United States Department of the Interior

BUREAU OF RECLAMATION
Central Valley Operations Office
3310 El Camino Avenue, Suite 300
Sacramento, California 95821

MAR 13 2019

151422-SWR2006-SA00268

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NAT'L MARINE FISHERIES SVC
WCR, CCVO SACRAMENTO, CA
#2158

IN REPLY REFER TO:

CVO-100
2.2.1.06

VIA ELECTRONIC MAIL AND U.S. MAIL

Ms. Maria Rea
Assistant Regional Administrator
California Central Valley Area Office
650 Capital Mall, Suite 5-100
Sacramento, CA 95814

Subject: Transmittal of March 2019 Central Valley Project (CVP) Reservoir Operations Forecasts

Dear Ms. Rea:

Pursuant to Reasonable and Prudent Alternative Action I.2.3 of the 2009 National Marine Fisheries Service (NMFS) Biological Opinion (BiOp), on February 15, 2019, the Bureau of Reclamation transmitted preliminary CVP operational forecasts and Sacramento River temperature model results for projected operations over the coming spring and summer (Enclosure 1). Reclamation's transmittal indicated that Reclamation believed the performance goals of Action I.2.3.A could be met. On February 19, 2019, the NMFS responded, providing a different interpretation of conditions, and recommending implementation of Action I.2.3.B (Enclosure 2). However, the response acknowledged that conditions were actively changing at that time, and noted the need to further review updated forecasts and conditions in March. This transmittal provides those updated CVP operational forecasts and Sacramento River temperature model results for projected operations over the coming spring and summer (Enclosures 3 and 4).

The enclosed outlooks and modeling runs are based on forecasts of reservoir inflows assuming both a 90 percent exceedance hydrology, and a 50 percent exceedance hydrology using information provided by the California Department of Water Resources based on March 1 hydrologic conditions. The outlooks and modeling runs have also taken into account the runoff conditions and changes in reservoir volume that have occurred thus far in the month of March. Temperature modeling results are based on the operational forecasts, and a Shasta Lake temperature stratification profile taken March 11, 2019. It is important to note that the enclosed outlooks and projections do not suggest a certain actual future outcome, but rather the statistical likelihood of projected outcomes including, but not limited to, projected storage and releases as well as temperature performance. Thus, the outlooks do not provide exact end-of-month storages, flow rates, or anticipated water temperatures, but general projections that will likely fall within the range of uncertainty based on the different hydrologic runoff conditions between the 90 percent and 50 percent hydrology.

Within the February correspondence between our respective agencies, each agency identified concerns with the forecasted meteorology utilized in the river water temperature modeling scenarios (see Enclosures 1 and 2). In the weeks since that time, the agencies have had initial discussions regarding that issue. From those meetings, the agencies recognize the need to continue discussions and evaluations of this issue. However, in the interim and for the purposes of the March forecasting in this particular year, the discussions indicated that a 30 percent meteorology represents an approach that provides an additional level of conservatism while recognizing the compounding concerns and extreme[1] nature of the 10 percent dataset identified in Reclamation's February transmittal. The 30 percent exceedance approach was utilized for two of the evaluations summarized in Enclosure 4. The agencies also discussed that the meteorology used at this time of year is derived from recent historic data rather than the local 3-month temperature outlooks, which was a misunderstanding in the February NMFS response letter.

Reclamation acknowledges that the model runs summarized in Enclosure 4 illustrate good early-season temperature performance upstream of Clear Creek, but the possibility during limited time periods in the April and May timeframe of challenges meeting a 56-degree daily average temperature at Balls Ferry. This is similar to modeling results that were presented and discussed with NMFS as well as the Sacramento River Temperature Task Group (SRTTG) during the spring of last year. These modeling results are due to the model projecting extremely warm runoff from local creeks downstream of Clear Creek (such as Cow Creek) towards the end of the spring runoff season. Attempts to rectify this result by forcing the model to release extremely cold water during these time periods were generally unsuccessful, and represent a modeled over-expenditure of the cold water pool early in the season. As with last year, Reclamation does not believe that attempting to force the model to behave in this manner provides an accurate indication of the real-time decisions and management that would be made under these conditions, and also that it would inappropriately affect the accuracy of overall model performance during the remainder of the temperature management season. In addition, the model results show that the warmer water issues are focused downstream of the spawning areas used by winter-run in recent years. As such, Reclamation believes both the modeling and management of this issue during the April and May timeframe should be further discussed with the SRTTG, in a similar manner to last year.

Notwithstanding the early-season side-inflow anomalies outlined above, the results of the temperature modeling software indicate the ability to meet a 56-degree daily average temperature at a compliance location of Balls Ferry for the remainder of the temperature control season under the 90 percent exceedance hydrology as illustrated in Enclosure 4. Under this same hydrology, the projected storage in Shasta Lake at the end of September is approximately 3.2 million acre-feet. We believe these conditions are consistent with the criteria for Action I.2.3.A in the NMFS

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[1] Out of the 33 years in the recent historic record (1985-2017); only 5 years contained 3 months greater than or equal to 10 percent exceedance equilibrium temperature, 1 year contained 4 months greater than or equal to 10 percent exceedance equilibrium temperature, and the average number of months greater than or equal to 10 percent exceedance equilibrium temperature for all years is only 1 month per year.

BiOp, and request that NMFS concur that it is likely the performance goals in Action I.2.3.A can be met.

Since we are within Action I.2.3.A, the Action does not require additional restrictions. With the projected operations illustrated in Enclosure 3, and other operating conditions throughout the CVP system, Reclamation anticipates the ability to support appropriately conservative allocation updates to Central Valley Project contractors. Reclamation recognizes the potential that these allocations may need to be modified during 2019 to address ongoing temperature planning and establishment of the temperature compliance point. As such, Reclamation does not believe that issuing allocation updates would foreclose future measures for the fishery protection under the Endangered Species Act as implemented through the actions identified in the NMFS BiOp.

Given the significantly improved hydrology over the past 4 weeks, coupled with the importance of timely decisions for the planning purposes of CVP water service contractors, Reclamation is striving to issue the aforementioned allocation updates by Friday March 15. Should NMFS have any questions or concerns regarding the enclosed information, we encourage you to contact us as soon as possible to ensure both agencies move quickly to adjust to the improved water supply conditions.

In the interest of expedient processing, Reclamation reiterates the observations originally raised in our letter of March 19, 2018, specifically that the results of NMFS's temperature-based mortality modeling are not an element of the regulatory processes contained in Action I.2.3, and thus are not a necessary step towards a determination under the Action. Reclamation understands NMFS's position with regard to those results as outlined in the NMFS response letter of March 28, 2018, but we suggest that information may be more appropriately reviewed and discussed in the context of the upcoming development process for the 2019 Temperature Management Plan. That process will be conducted over the next 9 weeks in coordination with the SRTTG, which will hold its next meeting on March 28, thus providing additional time for NMFS to complete the processing of those models and evaluations outside the context of the regulatory process under Action I.2.3.

We appreciate the discussions on these topics in recent weeks, and look forward to our continued coordination as we work on this year's temperature management plan. Please contact me at (916) 978-2197 or jrieker@usbr.gov if you have any questions regarding this transmittal.

Sincerely,

Jeffrey D. Rieker
Operations Manager

Enclosures

Enclosure 1

February 15, 2019
Transmittal of February 2019 Central Valley Project
Reservoir Operations Forecasts (without enclosures)

United States Department of the Interior

BUREAU OF RECLAMATION
Central Valley Operations Office
3310 El Camino Avenue, Suite 300
Sacramento, California 95821

IN REPLY
REFER TO:

CVO-100
2.2.1.06

FEB 15 2019

VIA ELECTRONIC MAIL AND U.S. MAIL

Ms. Maria Rea
Assistant Regional Administrator
California Central Valley Area Office
650 Capital Mall, Suite 5-100
Sacramento, CA 95814

Subject: Transmittal of February 2019 Central Valley Project (CVP) Reservoir Operations Forecasts

Dear Ms. Rea:

Pursuant to Reasonable and Prudent Alternative Action I.2.3 of the 2009 National Marine Fisheries Service (NMFS) Biological Opinion (BiOp), this transmittal provides the Bureau of Reclamation's preliminary CVP operational forecasts and Sacramento River temperature model results for projected operations over the coming spring and summer. Enclosed are Reclamation's updated CVP operational projections for the coming spring and summer (Enclosure 1), and a projection of Sacramento River temperature performance for the projected operations (Enclosure 2).

The enclosed outlooks and modeling runs are based on forecasts of reservoir inflows assuming both a 90 percent exceedance hydrology, and a 50 percent exceedance hydrology using information provided by the California Department of Water Resources based on February 1 hydrologic conditions. The outlooks and modeling runs have also taken into account the runoff conditions and changes in reservoir volume that have occurred thus far in the month of February. Temperature modeling results are based on the operational forecasts, and a Shasta Lake temperature stratification profile taken February 7, 2019. It is important to note that the enclosed outlooks and projections do not suggest a certain actual future outcome, but rather the statistical likelihood of projected outcomes including, but not limited to, projected storage and releases as well as temperature performance. Thus, the outlooks do not provide exact end-of-month storages, flow rates, or anticipated water temperatures, but general projections that will likely fall within the range of uncertainty based on the different hydrologic runoff conditions between the 90 percent and 50 percent hydrology.

As illustrated in the enclosures, the results of the temperature modeling software indicate the ability to meet a 56-degree daily average temperature at a compliance location of Balls Ferry under the 90 percent exceedance hydrology. Under this same hydrology, the projected storage in

Shasta Lake at the end of September is approximately 2.5 million acre-feet. We believe these conditions are consistent with the criteria for Action I.2.3.A in the NMFS BiOp, and request that NMFS concur that it is likely the performance goals in Action I.2.3.A can be met. We have enclosed additional information discussing uncertainties associated with the modeling results, including issues surrounding the use of a 10 percent exceedance meteorology, and additional uncertainties in the modeling software results in the September and October timeframes (Enclosures 3 and 4).

