



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
2.2.4.23

MAY 15 2019

VIA ELECTRONIC MAIL

Mr. Erik Ekdahl
Deputy Director
Division of Water Rights
State Water Resources Control Board
1001 I Street
14th Floor, Office 54
Sacramento, CA 95814

Subject: 2019 Sacramento River Temperature Management Plan per Water Rights Order 90-5

Dear Mr. Ekdahl:

This letter transmits the Sacramento River Temperature Management Plan (SRTMP) for Water Year 2019 pursuant to Water Rights Order 90-5. The SRTMP represents a balanced approach to management of the cold water pool in Shasta Reservoir during the spring, summer, and fall of 2019. As detailed in the Draft Temperature Reporting and Coordination Protocol for Water Year 2019 that we transmitted to your office on December 14, 2018 (Enclosure 1), the Bureau of Reclamation worked cooperatively on the development of the SRTMP with State Water Resources Control Board, as well as the National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service, California Department of Fish and Wildlife, Western Area Power Administration, and other agencies represented on the Sacramento River Temperature Task Group (SRTTG) throughout the months of February through May.

Reclamation's plan includes input and recommendations from the SRTTG meetings on March 28, 2019, and April 25, 2019, as well as a public stakeholder meeting held on May 6, 2019. The SRTMP focuses on leveraging the Shasta Temperature Control Device capabilities and maintaining reasonable temperature targets that will maximize protection of the species, while ensuring cold water will be able to be effectively utilized through the season. This approach will also help Reclamation meet other obligations and maintain commitments for operation of the Central Valley Project (CVP) and State Water Project (SWP) in conjunction with the California Department of Water Resources.

Preliminary temperature operation modeling scenarios and results were distributed to the SRTTG this year on February 28, March 28, and April 24. In addition, Reclamation has provided additional modeling results and model output files throughout the spring to NMFS as part of the processes outlined under Reasonable and Prudent Alternative I.2.3 of the NMFS 2009 Biological

Opinion on the Coordinated Long-term Operation of the CVP and SWP. Reclamation solicited feedback from SRTTG members as well as stakeholders and interested parties throughout the Central Valley on the proposed operation/simulation results. Reclamation has developed the following plan based on recommendations from SRTTG members. No modifications to the plan were recommended by stakeholders and interested parties in response to the May 6 public stakeholder meeting.

The SRTMP consists of a compliance point at Balls Ferry, using a 56°F daily average temperature (DAT) metric from May 15 through October 31. The planned temperature management operation also includes an evaluation study similar to those conducted in several recent years, targeting 53.5°F DAT at the Sacramento River-Clear Creek (CCR) gauging station during the same time frame. Use of this location provides for targeting consistent temperatures closer to the location of actual anticipated spawning, which is an operational strategy Reclamation and NMFS have discussed over the past several years.

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. In addition, ongoing modeling results will be completed for each monthly SRTTG meeting and more often as necessary. These results will be considered should those results indicate increased (or decreased) risk to fall temperature performance. In the event that actual cold water pool conditions vary from what is projected, and the fall temperature performance appears at risk, Reclamation will reconvene the SRTTG in preparation for an “off-ramp” of the evaluation study. 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. 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.

Enclosed (Enclosure 2) are the operational forecasts as well as the latest temperature modeling results targeting 53.5°F DAT at the CCR gauging station May 15 through October 31. The runs include both the April 50 percent and 90 percent exceedance hydrology forecasts and operational outlooks, with meteorological forecasts at 50 percent and 25 percent exceedances. Operational release performance was based on the two probabilistic hydrologic assumptions rather than fixed flowrates; actual release operations are expected to be within the specified ranges on an average monthly basis based on the hydrologic and operational considerations at that time. For this reason, daily operations may vary higher or lower from the projected monthly averages. Results using the 90 percent exceedance hydrology forecast illustrate a projected end of September storage in Shasta Reservoir of approximately 2.9 million acre-feet. The simulation results indicated confidence in accomplishing temperature management, as proposed, with an end of September cold water pool less than 56°F of at least 700,000 acre-feet, and that the first side gate use of the Shasta Reservoir Temperature Control Device would begin between late September and early October, and full side gate use expected in late October or November.

