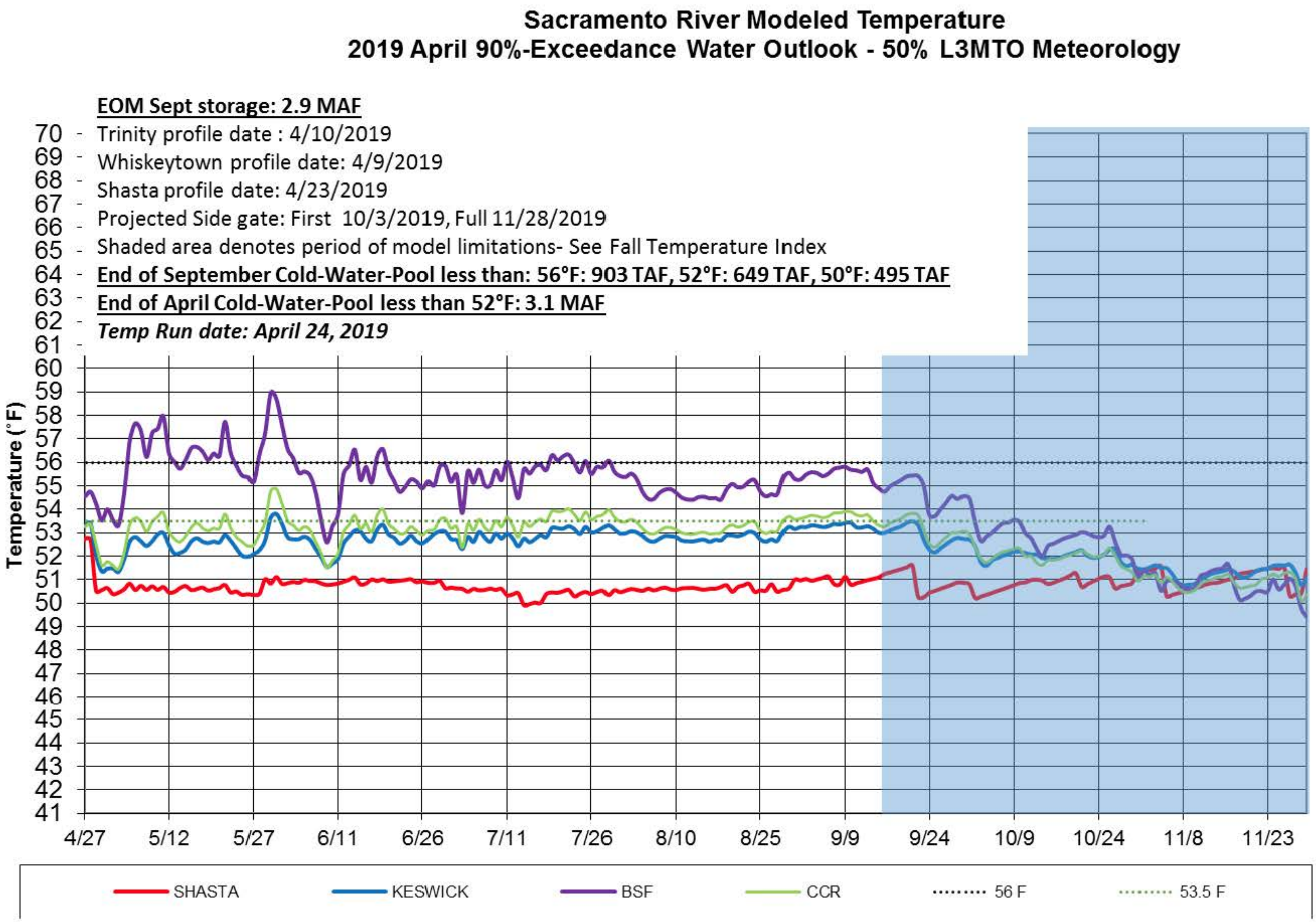

Figure 2. April 2019 simulated Sacramento River temperatures 90% runoff exceedance hydrology and 50% L3MTO meteorology.