Since we are within Action I.2.3.A, the Action does not require additional restrictions. With the projected operations illustrated in Enclosure 1, and other operating conditions throughout the CVP system, Reclamation anticipates the ability to support appropriately conservative initial allocations to Central Valley Project contractors, which we intend to issue on Wednesday February 20. Reclamation recognizes the potential that these allocations may need to be modified during 2019 to address ongoing temperature planning and establishment of the temperature compliance point. As such, Reclamation does not believe that issuing initial allocations would foreclose future measures for the fishery protection under the Endangered Species Act as implemented through the actions identified in the NMFS BiOp. Should NMFS have any questions or concerns, or need additional information regarding the enclosed outlooks and projections, we encourage you to contact us as soon as possible to ensure we maintain the schedule of activities necessary for the allocation notifications. In addition, Reclamation requests that NMFS take all appropriate steps to ensure that its written evaluation of these forecasts and final determination can still be provided prior to February 20 should a lapse in appropriations occur in the coming days.

We look forward to our continued coordination as we work throughout this spring on the development of the Sacramento River temperature management plan for 2019, in coordination with the Sacramento River Temperature Task Group (SRTTG). Our initial meeting for the SRTTG is currently scheduled for February 28, 2019. In addition to the development of a plan pursuant to both the NMFS BiOp and the State Water Resources Control Board's Order 90-5, we anticipate that, through this process, the agencies will be able to fully evaluate the potential for additional operational studies this year for targeting specific temperatures closer to the actual locations of redds, as in the past several years.

Please contact me at (916) 978-2197 or jrieker@usbr.gov if you have any questions regarding this transmittal.

Sincerely,

For Jeff Rieker
Operations Manager

Enclosures

Enclosure 2

February 19, 2019
NMFS Response to Transmittal of
February Reservoir Operations Forecast
Per RPA Action I.2.3 (without enclosures)

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

February 19, 2019

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

Re: Transmittal of February Reservoir Operations Forecast Per RPA Action I.2.3

Thank you for the opportunity to review the U.S. Bureau of Reclamation's (Reclamation) Central Valley Project (CVP) reservoir operations February forecast of hydrology and projection of temperature management options for water year 2019 and the opportunity to provide Reclamation with technical assistance regarding implementation of reasonable and prudent alternative (RPA) Action I.2.3. Your February 15, 2019 letter included results of the 90 and 50 percent exceedance CVP reservoir operations forecasts, and water temperature modeling using 50 and 10 percent long-term 3-month temperature outlooks (L3MTO).

For purposes of compliance with RPA Action I.2.3 described in NOAA's National Marine Fisheries Service's (NMFS) June 4, 2009, conference and biological opinion on the long-term operation of the CVP and State Water Project (SWP), NMFS shall review the February forecast to determine whether the predicted delivery schedule is likely to leave sufficient water for temperature management to meet Endangered Species Act (ESA) requirements, and provide a written evaluation to Reclamation prior to Reclamation making the first allocation announcements. The objective of this RPA action is to use a conservative forecast as early as possible to protect the cold water pool in Shasta Reservoir so that suitable habitat can be maintained downstream during the summer and fall for federally listed endangered Sacramento River winter-run Chinook salmon *(Oncorhynchus tshawytscha)*, and threatened Central Valley spring-run Chinook salmon (*O. tshawytscha).*

NMFS has reviewed Reclamation's February 2019 CVP reservoir operations forecasts (Enclosure 1) and corresponding water temperature model runs for the Sacramento River (Enclosure 2). In addition, the NMFS-Southwest Fisheries Science Center (SWFSC) has provided model run results for the River Assessment for Forecasting Temperature (RAFT), and temperature-dependent mortality estimates using Reclamation's HEC-5Q model and the NOAA CE-QUAL-W2 reservoir model (Enclosure 3).

The CVP reservoir operations February forecast is based on estimated runoff within the Sacramento River Basin as of February 1, 2019, and forecasted inflow and projected storage are shown in (Table 1). As of February 1, 2019, the Sacramento Valley Water Year Type Index (SVI) was 6.9 (50 percent exceedance) and classified as below normal (*http://cdec.water.ca.gov/cgi-progs/iodir_ss/wsi*).

Table 1. Bureau of Reclamation's February CVP reservoir operations percent exceedance forecast for estimated annual inflow, and projected end of April and September storages into Shasta Reservoir in million acre-feet (MAF) for 2019.

Exceedance forecast (percent)	Estimated annual inflow (MAF)	End of April projected storage (MAF)	End of September projected storage (MAF)
90	4.46	4.05	2.65
50	4.99	4.40	3.12

The resulting HEC-5Q water temperature model runs based on the 90 percent exceedance hydrological and average historic meteorological conditions forecast (50% L3MTO) indicate that 56°F daily average temperature (DAT) at the Balls Ferry compliance point may not be met throughout the entire temperature management season (Figures 1 and 4 of Enclosure 2). Because past analyses have shown that the temperature model does not perform well in late September and October, Reclamation used the relationship between end-of-September (EOS) Shasta Reservoir volume below 56°F and projected water temperature at Balls Ferry in order to better predict fall water temperatures (Figure 4 of Enclosure 2). Results indicated that between September 20 and October 31, the historical maximum mean 3-day water temperature would be approximately 56.3°F.

Reclamation expressed concern regarding the use of a 10 percent exceedance meteorology coupled with a 90 percent exceedance hydrology in modeling runs, which may have a compounding effect, resulting in projected temperature performance well in excess of a 90 percent overall exceedance. However, NMFS thinks that hydrology and meteorology, although somewhat related, are relatively independent, and therefore, both should be considered in any modeled projections of temperature management. For example, long-range average temperature data from NOAA's National Climatic Data Center from May through October in the Sacramento region show increasing average temperatures through time (Figure 1).

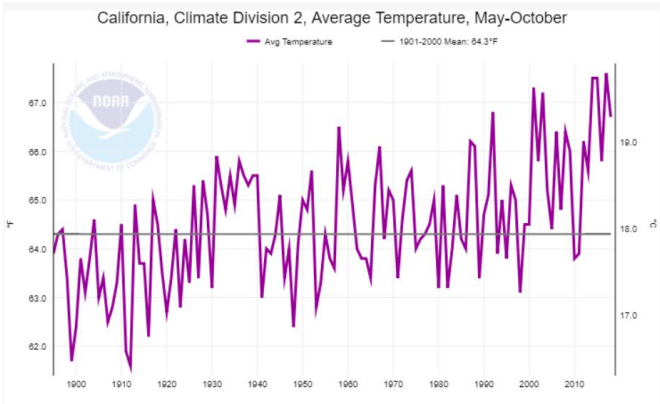

Figure 1. NOAA's National Climatic Data Center long-range data set showing an increasing trend in average temperatures from May through October (https://www.ncdc.noaa.gov/cag/divisional/time-series/0402/tavg/6/10/1895-2019?base_prd=true&firstbaseyear=1985&lastbaseyear=2017)

In addition, NOAA's National Weather Service (NWS) Climate Prediction Center (CPC) predicts a higher probability of above normal temperatures (1981-2000 average) across the western states in July, August, and September, 2019 (Figure 2).

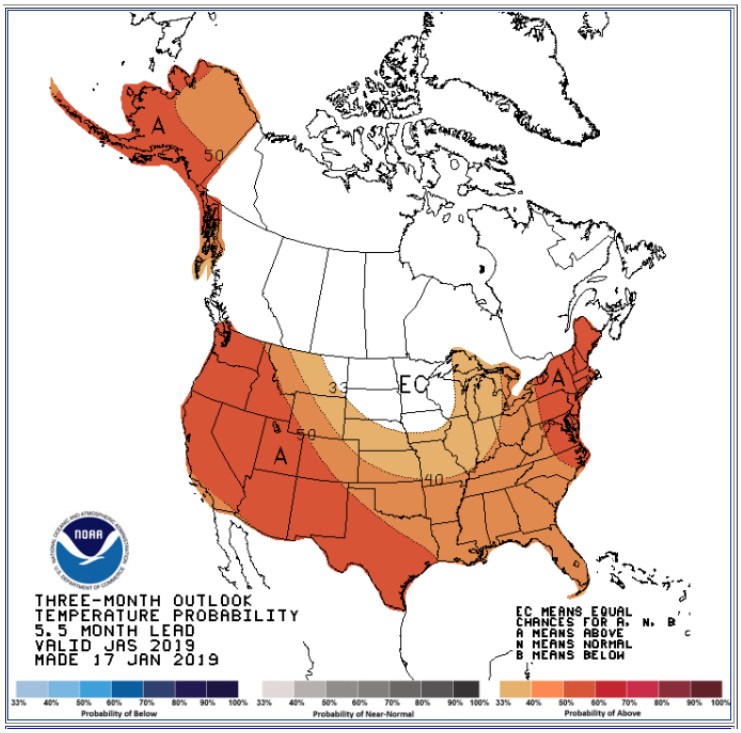

Figure 2. NOAA's National Weather Service's Climate Prediction Center's forecast of temperatures in July, August, and September, 2019 (https://www.cpc.ncep.noaa.gov/products/predictions/long_range/seasonal.php?lead=6)

Finally, NOAA-NWS CPS projects above average air temperatures (≈ 1°F warmer than the 1981-2010 average) in July, August, and September 2019, indicating that the use of 50% L3MTO is not conservative (Figure 3).