Water Rights Order 90-5 requires Reclamation to “report any change in the location where it will meet the temperature requirement” of 56°F on the Sacramento River, and “file an operation plan showing Permittee’s strategy to meet the temperature requirement at the new location.” Given the terms of Order 90-5 and the commitments above, Reclamation believes the proposed SRTMP will accomplish temperature management of 56°F at a Balls Ferry compliance point and provide additional information for ongoing refinement of temperature management practices through the aforementioned evaluation study. Enclosed, for your reference, is a concurrence letter from NMFS regarding the SRTMP (Enclosure 3).

We look forward to working with you and your staff as we manage water resources and temperature this water year. Should you have questions or wish to discuss further, please feel free to contact me at jrieker@usbr.gov or (916) 979-2197.

Sincerely,



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Operations Manager

Enclosures

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cc: Continued from previous page.

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Enclosure 1

DRAFT
**Reclamation Temperature Reporting/Coordination Protocol Pursuant to Order 90-5
Water Year 2019**

December 14, 2018

Duration

The duration of this protocol will be for Water Year 2019. Reclamation is proposing a single year protocol in recognition of the fact that water operations and temperature management on the Sacramento River may undergo changes in 2019 and/or thereafter as the result of several ongoing processes. These processes include, but are not limited to the following:

- Development of new Biological Opinion(s) for the Central Valley Project as a result of the October 19, 2018 Presidential Memorandum on Promoting the Reliable Supply and Delivery of Water in the West
- Potential changes in future years associated with the State Water Resources Control Board (Board) update to the 2006 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary

Communication and Coordination

December 2018 through January 2019

Reclamation plans to provide monthly updates via email to the Sacramento River Temperature Task Group (SRTTG), outlining current river and reservoir conditions, operations, hydrology, meteorology, and long-range precipitation forecast information. Should any significant issues arise concerning temperature management for the 2019 season in this timeframe, an SRTTG meeting will be convened, as appropriate.

February through May 2019

Reclamation will convene SRTTG meetings from February through May on a monthly basis, or more often as necessary to ensure communication and coordination among the parties as planning is completed for the temperature management season.

Reclamation will prepare initial projections of anticipated temperature management capability and considerations in mid-February based on the February hydrologic and runoff forecasts from the Department of Water Resources and National Weather Service River Forecast Center. These projections are anticipated to be shared with the SRTTG in the third full week of February, and represents the initiation of the process for developing temperature management plans for the year, recognizing that the forecasts remain highly uncertain this early in the year. The initial projections are also anticipated to be utilized for the activities associated with Action I.2.3 of the NMFS Biological Opinion.

Reclamation will prepare updated projections of anticipated temperature management capability and considerations in mid-March and mid-April as updated hydrologic forecasts become available, and more often should sufficient new information warrant. These updated projections

will be shared with the SRTTG in advance of scheduled SRTTG meetings, and will assist with ongoing development of an initial draft temperature management plan. Reclamation anticipates having that initial draft temperature management plan prepared in association with the April SRTTG meeting, which is currently anticipated to occur on or about April 25, 2019. This schedule will provide for coordination with the NMFS Biological Opinion process, and specifically Action I.2.4 of the NMFS Biological Opinion.

Reclamation anticipates presenting the initial draft temperature management plan at a stakeholder meeting to include Central Valley Project and State Water Project water and power contractors, Tribes, non-governmental organizations, and other interested parties during the first full week of May. Based on feedback from that meeting and any other ongoing dialog among the SRTTG, Reclamation anticipates submitting a final temperature management plan to the Board on or about May 15, 2019. This timing will also provide for coordination with the requirements under Action I.2.4 of the NMFS Biological Opinion.

June through October 2019

Reclamation plans to convene SRTTG meetings each month through October, or more often as warranted by any changing conditions, to ensure tracking and monitoring of the temperature management plan. Should changes to the plan be necessary, those changes will be developed through communication and coordination with the SRTTG, and other interested parties as warranted.