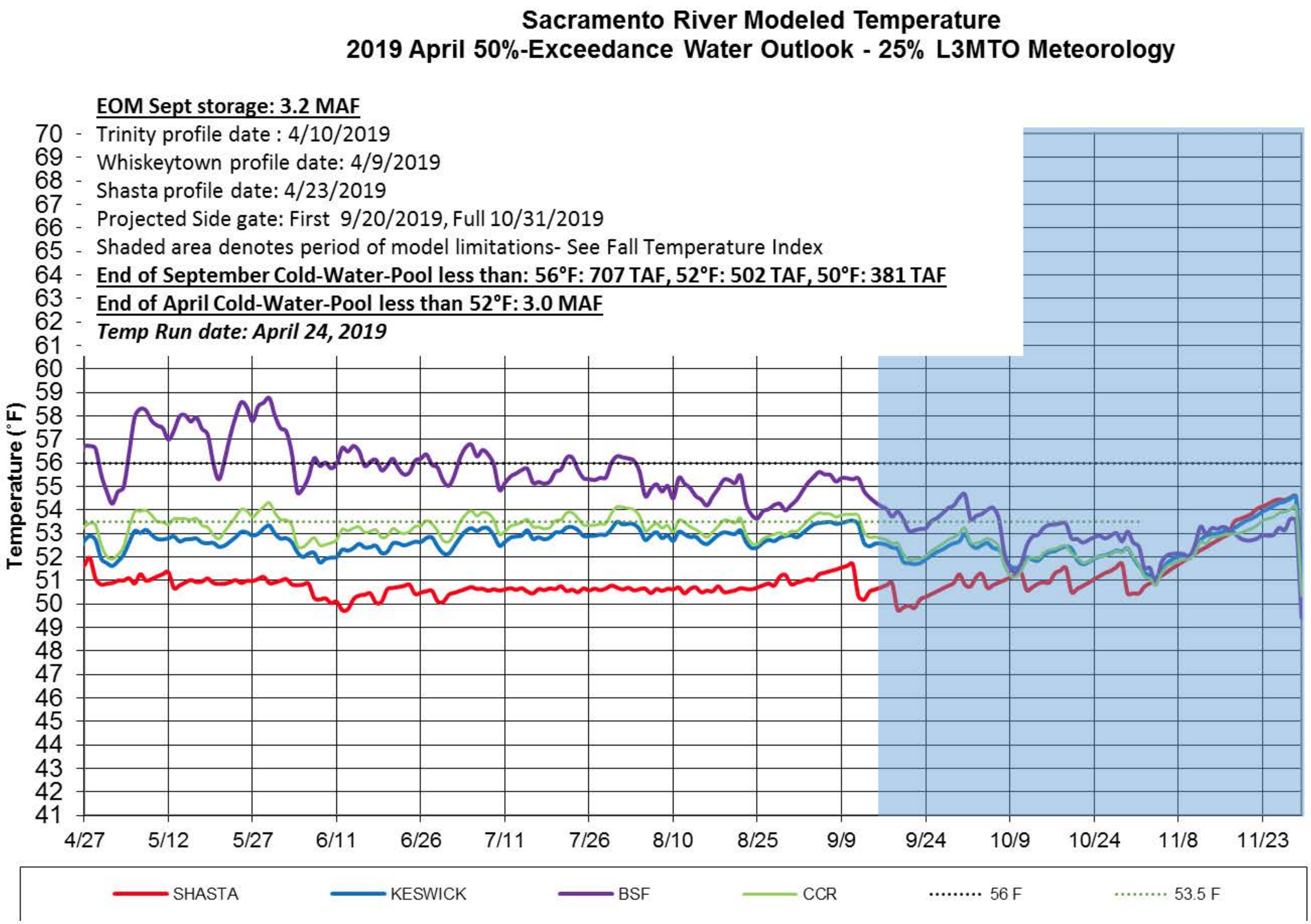

Figure 3. April 2019 simulated Sacramento River temperatures 50% runoff exceedance hydrology and 30% L3MTO meteorology.

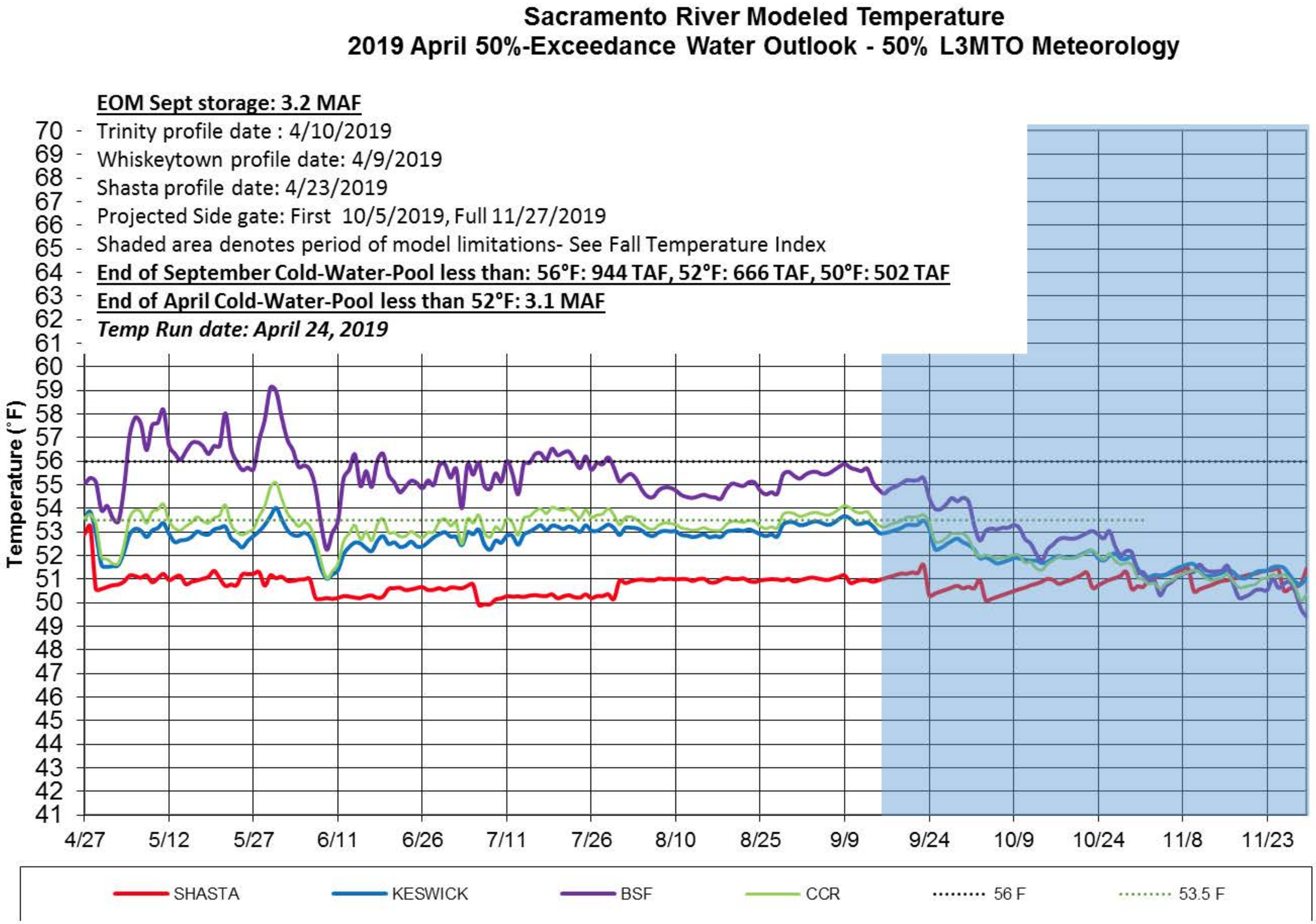

Figure 4. April 2019 simulated Sacramento River temperatures 50% runoff exceedance hydrology and 50% L3MTO meteorology

Figure 5-7 <u>Model Performance and Fall Temperature Index</u>:

1. Based on past analyses, the temperature model does not perform well in late September and October. One factor is that the modeled release temperatures are cooler than has historically been achieved when all release is through the side gates (lowest gates), especially when there's a large temperature gradient between the pressure relief gates (PRG) and the side gates.
2. Based on historical records, the end-of-September Lake Shasta volume below 56˚F is a good indicator of fall water temperature in the river reach to Balls Ferry.
3. Based on these records and estimates, the charts below illustrates a range of uncertainty in the expected river temperatures based on the end-of-September lake volume less than 56˚F.