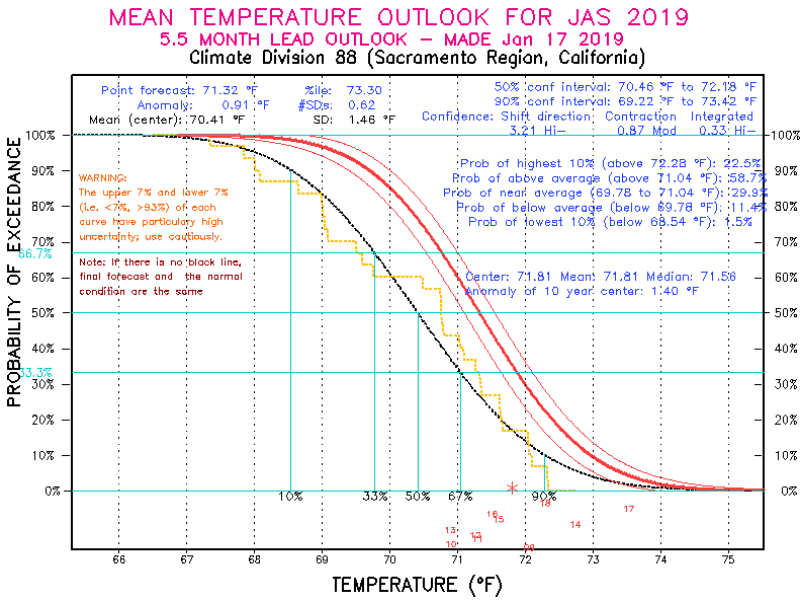

Figure 3. NOAA's National Weather Service Climate Prediction Center mean temperature outlook for July, August, and September 2019 for the Sacramento Region, California. Probability of exceedance curves give the forecast probability that a temperature, shown on the horizontal axis, will be exceeded for the given season at the given lead time (https://www.cpc.ncep.noaa.gov/products/predictions/long_range/poe_graph_index.php?lead=6&climdiv=88&var=t).

Finally, regarding the 90% exceedance forecast with 50% L3MTO projects full side gate access on September 22, 2019, whereas full side gate access is forecasted to occur on September 1, 2019 with either of the 10% L3MTO scenarios. A 3-week difference in full side gate access using more conservative meteorological conditions indicates sensitivity to ambient temperatures and further uncertainty in attaining 56°F at Balls Ferry reliably throughout September and October.

In addition to examining the ability to meet 56°F at Balls Ferry, NMFS analyzed predicted temperature dependent mortality. Tables 2 and 3 (summarized from Enclosure 3), provide results from the temperature-dependent egg mortality model using the NMFS-SWFSC CE-QUAL-W2 and Reclamation's HEC-5Q reservoir models, respectively. While the model uses a historical set of redd distribution and does not project actual mortality, results provide relative comparisons across scenarios. Note that the temperature-dependent mortality model estimates using NMFS-SWFSC's CE-QUAL-W2 reservoir model are 2.11-3.61 percent higher than those using Reclamation's HEC-5Q reservoir model.

Table 2. Estimated temperature-dependent egg mortality for 2019 under different hydrological and meteorological percent exceedance forecast scenarios, using NMFS-SWFSC's CE-QUAL-W2 reservoir model, and assuming 2012-17 spatial and temporal redd distribution.

Hydrology	Meteorology	Percent temperature-dependent egg mortality		
		Mean	Median	95% CI
50%	10%	40.78	42.89	0.08-74.02
50%	50%	13.64	4.07	0.08-61.16
90%	10%	37.07	38.8	0.08-73.7
90%	50%	20.6	16.56	0.08-63.79

Table 3. Estimated temperature-dependent egg mortality for 2019 under different hydrological and meteorological percent exceedance forecast scenarios, using Reclamation's HEC-5Q reservoir model, and assuming 2012-17 spatial and temporal redd distribution.

Hydrology	Meteorology	Percent temperature-dependent egg mortality		
		Mean	Median	95% CI
50%	10%	37.37	38.32	0.08-72.63
50%	50%	11.53	1.83	0.08-58.6
90%	10%	33.46	33.59	0.08-72.2
90%	50%	17.55	12.07	0.08-61.75

Under the 90% exceedance hydrology, the projected storage in Shasta Reservoir at the end of September is approximately 2.65 million acre feet, indicating that the metric is met for RPA Action I.2.3.A.

In summary, NMFS concludes that February conditions, forecasted operations, and modeling based on 90 percent hydrology and best available information on predicted meteorology do not show that a 56°F temperature at Balls Ferry can be attained throughout the temperature management season. Therefore, at this time, NMFS recommends the implementation of RPA Action I.2.3.B. We understand that the hydrology (including Shasta storage and snow pack) has improved since the California Department of Water Resources provided information based on February 1 hydrologic conditions, and you may be making initial allocations based on this information. NMFS would like to review the final March forecast and associated modeling before making a final determination on whether the proposed operations reliably show an ability to meet 56°F at Balls Ferry throughout the temperature management season. We are also willing to have further discussions between now and the March forecast about the most likely meteorology based on NOAA's National Weather Service and Climate Prediction Service CPC outputs, and how to integrate these forecasts with your model. Our intent is to get the most reliable air temperature predictions for the summer of 2019, while not being overly conservative. NMFS looks forward to receiving the updated hydrology, updated forecast and associated Keswick release schedule in March and is willing to share technical information in the interim to align approaches.

If you have any questions regarding this letter, please contact me at maria.rea@noaa.gov or at (916) 930-3600, or have your staff contact Garwin Yip at (916) 930-3611 or via e-mail at garwin.yip@noaa.gov.

Sincerely,

Maria C. Rea
Assistant Regional Administrator

Enclosures:

1. Reclamation's CVP Operations February 90 and 50 percent exceedance forecasts (2 pages)
2. Reclamations preliminary water temperature analysis based on four scenarios cross-factoring 90 and 50 percent exceedance hydrology with 10 and 50 percent exceedance meteorology (18 pages)
3. NMFS-SWFSC RAFT and temperature-dependent mortality model results for the four forecast and meteorology scenarios (6 pages)

cc: ARN File: 151422SWR2006SA00268

Enclosure 3

CVP Operational Forecasts

Estimated CVP Operations 90% Exceedance

Storages

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

		Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Trinity	**1739**	**1867**	**1945**	**1989**	**1959**	**1821**	**1669**	**1540**	**1508**	**1489**	**1499**	**1531**	**1616**
	Elev.	2332	2337	2340	2338	2328	2317	2306	2304	2302	2303	2306	2313
Whiskeytown	**247**	**206**	**238**	**238**	**238**	**238**	**238**	**238**	**206**	**206**	**206**	**206**	**206**
	Elev.	1199	1209	1209	1209	1209	1209	1209	1199	1199	1199	1199	1199
Shasta	**3948**	**3963**	**4350**	**4398**	**4127**	**3683**	**3378**	**3194**	**3019**	**2929**	**2982**	**3133**	**3438**
	Elev.	1046	1060	1062	1052	1036	1024	1016	1009	1005	1007	1014	1026
Folsom	**598**	**738**	**878**	**964**	**952**	**787**	**643**	**560**	**460**	**381**	**319**	**320**	**382**
	Elev.	443	457	465	464	448	433	424	411	400	390	391	400
New Melones	**2005**	**1875**	**1845**	**1873**	**1885**	**1818**	**1749**	**1709**	**1663**	**1674**	**1688**	**1700**	**1644**
	Elev.	1041	1038	1041	1042	1035	1029	1025	1020	1021	1023	1024	1018
San Luis	**921**	**966**	**823**	**587**	**425**	**225**	**75**	**86**	**210**	**287**	**504**	**664**	**796**
	Elev.	543	517	478	449	411	382	380	386	395	434	460	478
Total		9615	10080	10049	9586	8572	7750	7327	7064	6965	7198	7553	8081

Monthly River Releases (TAF/cfs)

Trinity	TAF	18	32	258	126	68	53	52	23	18	18	18	17
	cfs	**300**	**540**	**4,189**	**2,120**	**1,102**	**857**	**870**	**373**	**300**	**300**	**300**	**300**
Clear Creek	TAF	12	13	13	17	9	9	9	12	12	12	12	11
	cfs	**200**	**218**	**216**	**288**	**150**	**150**	**150**	**200**	**200**	**200**	**200**	**200**
Sacramento	TAF	1229	327	443	625	738	566	416	428	352	277	246	222
	cfs	**20000**	**5500**	**7200**	**10500**	**12000**	**9200**	**7000**	**6955**	**5909**	**4500**	**4000**	**4000**
American	TAF	430	238	314	238	258	234	169	135	119	123	111	100
	cfs	**7000**	**4000**	**5100**	**4000**	**4200**	**3811**	**2849**	**2202**	**2000**	**2000**	**1800**	**1800**
Stanislaus	TAF	277	83	92	56	18	18	18	49	12	12	14	83
	cfs	**4500**	**1400**	**1500**	**940**	**300**	**300**	**300**	**797**	**200**	**200**	**232**	**1500**

Trinity Diversions (TAF)

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Carr PP	2	55	17	75	100	101	70	18	21	12	3	2
Spring Crk. PP	**50**	**25**	**10**	**60**	**90**	**90**	**60**	**40**	**15**	**12**	**10**	**20**

Delta Summary (TAF)

		Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Tracy		199	54	55	255	268	240	259	270	150	270	220	230
USBR Banks		0	0	0	0	24	24	24	0	0	0	0	0
Contra Costa		12.7	12.7	12.7	9.8	11.1	12.7	14.0	16.8	18.4	18.3	14.0	14.0
Total USBR		212	66	68	265	303	277	297	287	168	288	234	244
Total Export		387	102	105	445	500	511	513	413	318	528	394	404
COA Balance		0	0	0	0	0	0	0	9	9	9	9	9
Old/Middle River Std.													
Old/Middle R. calc.		-239	581	-110	-5,221	-6,207	-6,340	-6,565	-5,058	-4,258	-6,656	-4,959	-4,950
Computed DOI		80214	29030	20952	11145	8004	5694	7094	7109	7682	6849	11778	12139
Excess Outflow		66517	7531	9549	1748	0	0	0	0	588	2342	5775	738
% Export/Inflow		7%	5%	6%	34%	39%	46%	46%	42%	37%	54%	36%	38%
% Export/Inflow std.		35%	35%	35%	35%	65%	65%	65%	65%	65%	65%	65%	45%

Hydrology

	Trinity		Shasta		Folsom		New Melones	
Water Year Inflow (TAF)	1259		5,962		3,167		1264	
Year to Date + Forecasted % of mean	104%		108%		116%		120%	

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.