Changes in Regulations or Operating Agreements

Should any relevant regulations or agreements change prior to October 2019, Reclamation will review this protocol and contact the Board with any necessary changes to it. This includes any relevant new Biological Opinions.

Extreme Conditions

Though the above communication and coordination protocol is designed to provide for adequate interaction across any hydrologic or operational conditions faced in 2019, should drought or other extreme conditions require Reclamation to deviate from the above protocol, Reclamation anticipates these deviations would follow the process outlined in Action I.2.3.C of the NMFS Biological Opinion. Reclamation will contact the Board should conditions warrant changes to this protocol based on extreme conditions.

Reclamation further intends to inform the Board as soon as practicable regarding any change in circumstances, obligations or operations relevant to this protocol.

Monitoring and Reporting

For Water Year 2019, Reclamation plans to continue the monitoring and reporting practices that have been conducted throughout the 2018 Water Year. These include the following:

- Monthly letters to the Board containing relevant data and information as identified in Order 90-5 (example from November 2018 enclosed)
- Near-real time reporting through Reclamation’s web interface of relevant information, located at the following website: <https://www.usbr.gov/mp/cvo/vungvari/sactemprpt.pdf>
- Transmittal of pertinent data and information to the SRTTG prior to meetings or more often as conditions warrant, including applicable modeling and tracking information during the course of the temperature management season. It is anticipated that the specifics of the modeling and tracking information that will be utilized in 2019 will be outlined in the development of the final temperature management plan for the year.

Reclamation intends to provide temperature profile measurements for Shasta, Whiskeytown, and Trinity Reservoirs in Water Year 2019 as shown in the following table:

Reservoir	Every Month	Every Two Weeks	Every Week	Comment
Shasta	01/01 – 03/01 12/1 – 12/31	03/01 – 05/01 11/15 – 12/01	05/01 – 11/15	25 ft intervals for “Every Month”, otherwise 5 ft intervals
Whiskeytown	01/01 – 12/31	N/A	N/A	25 ft intervals
Trinity	01/01 – 12/31	N/A	N/A	25 ft intervals

The time and depth intervals identified above are linked to the historical stratification and de-stratification of the lakes. When de-stratified and temperature management is inactive, a finer resolution of the thermal profile at Shasta Reservoir is not needed.

Reclamation believes that monthly temperature profiles for Whiskeytown and Trinity are sufficient to capture the thermal dynamics; both have limited abilities to actively manage selective withdrawal and the cold-water-pool volume does not rapidly change for most of the year. Reclamation will post the corresponding isothermobaths on our website identified above as soon as the information becomes available.

As in past years, Reclamation intends to rely on the California Department of Fish and Wildlife’s (CDFW) redd dewatering monitoring program for 2019 to provide information on potential redd dewatering and stranding for informing real-time operations of Shasta and Keswick Dams. Reclamation will continue to coordinate with CDFW on river operations and any flood control releases to ensure this program can be safely and effectively implemented.

It is Reclamation’s understanding that the manner in which the information is provided on Reclamation’s website and in its letters currently meets the needs of the Board and fisheries agencies for the locations currently being monitored. Should the Board or fisheries agencies require the data from any of the monitoring stations outlined above in other formats, or obtain data from other monitoring sites that Reclamation maintains or has access to, Reclamation can work with the Board or fisheries agencies to provide that data.

Enclosure 2

Estimated CVP Operations 90% 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	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	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)

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

Water Year Inflow (TAF)	Trinity	Shasta	Folsom	New Melones
Year to Date + Forecasted	1506	6,804	3,598	1483
% 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.

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	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

Water Year Inflow (TAF)	Trinity	Shasta	Folsom	New Melones
Year to Date + Forecasted	1592	7,119	3,967	1661
% 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.

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.