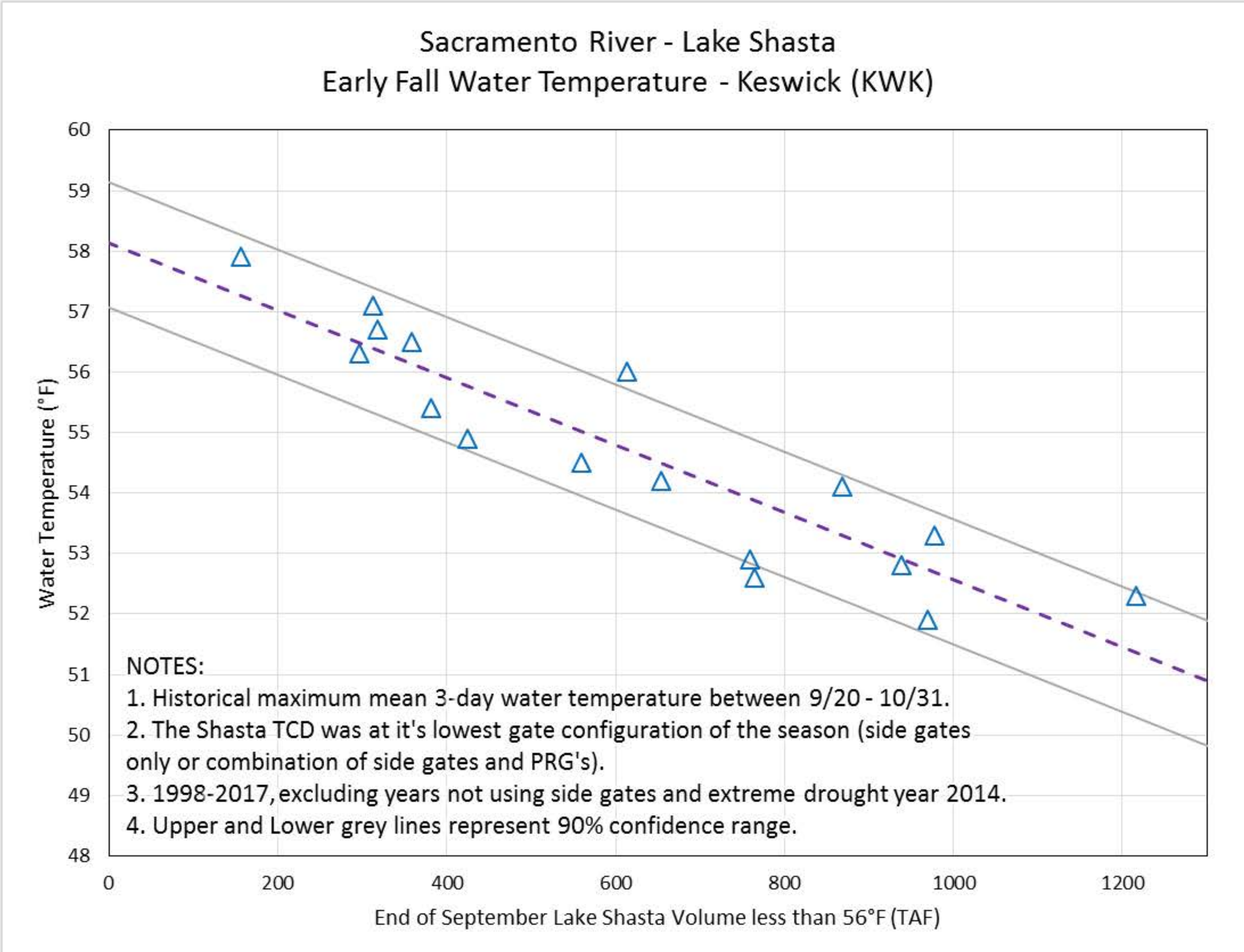

Figure 5. Historical relationship between Lake Shasta cold-water-pool characteristics and early fall Keswick water temperature.