3/13/2019

Estimated CVP Operations 50% Exceedance

Storages

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

		Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Trinity	**1739**	**1904**	**2065**	**2079**	**2029**	**1891**	**1744**	**1606**	**1580**	**1567**	**1594**	**1658**	**1769**
	Elev.	2334	2345	2346	2343	2333	2322	2312	2310	2309	2311	2316	2324
Whiskeytown	**247**	**206**	**238**	**238**	**238**	**238**	**238**	**238**	**206**	**206**	**206**	**206**	**206**
	Elev.	1199	1209	1209	1209	1209	1209	1209	1199	1199	1199	1199	1199
Shasta	**3948**	**3899**	**4382**	**4542**	**4365**	**3986**	**3672**	**3397**	**3235**	**3254**	**3339**	**3638**	**3955**
	Elev.	1044	1061	1067	1061	1047	1035	1025	1018	1019	1022	1034	1046
Folsom	**598**	**725**	**875**	**964**	**961**	**855**	**748**	**605**	**496**	**466**	**455**	**483**	**495**
	Elev.	442	457	465	465	455	444	429	416	412	411	414	416
New Melones	**2005**	**1871**	**1877**	**1953**	**2026**	**2001**	**1945**	**1908**	**1864**	**1874**	**1892**	**1916**	**1962**
	Elev.	1040	1041	1048	1055	1052	1047	1044	1040	1041	1042	1045	1049
San Luis	**921**	**972**	**865**	**647**	**489**	**290**	**170**	**49**	**47**	**29**	**237**	**411**	**554**
	Elev.	544	521	486	471	463	451	426	414	407	446	472	497
Total		9576	10301	10424	10108	9263	8516	7803	7427	7396	7722	8312	8940

Monthly River Releases (TAF/cfs)

Trinity	TAF	18	28	258	126	68	53	52	23	18	18	18	17
	cfs	**300**	**477**	**4,189**	**2,120**	**1,102**	**857**	**870**	**373**	**300**	**300**	**300**	**300**
Clear Creek	TAF	12	13	13	17	9	9	9	12	12	12	15	11
	cfs	**200**	**218**	**216**	**288**	**150**	**150**	**150**	**200**	**200**	**200**	**240**	**200**
Sacramento	TAF	1414	416	492	595	707	615	565	430	297	307	307	444
	cfs	**23000**	**7000**	**8000**	**10000**	**11500**	**10000**	**9500**	**7000**	**5000**	**5000**	**5000**	**8000**
American	TAF	492	387	461	357	248	215	250	184	119	123	123	250
	cfs	**8000**	**6500**	**7500**	**6000**	**4030**	**3500**	**4200**	**3000**	**2003**	**2000**	**2000**	**4500**
Stanislaus	TAF	277	97	120	65	26	25	24	52	18	18	22	20
	cfs	**4500**	**1633**	**1958**	**1100**	**429**	**400**	**400**	**842**	**300**	**300**	**358**	**364**

Trinity Diversions (TAF)

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Carr PP	4	51	1	71	99	100	89	13	25	12	0	2
Spring Crk. PP	**70**	**30**	**2**	**60**	**90**	**90**	**80**	**35**	**20**	**15**	**20**	**35**

Delta Summary (TAF)

		Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Tracy		200	89	74	259	270	270	128	145	55	260	235	240
USBR Banks		0	0	0	0	24	24	24	0	0	0	0	0
Contra Costa		12.7	12.7	12.7	9.8	11.1	12.7	14.0	16.8	18.4	18.3	14.0	14.0
Total USBR		213	102	86	269	305	307	166	162	73	278	249	254
Total Export		433	161	136	528	706	577	266	237	173	538	424	464
COA Balance		0	0	0	0	73	73	70	70	70	70	70	70
Old/Middle River Std.													
Old/Middle R. calc.		136	1,881	1,094	-5,996	-8,583	-6,975	-3,172	-2,606	-2,041	-6,532	-4,971	-5,045
Computed DOI		95993	48781	33982	17314	8004	6377	16019	12266	11397	10183	16918	30707
Excess Outflow		82296	23735	13388	6051	0	2375	0	862	0	5677	10915	19307
% Export/Inflow		7%	5%	5%	30%	48%	47%	18%	20%	17%	45%	29%	21%
% Export/Inflow std.		35%	35%	35%	35%	65%	65%	65%	65%	65%	65%	65%	45%

Hydrology

	Trinity		Shasta		Folsom		New Melones	
Water Year Inflow (TAF)	1317		6,592		3,741		1512	
Year to Date + Forecasted % of mean	109%		119%		137%		143%	

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.

3/13/2019

Enclosure 4

Sacramento River Water Temperature Modeling Results

March 13, 2019

Upper Sacramento River – March 2019 Preliminary Temperature Analysis

Location (°F DAT)	APR	MAY	JUN	JUL	AUG	SEP*	OCT*
February 90%-Exceedance Outlook – 30% Historical Meteorology							
Keswick Dam KWK	53.0	52.4	52.1	52.9	52.8	See Figures 1 and 2	See Figures 1 and 2
Sac. R. abv Clear Creek CCR	53.6	53.3	52.7	53.4	53.4	See Figures 1 and 3	See Figures 1 and 3
Balls Ferry BSF	56.6	57.6	55.8	55.7	55.5	See Figures 1 and 4	See Figures 1 and 4

Model Run	End of September Cold Water Pool <56°F (TAF)	First Side Gate	Full Side Gates
90% Hydro, 30% Met	883	9/17/19	10/30/19

Model Run Date March 13, 2019

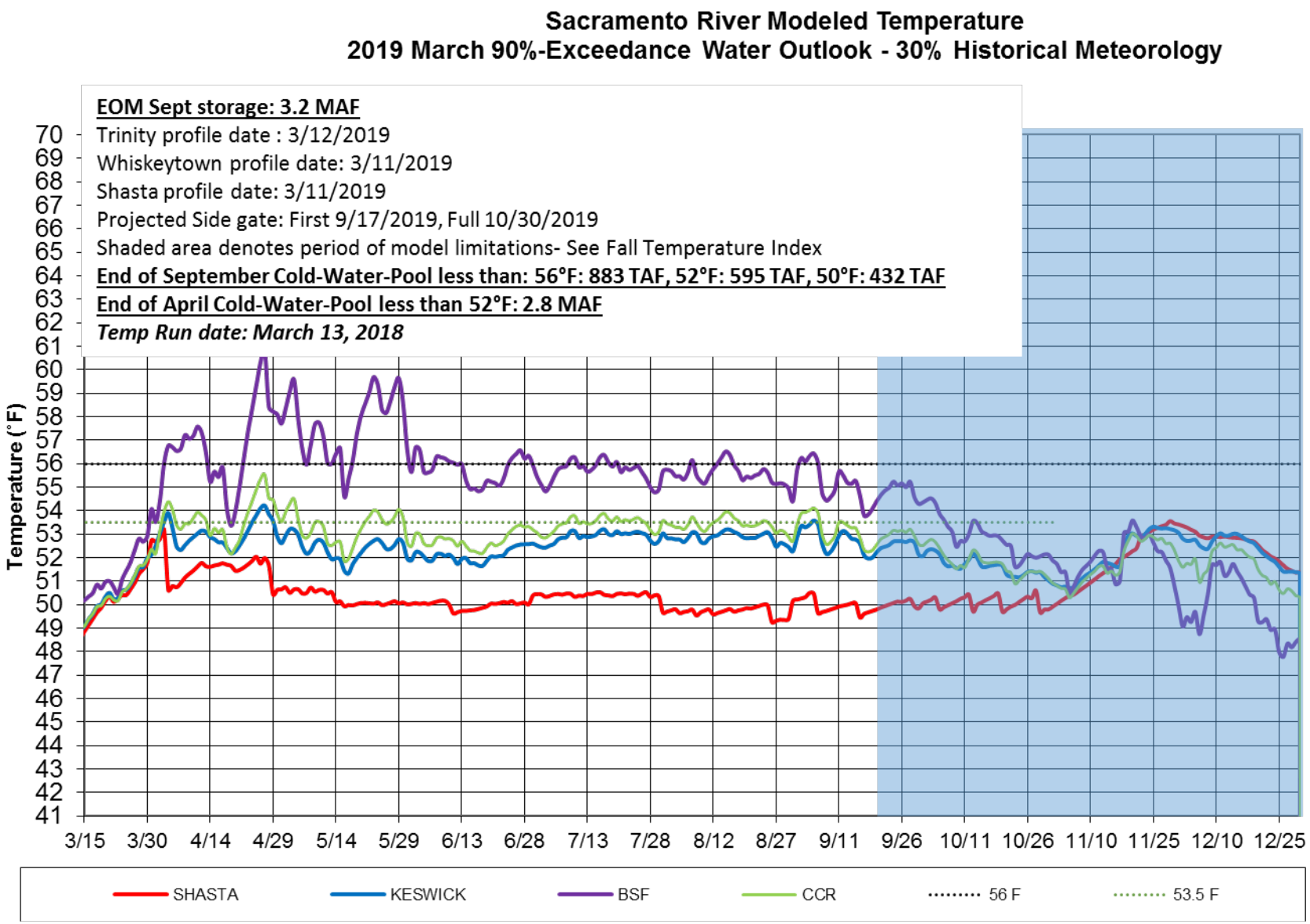

Figure 1. March 2019 simulated Sacramento River temperatures 90% runoff exceedance hydrology and 30% historical

meteorology.