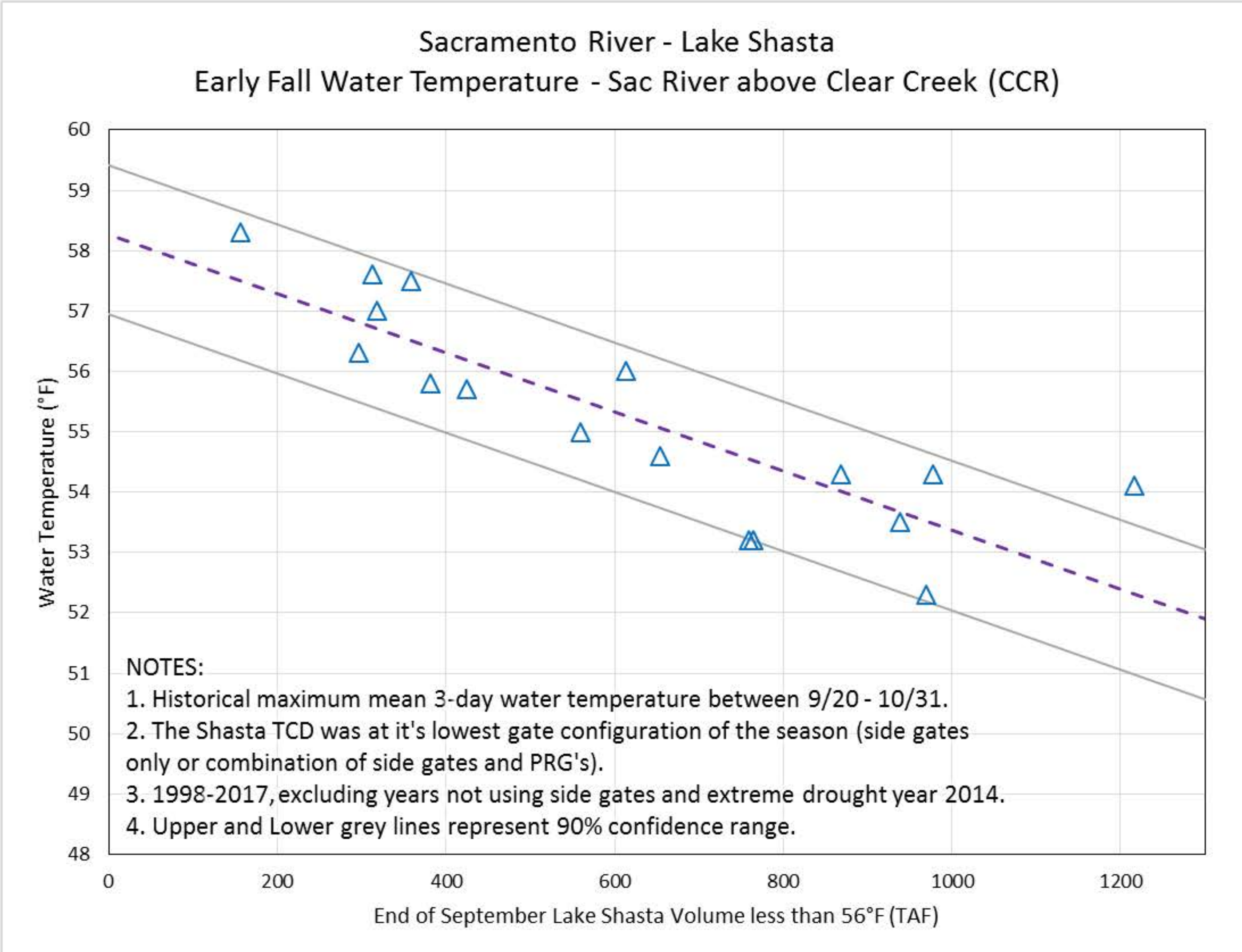

Figure 6. Historical relationship between Lake Shasta cold-water-pool characteristics and early fall Sacramento River above Clear Creek confluence water temperature.

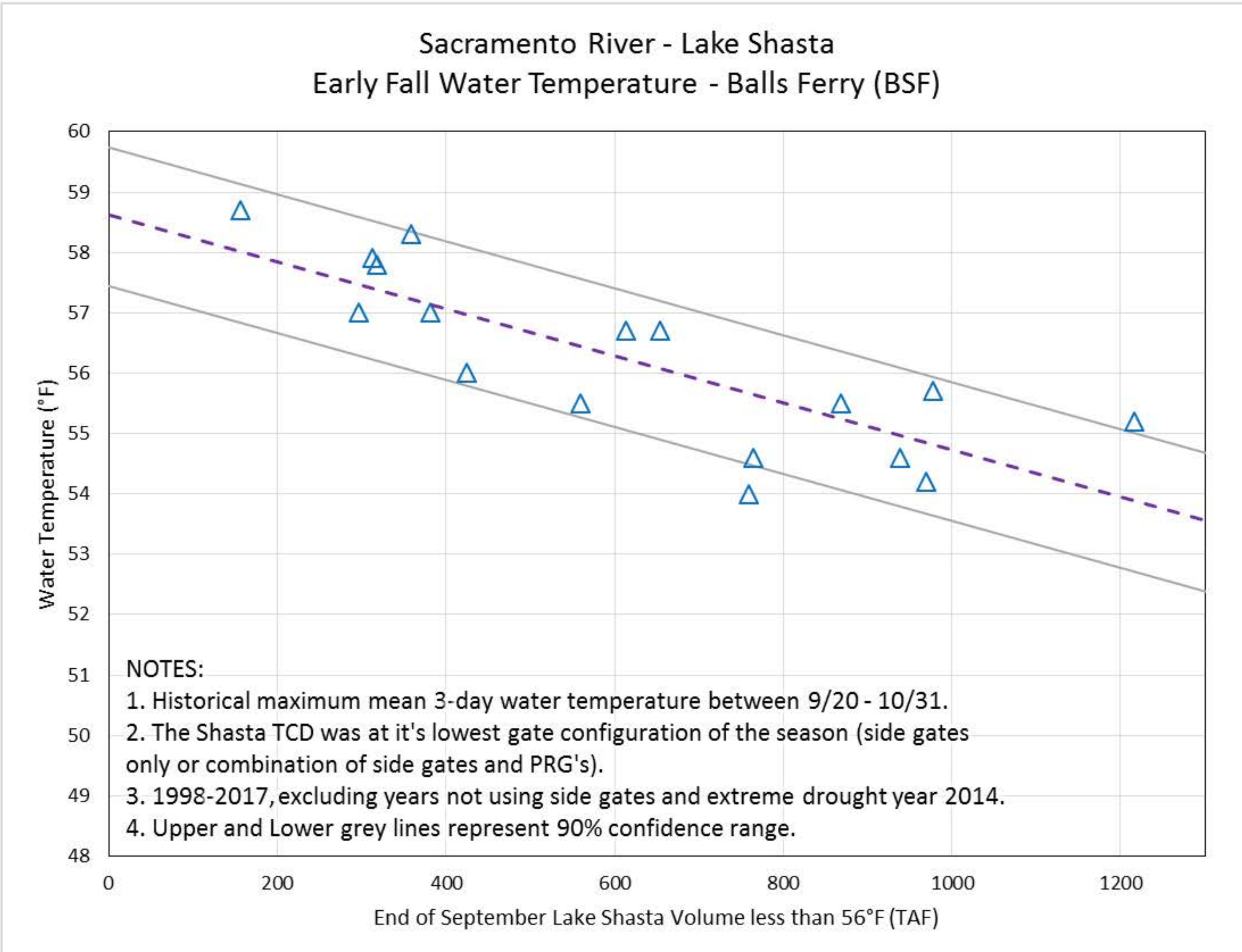

Figure 7. Historical relationship between Lake Shasta cold-water-pool characteristics and early fall Balls Ferry water temperature.