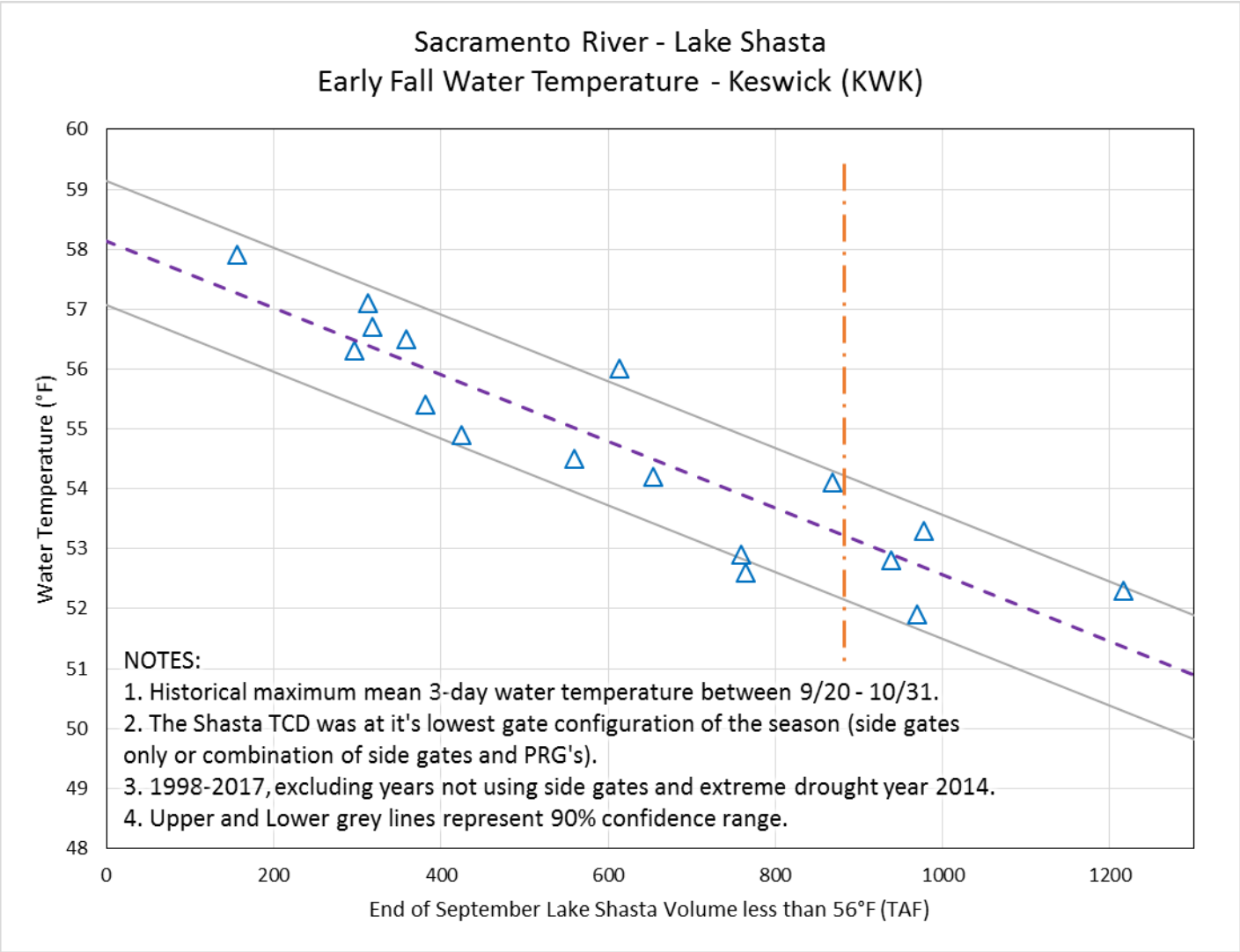

Figure 2. Historical relationship between Lake Shasta cold-water-pool characteristics and early fall Keswick water temperature and identifying relationship with 883 TAF end of September of cold-water-pool.

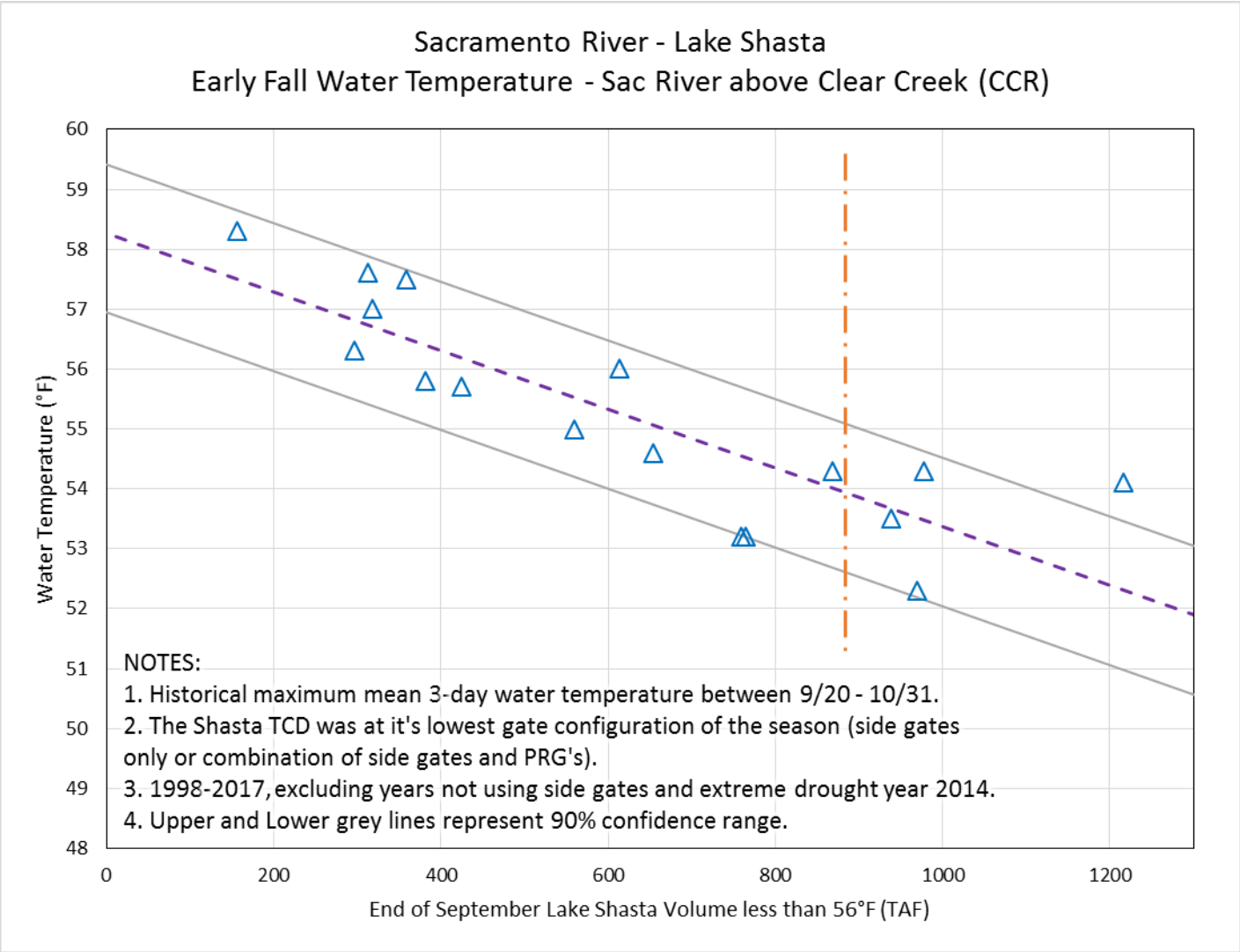

Figure 3. Historical relationship between Lake Shasta cold-water-pool characteristics and early fall Sacramento River above Clear Creek confluence water temperature and identifying relationship with 883 TAF end of September of cold-water-pool.