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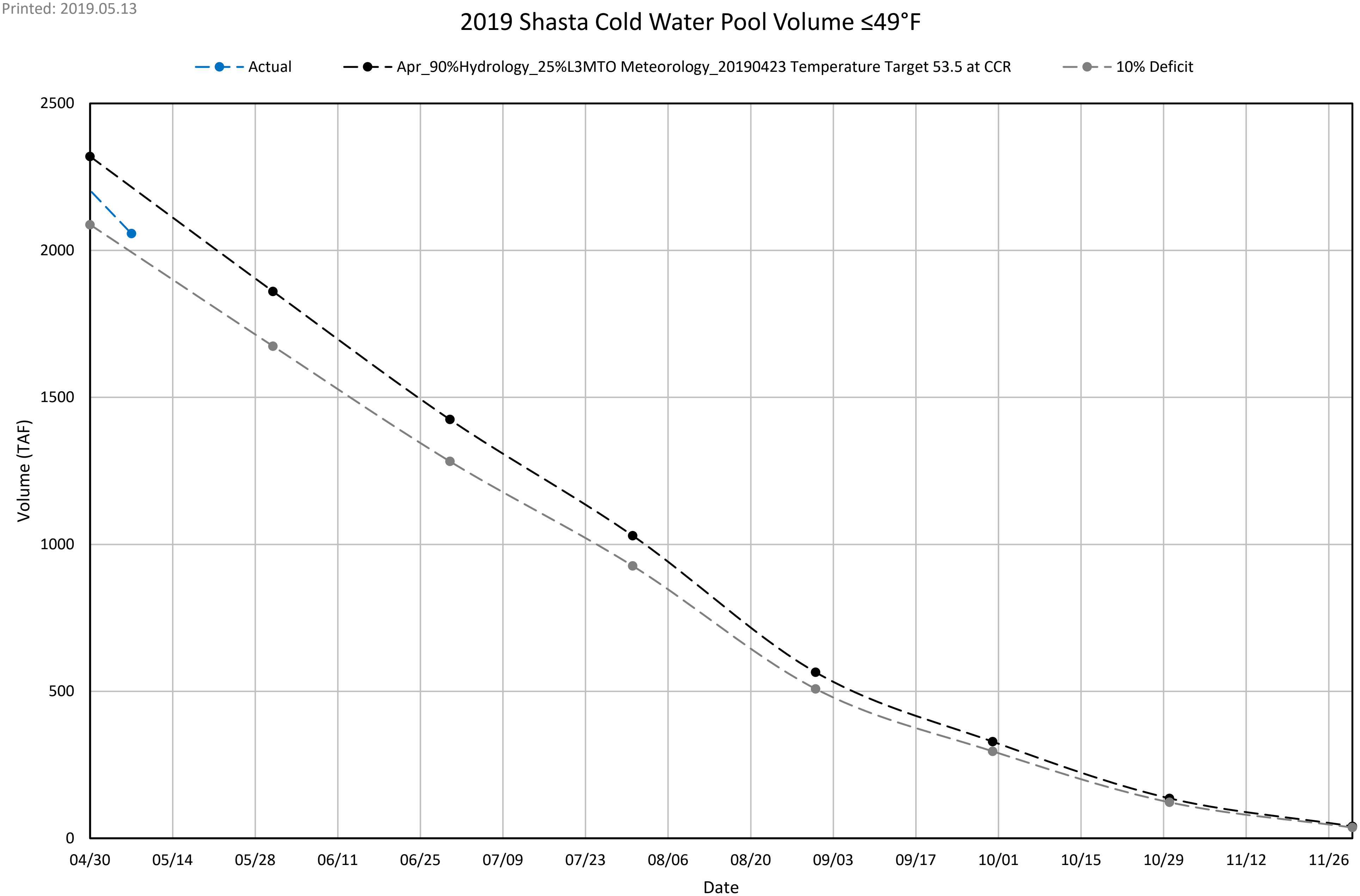

Enclosure 2

Summary Document for Shasta/Keswick Operational Scenarios
Prepared by the Southwest Fisheries Science Center on May 9th, 2019

Below are results comparing four USBR scenarios ran May 7th 2019. Scenarios differ by hydrology (Input 50 or 90 percent exceedance) and air temperature (25 or 50 exceedance of L3MTO). Inputs from scenarios are used to generate daily average Sacramento River water temperatures using the RAFT model and associated temperature-dependent egg mortality and survival estimates using the NMFS temperature mortality model (Martin et al. 2017) for the 2019 temperature management season (Table 1 and Figures 2-3). Additionally, a set of mortality model runs were generated using USBR's HEC-5Q model output (Table 2 and Figures 4-5) for comparison purposes, where the RAFT model was not used, but temperatures from the HEC-5Q nodes were linearly interpolated in space.

Further details of modeling methods are at: http://oceanview.pfeg.noaa.gov/CVTEMP/

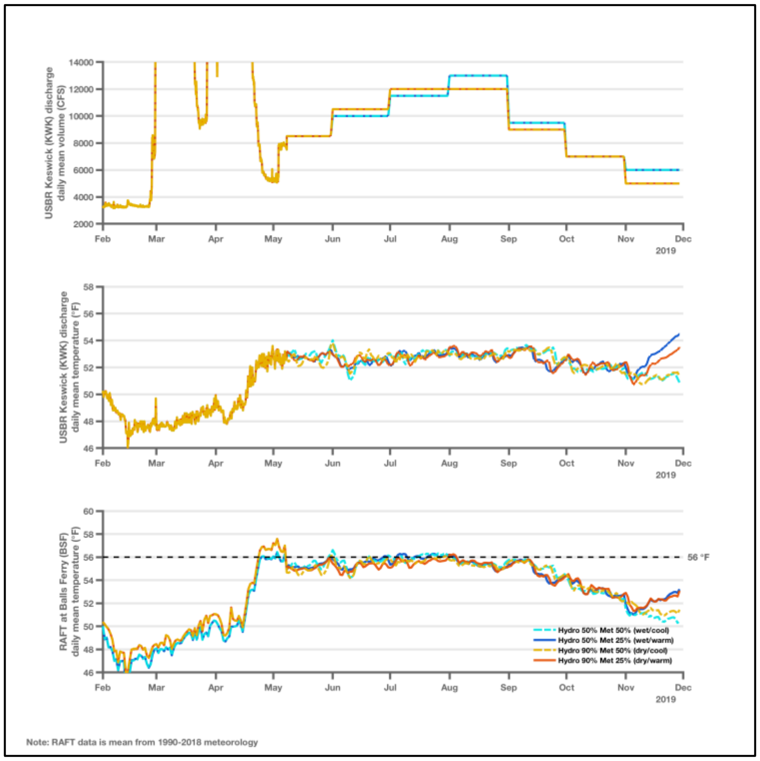

Figure 1: Summary plots showing differences in Keswick discharge volume and temperature, and Balls Ferry RAFT predicted temperature for four scenarios assessed.

Table 1: Estimated temperature-dependent egg mortality under different scenarios assuming a 2012-2017 spatial and temporal redd distribution.

Scenario	Mean (%)	Median (%)	Lower (%)	Upper (%)
APR_24_2019_INPUT_50_OUTPUT_50_25L3MTO (Wetter/Warmer)	9.17	1.5	0.08	53.6
APR_24_2019_INPUT_50_OUTPUT_50_50L3MTO (Wetter /Cooler)	10.69	1.7	0.08	57.35
APR_24_2019_INPUT_90_OUTPUT_90_25L3MTO (Drier/ Warmer)	9.57	1.88	0.08	54.37
APR_24_2019_INPUT_90_OUTPUT_90_50L3MTO (Drier / Cooler)	9.42	0.88	0.08	55.6

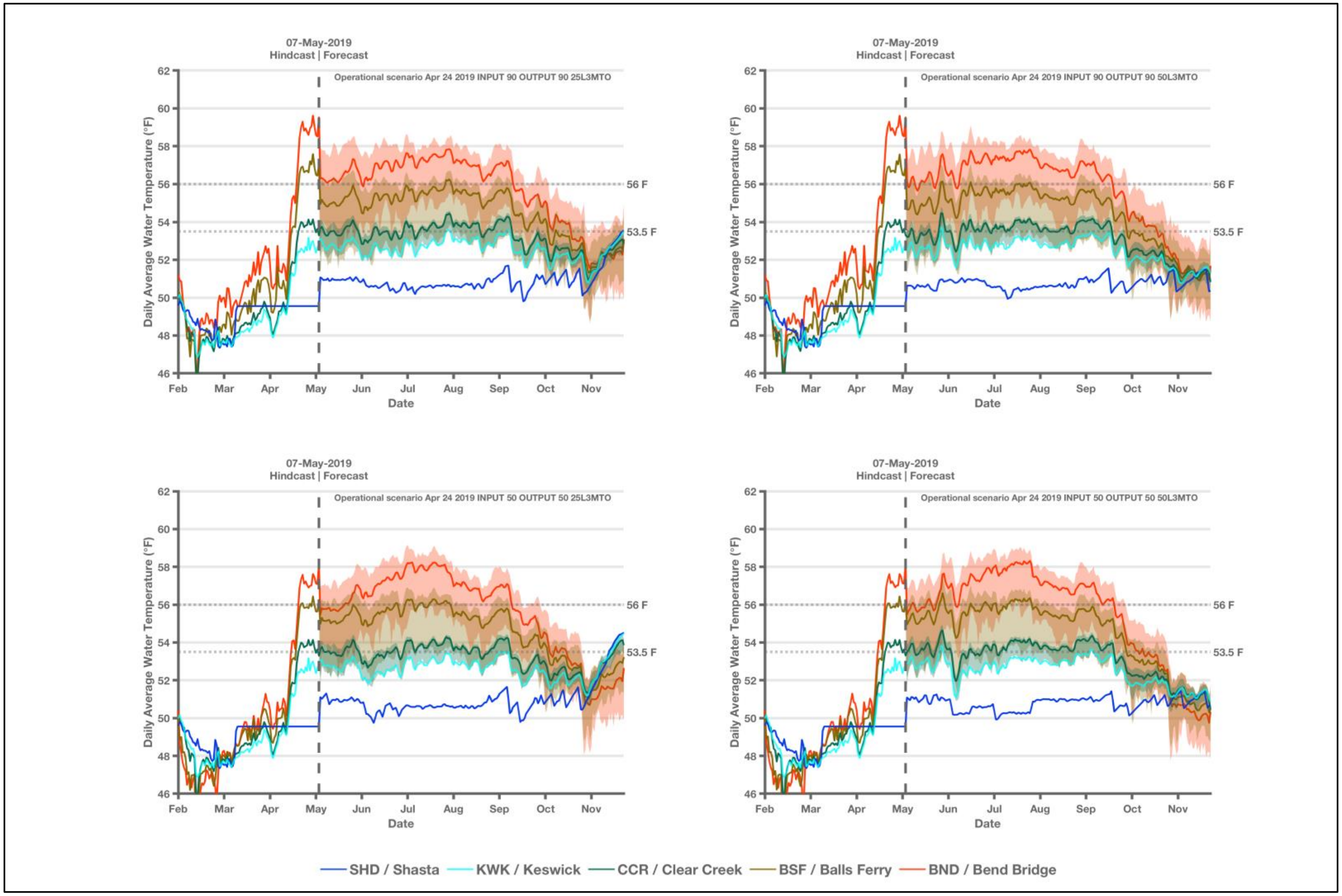

Figure 2: Estimated daily average water temperature produced by scenario input (Shasta and Keswick) and the RAFT model (Clear Creek, Balls Ferry, and Bend Bridge) under the four April 24th 2019 scenarios. NOTE: Shasta temperature gauge has been off-line since March.