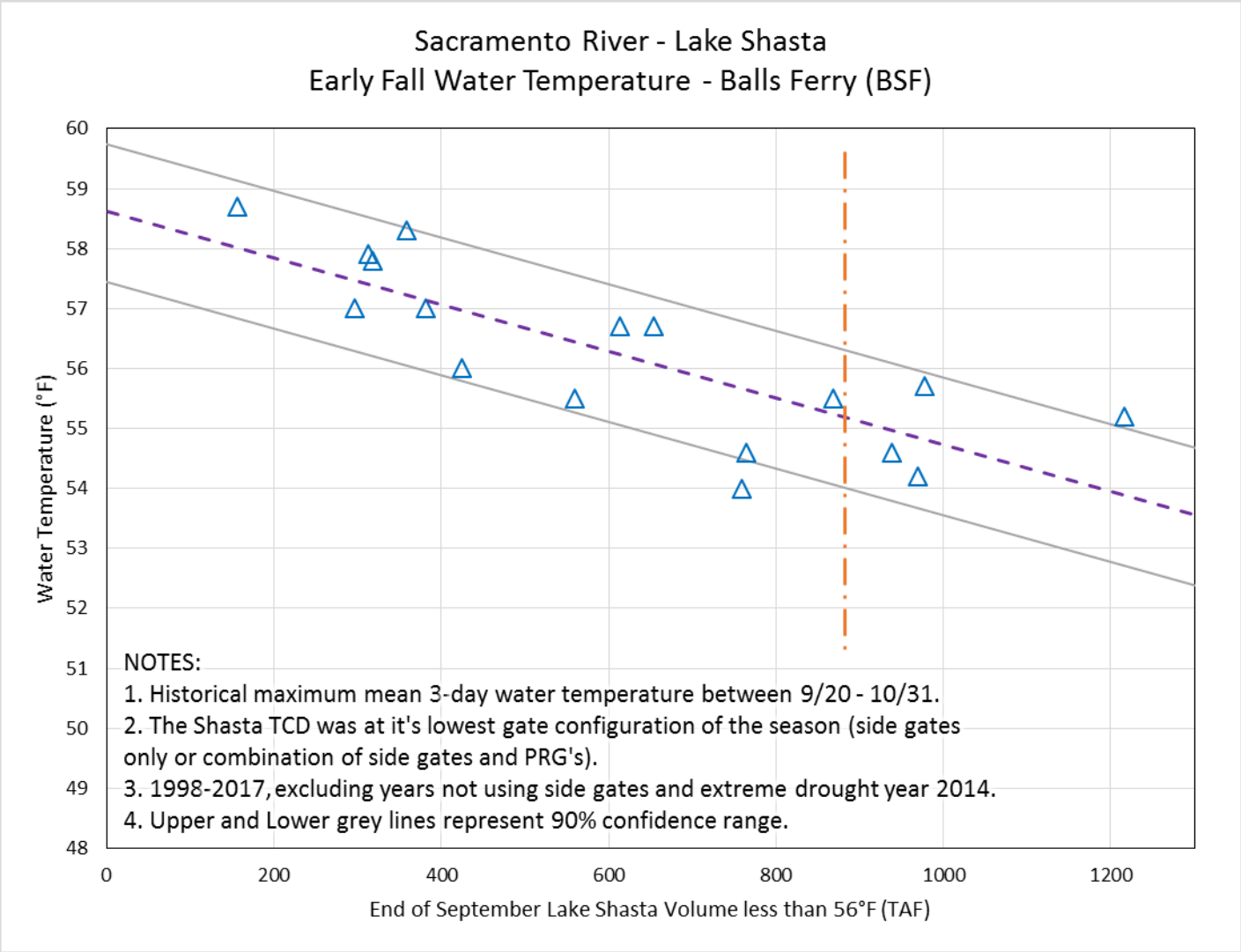

Figure 4. Historical relationship between Lake Shasta cold-water-pool characteristics and early fall Balls Ferry water temperature and identifying relationship with 883 TAF end of September of cold-water-pool.

* 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 2-4). 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 Model Inputs, Assumptions, Limitations and Uncertainty:

1. The latest available profiles for Shasta, Trinity, and Whiskeytown were taken on March 11, March 12, and March 11, respectively. Model results are sensitive to initial reservoir temperature conditions and the model performs best under highly stratified conditions. The March 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 low creek flows cause significant additional warming in the upper Sacramento River during spring.
3. Operation is based on the March 2019 Operation Outlooks (monthly flows, reservoir release, and end-of-month reservoir storage) for the 90%- and 50%-exceedances. 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 30% patterned after like months on a 6-hour time-step. Assumed inflows temperature remain static inputs and do not vary with the assumed meteorology. Tools to use long-term three-month-temperature outlooks, driven by the NOAA NWS Climate Prediction Center (CPC) are available beginning April, prior to April historical meteorology is used.
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, 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.

Supplemental Modeling Information

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

Location (°F DAT)	APR	MAY	JUN	JUL	AUG	SEP*	OCT*
February 90%-Exceedance Outlook – 50% Historical Meteorology							
Keswick Dam KWK	53.0	52.3	51.8	52.6	52.7	See Figures 5 and 8	See Figures 5 and 8
Sac. R. abv Clear Creek CCR	53.6	53.1	52.4	53.0	53.2	See Figures 5 and 9	See Figures 5 and 9
Balls Ferry BSF	56.5	57.2	55.3	55.0	55.4	See Figures 5 and 10	See Figures 5 and 10
February 50%-Exceedance Outlook – 30% Historical Meteorology							
Keswick Dam KWK	52.8	52.2	52.1	53.1	53.6	See Figures 6 and 8	See Figures 6 and 8
Sac. R. abv Clear Creek CCR	53.3	53.0	52.8	53.6	54.0	See Figures 6 and 9	See Figures 6 and 9
Balls Ferry BSF	56.0	57.1	56.0	55.9	56.0	See Figures 6 and 10	See Figures 6 and 10

Location (°F DAT)	APR	MAY	JUN	JUL	AUG	SEP*	OCT*
February 50%-Exceedance Outlook – 50% Historical Meteorology							
Keswick Dam KWK	52.6	52.1	51.9	52.7	53.4	See Figures 7 and 8	See Figures 7 and 8
Sac. R. abv Clear Creek CCR	53.1	52.8	52.5	53.2	53.8	See Figures 7 and 9	See Figures 7 and 9
Balls Ferry BSF	55.8	56.7	55.5	55.3	55.7	See Figures 7 and 10	See Figures 7 and 10

Model Run	End of September Cold Water Pool <56°F (TAF)	First Side Gate	Full Side Gates
90% Hydro, 50% Met	912	9/19/19	11/03/19
50% Hydro, 30% Met	682	9/13/19	10/24/19
50% Hydro, 50% Met	699	9/14/19	10/26/19

Model Run Date March 13, 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 2-4). 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 5 through 7. The relationship between end-of-September lake volume below 56°F and a Balls Ferry compliance through fall is based on the Figures 8-10.

Temperature Model Inputs, Assumptions, Limitations and Uncertainty:

1. The latest available profiles for Shasta, Trinity, and Whiskeytown were taken on March 11, March 12, and March 11, respectively. Model results are sensitive to initial reservoir temperature conditions and the model performs best under highly stratified conditions. The March 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 low creek flows cause significant additional warming in the upper Sacramento River during spring.
3. Operation is based on the March 2019 Operation Outlooks (monthly flows, reservoir release, and end-of-month reservoir storage) for the 90%- and 50%-exceedances. 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 30% and 50%

patterned after like months on a 6-hour time-step. Assumed inflows temperature remain static inputs and do not vary with the assumed meteorology. Tools to use long-term three-month-temperature outlooks, driven by the NOAA NWS Climate Prediction Center (CPC) are available beginning April, prior to April historical meteorology is used.

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, 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.

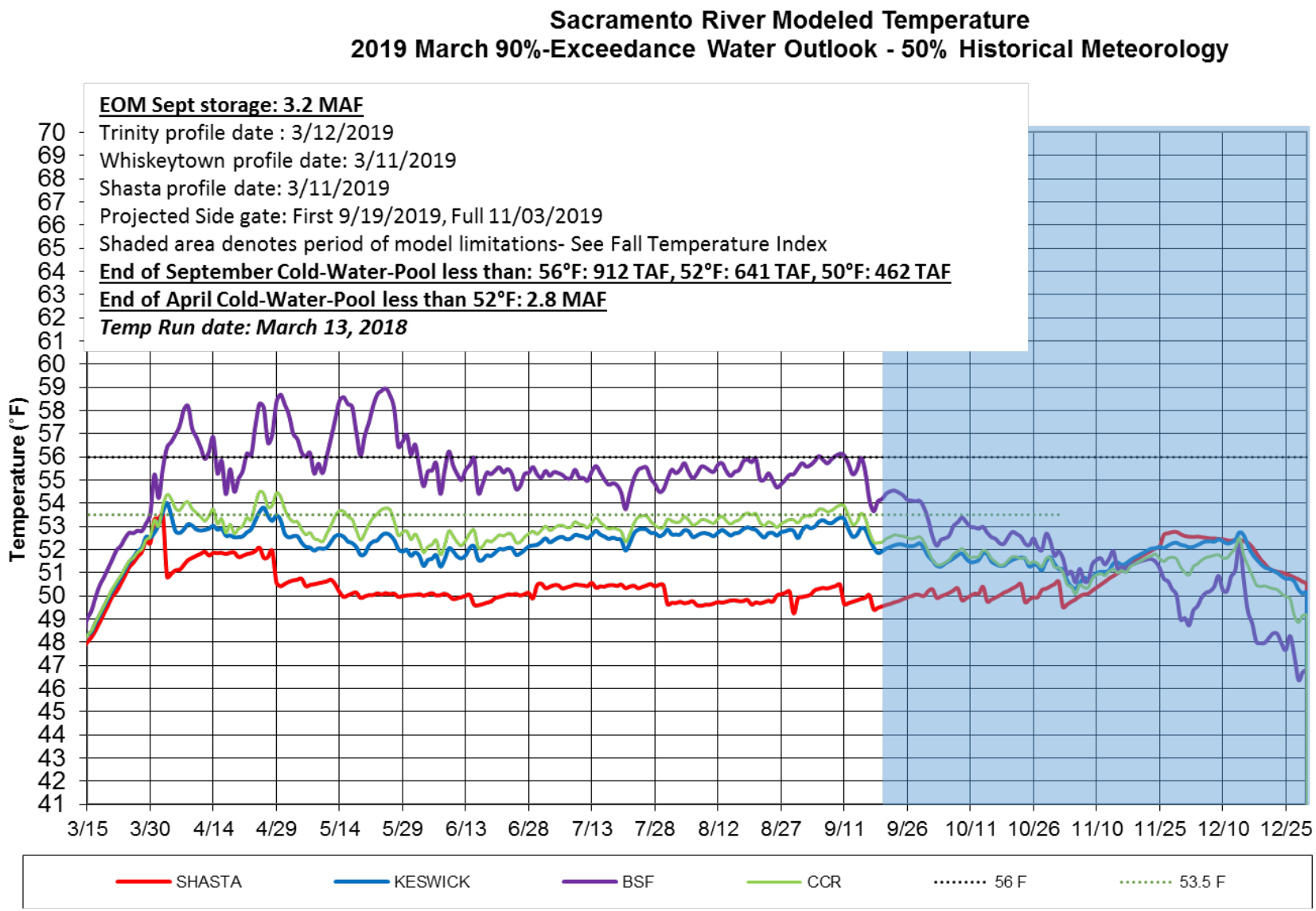

Figure 5. March 2019 simulated Sacramento River temperatures 90% runoff exceedance hydrology and 50% historical meteorology.