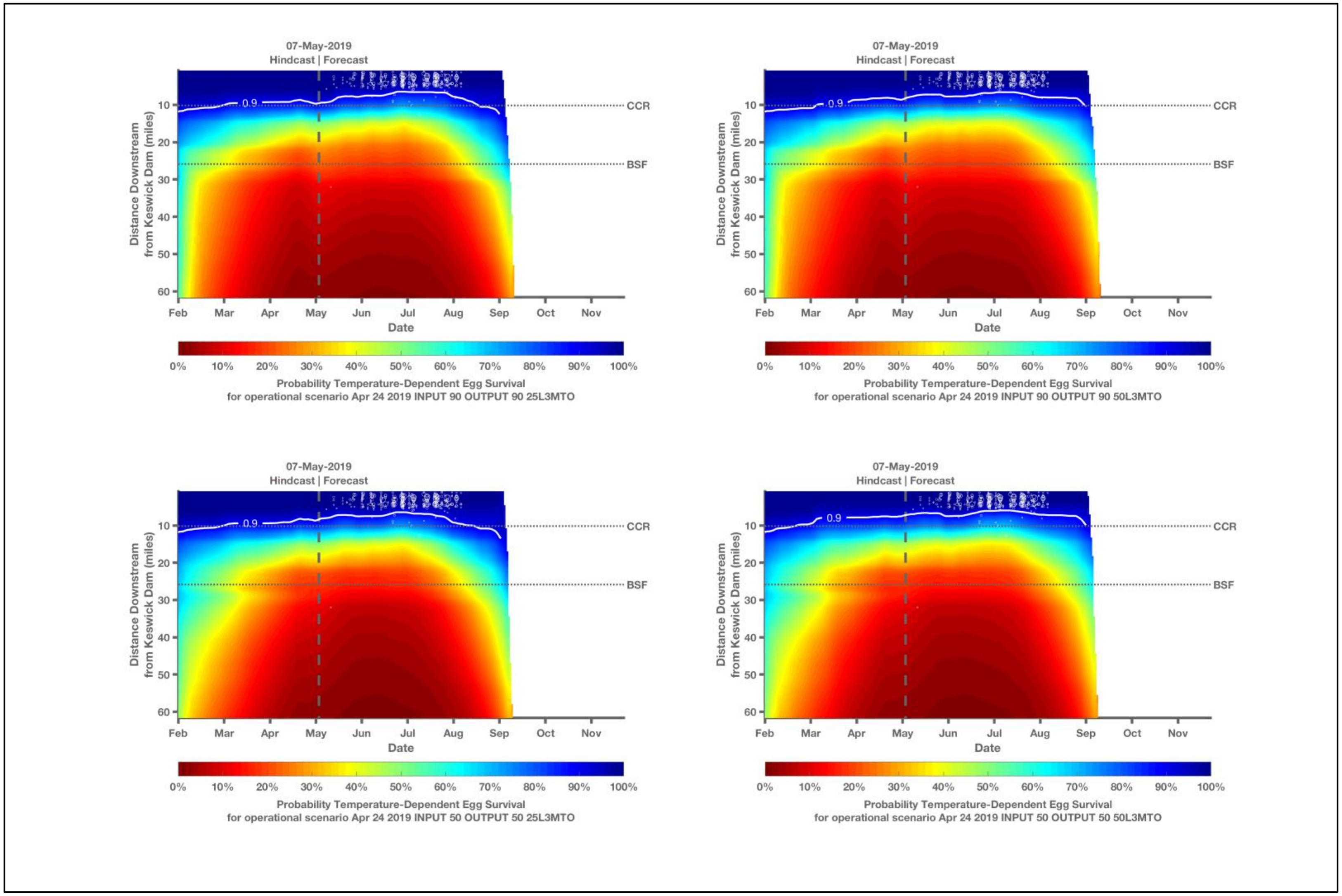

Figure 3: Estimated temperature-dependent egg survival produced by the NMFS temperature mortality model under the four April 24th 2019 scenarios.

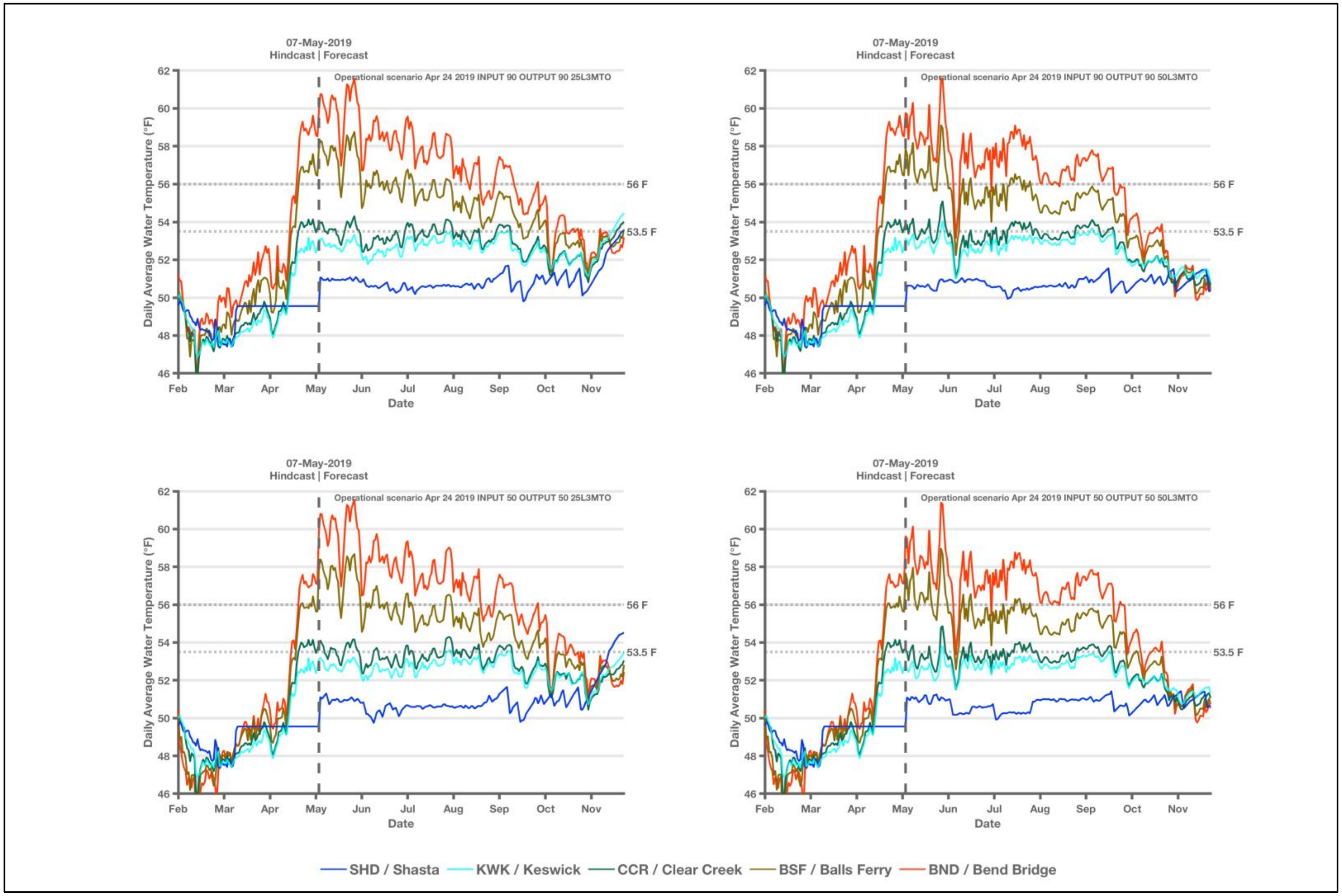

Figure 4: Estimated daily average water temperature produced by scenario input (Shasta, Keswick, Clear Creek, Balls Ferry, and Bend Bridge) under the four April 24th 2019 scenarios using HEC-5Q output. NOTE: Shasta temperature gauge has been off-line since March.