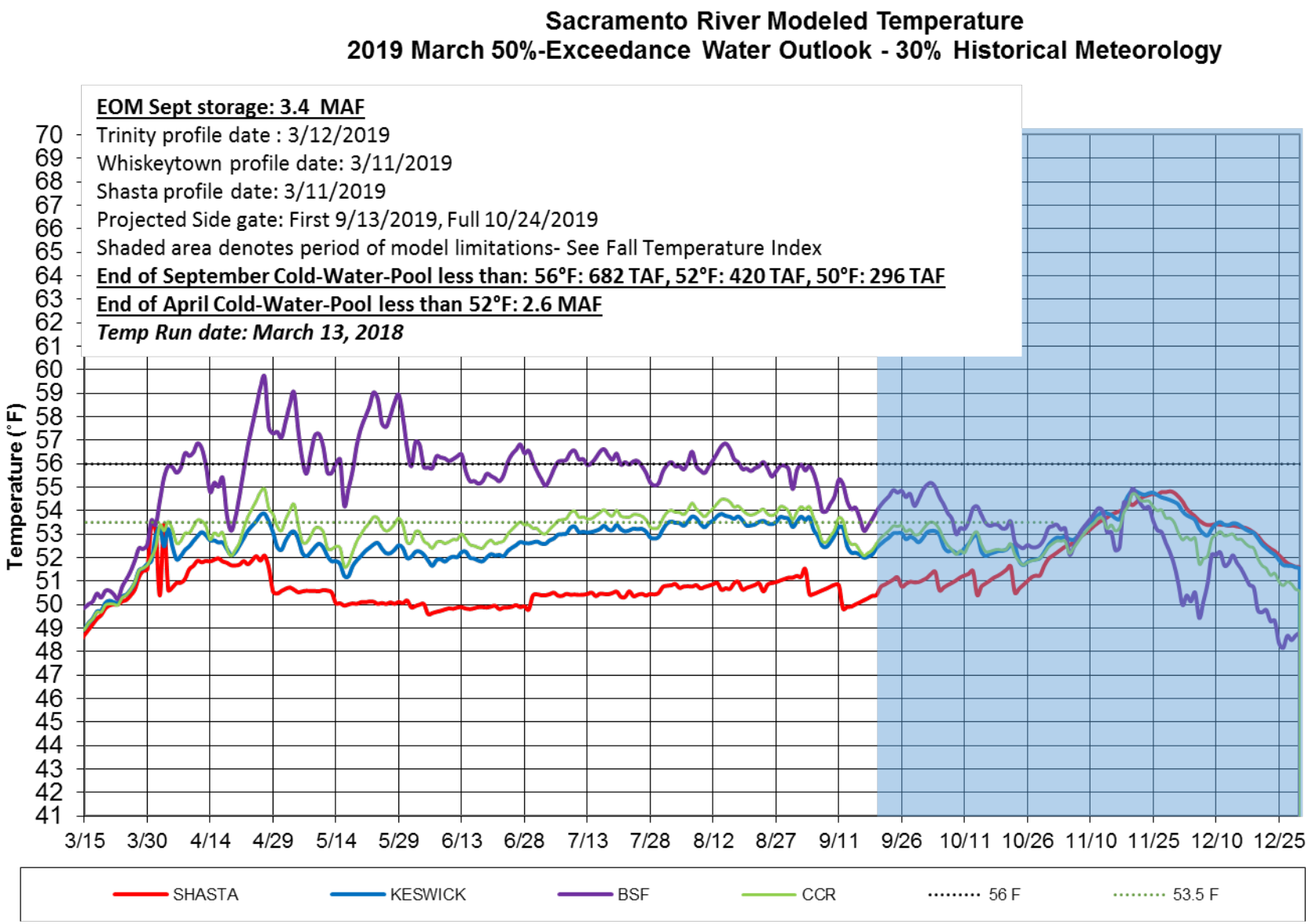

Figure 6. March 2019 simulated Sacramento River temperatures 50% runoff exceedance hydrology and 30% historical meteorology.

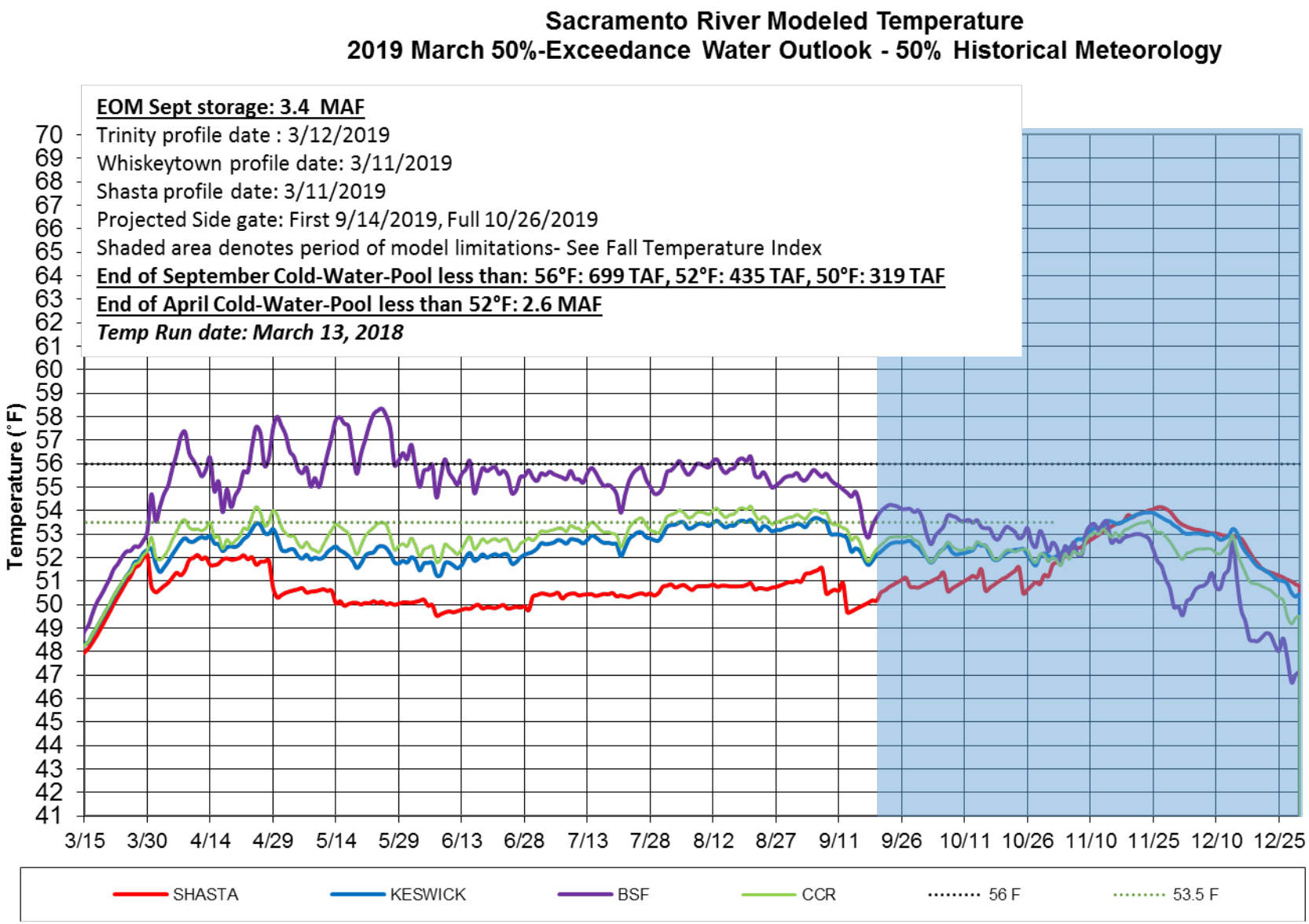

Figure 7. March 2019 simulated Sacramento River temperatures 50% runoff exceedance hydrology and 50% historical meteorology.

Figure 8-10 <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.

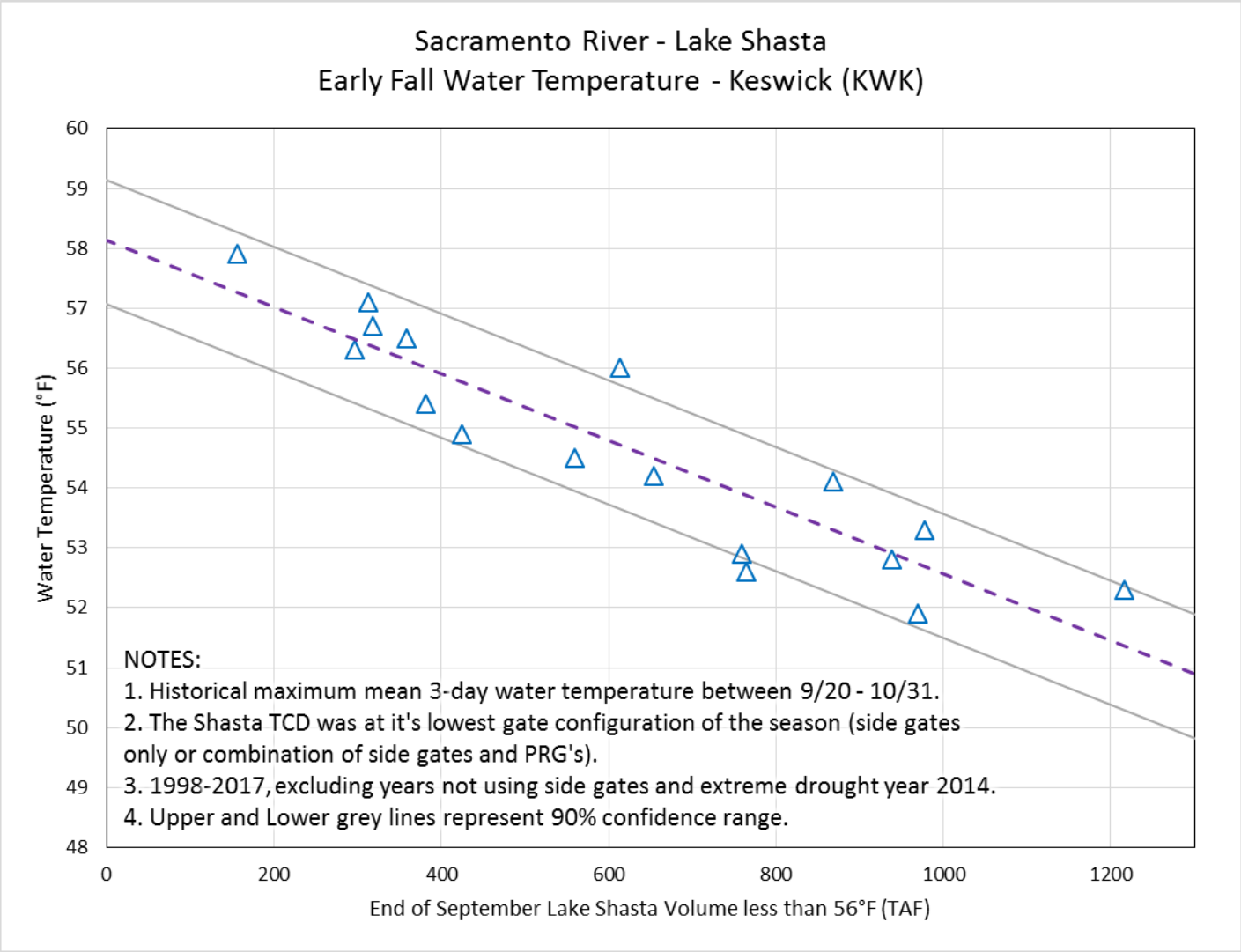

Figure 8. Historical relationship between Lake Shasta cold-water-pool characteristics and early fall Keswick water temperature.

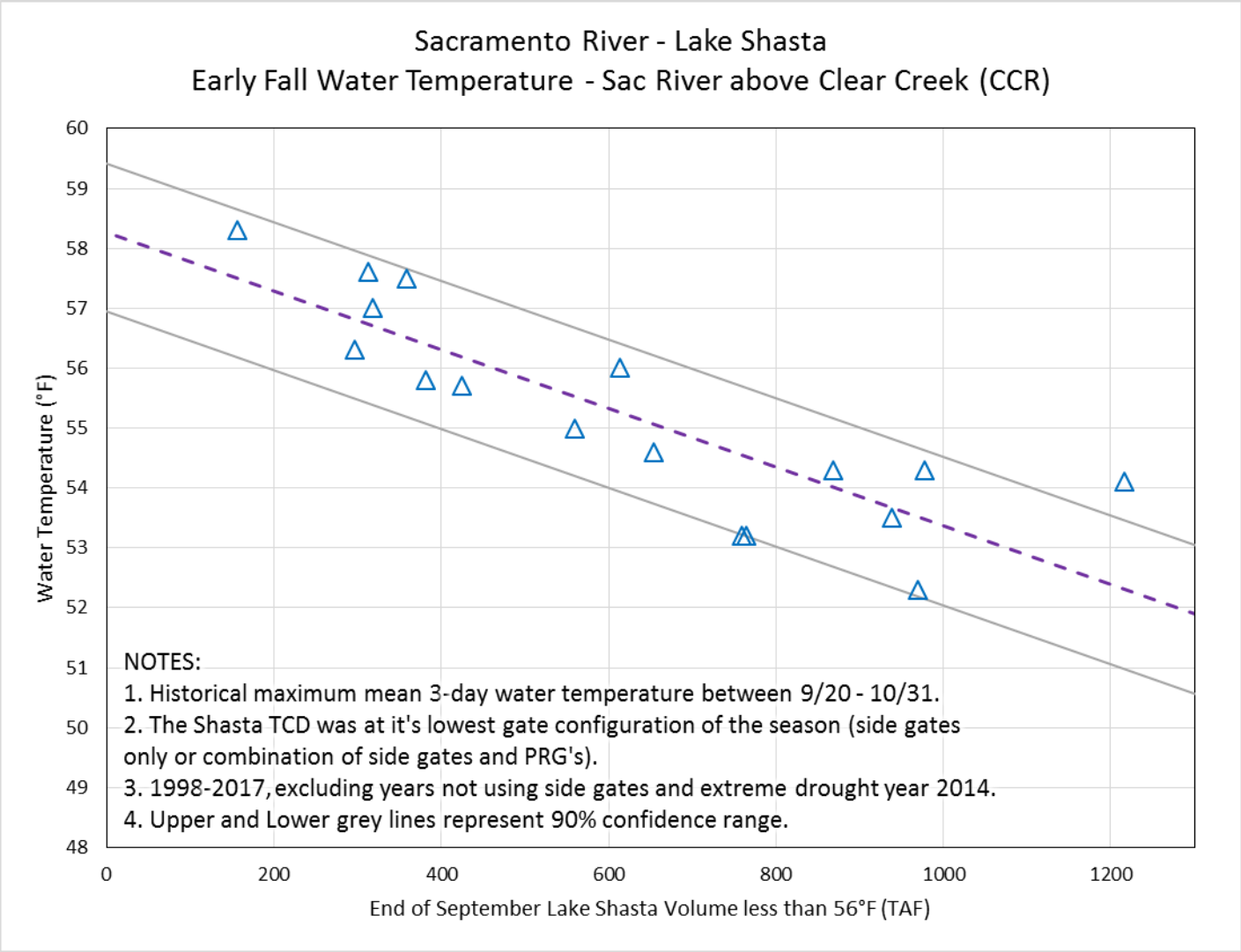

Figure 9. Historical relationship between Lake Shasta cold-water-pool characteristics and early fall Sacramento River above Clear Creek confluence water temperature.

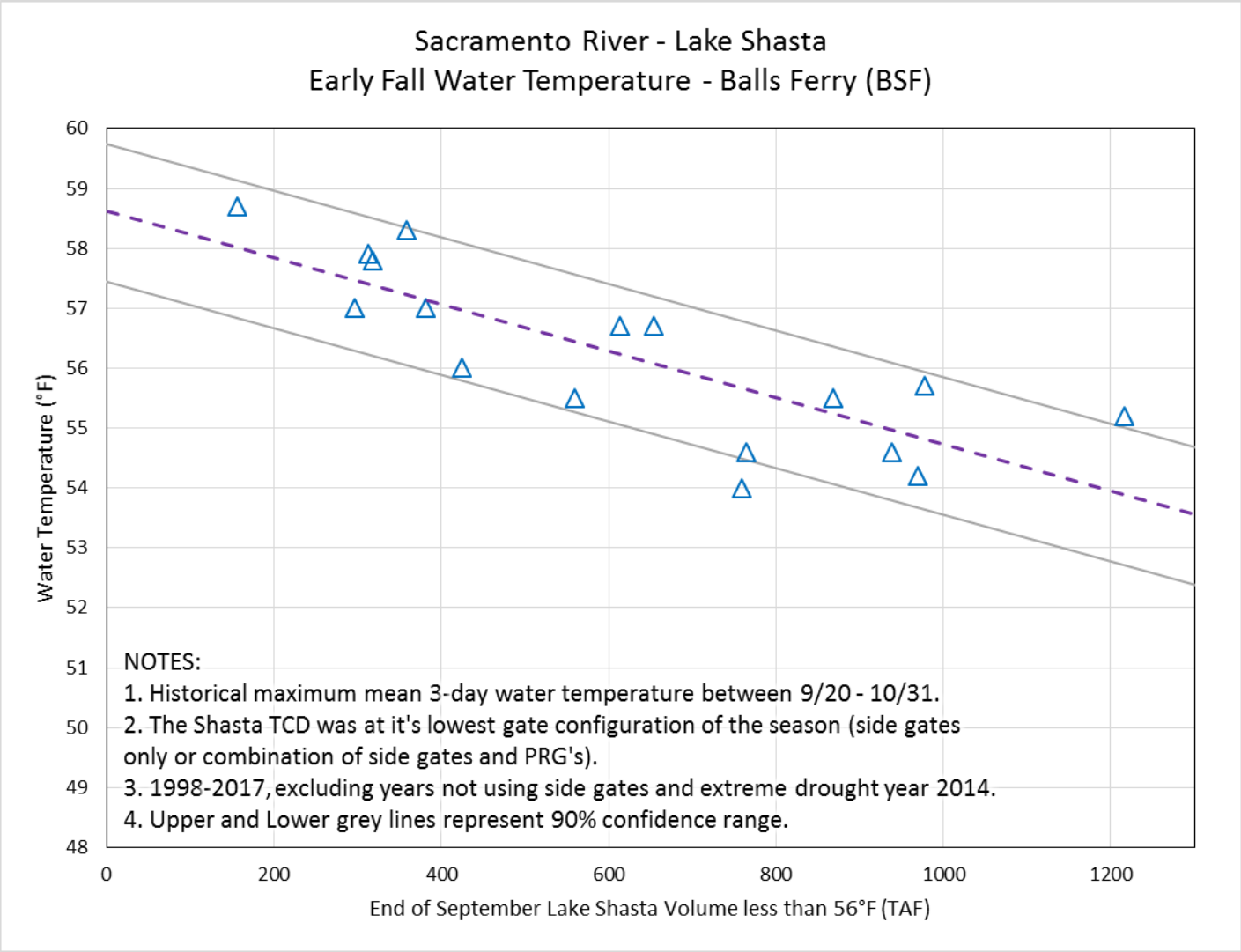

Figure 10. Historical relationship between Lake Shasta cold-water-pool characteristics and early fall Balls Ferry water temperature.