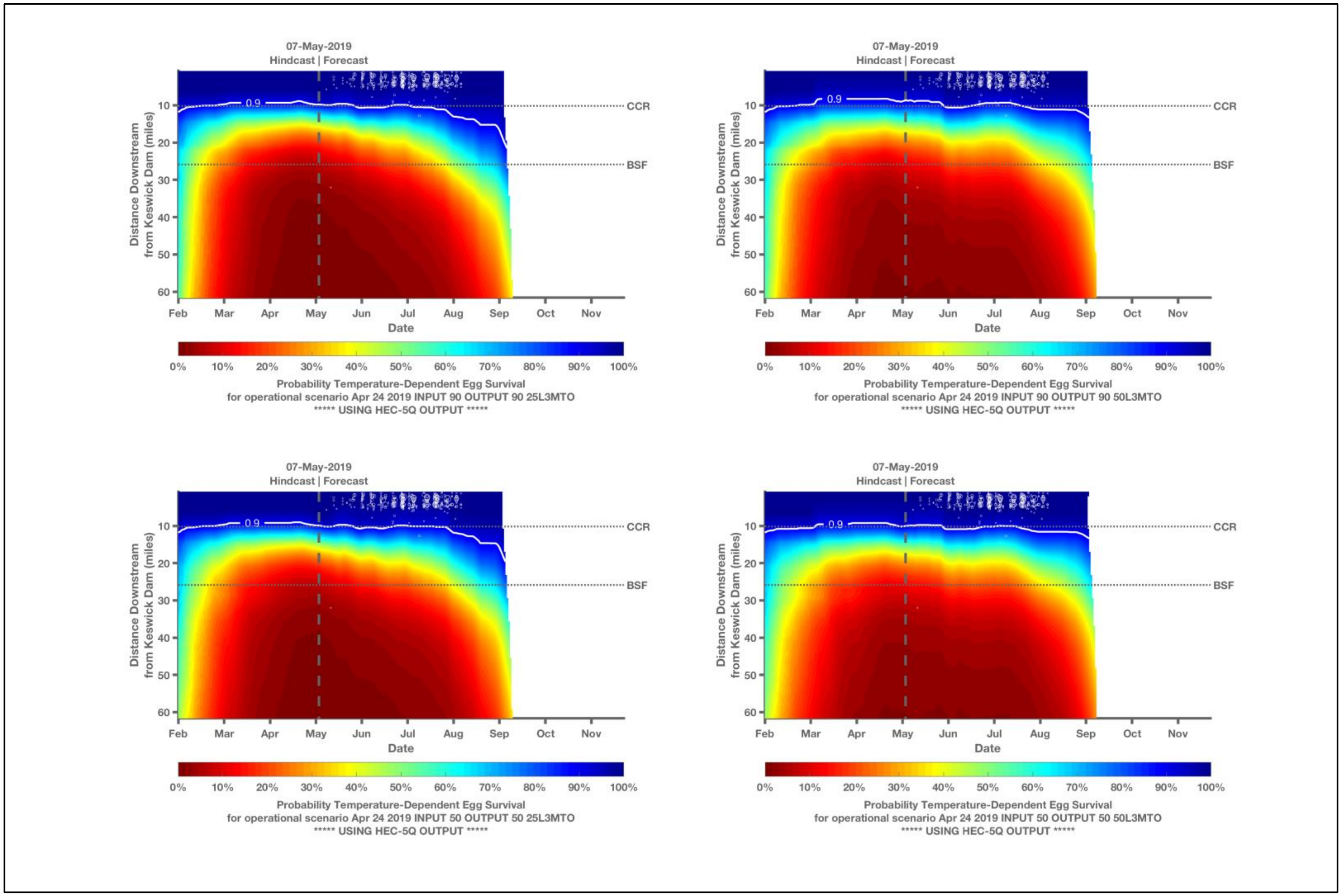

Figure 4: Estimated temperature-dependent egg survival produced by the NMFS temperature mortality model under the four April 24th 2019 scenarios using HEC-5Q output. To generate temperatures between HEC-5Q model nodes (KESWICK, CLEAR_CR, BALL_FERRY, JELLYS_FERRY, BEND_BR, and RED_BLIFF) linear interpolation was used.

Table 2: Estimated temperature-dependent egg mortality under different scenarios assuming a 2012-2017 spatial and temporal redd distribution using HEC-5Q output.

Scenario	Mean (%)	Median (%)	Lower (%)	Upper (%)
APR_24_2019_INPUT_50_OUTPUT_50_25L3MTO (Wetter/Warmer)	8.51	1.26	0.08	52.15
APR_24_2019_INPUT_50_OUTPUT_50_50L3MTO (Wetter /Cooler)	8.35	0.38	0.08	53.46
APR_24_2019_INPUT_90_OUTPUT_90_25L3MTO (Drier/ Warmer)	8.11	0.69	0.08	51.49
APR_24_2019_INPUT_90_OUTPUT_90_50L3MTO (Drier / Cooler)	9.48	0.88	0.08	55.18

Reference:

Martin, B. T., Pike, A., John, S. N., Hamda, N., Roberts, J., Lindley, S. T. and Danner, E. M. (2017), Phenomenological vs. biophysical models of thermal stress in aquatic eggs. Ecology Letters 20: 50–59. doi:10.1111/ele.12705