Sacramento River Modeled Temperature 2019 April 90%-Exceedance Water Outlook - 25% L3MTO Meteorology

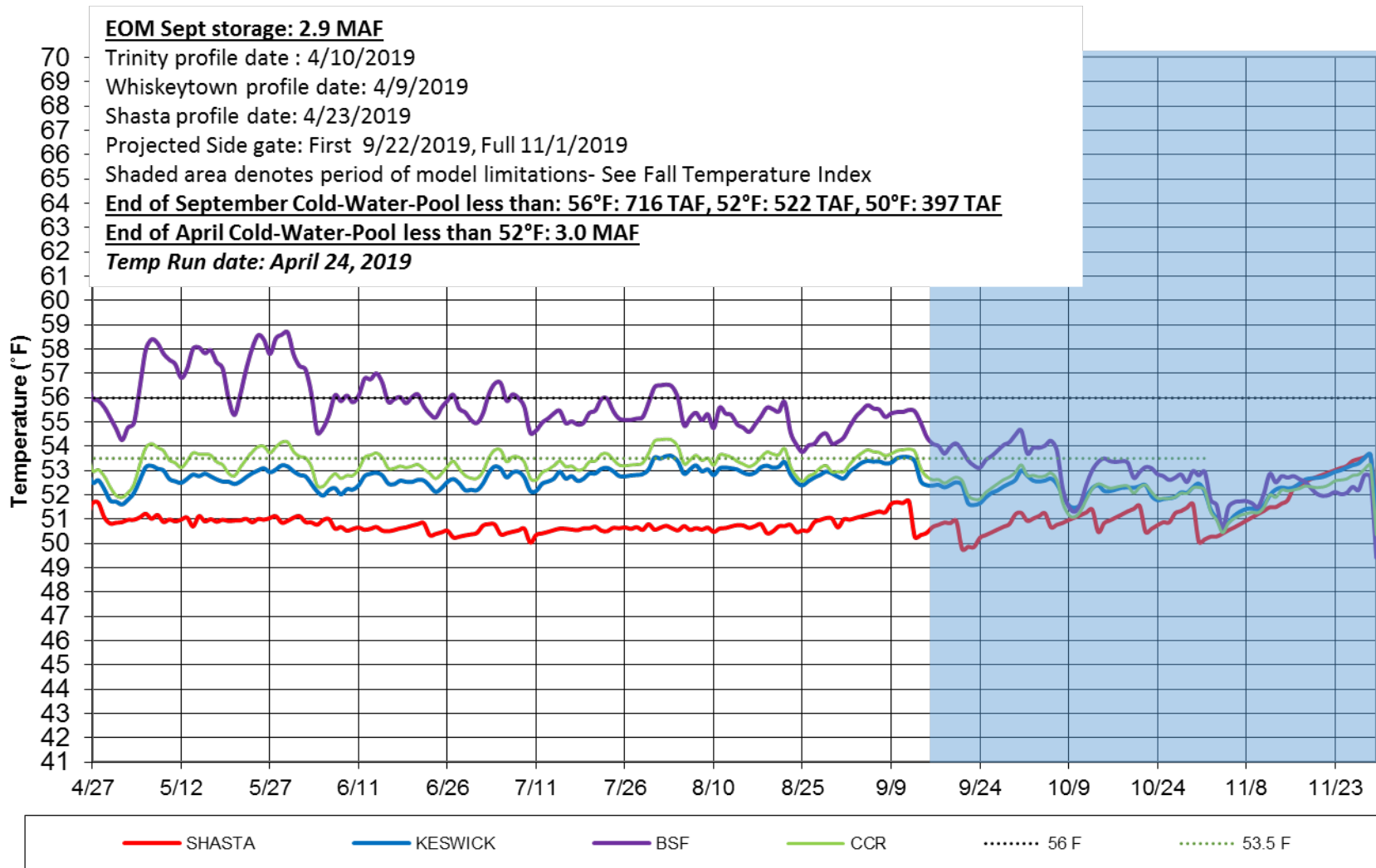


Figure 1. April 2019 simulated Sacramento River temperatures 90% runoff exceedance hydrology and 25% L3MTO meteorology.

Sacramento River Modeled Temperature 2019 April 90%-Exceedance Water Outlook - 50% L3MTO Meteorology

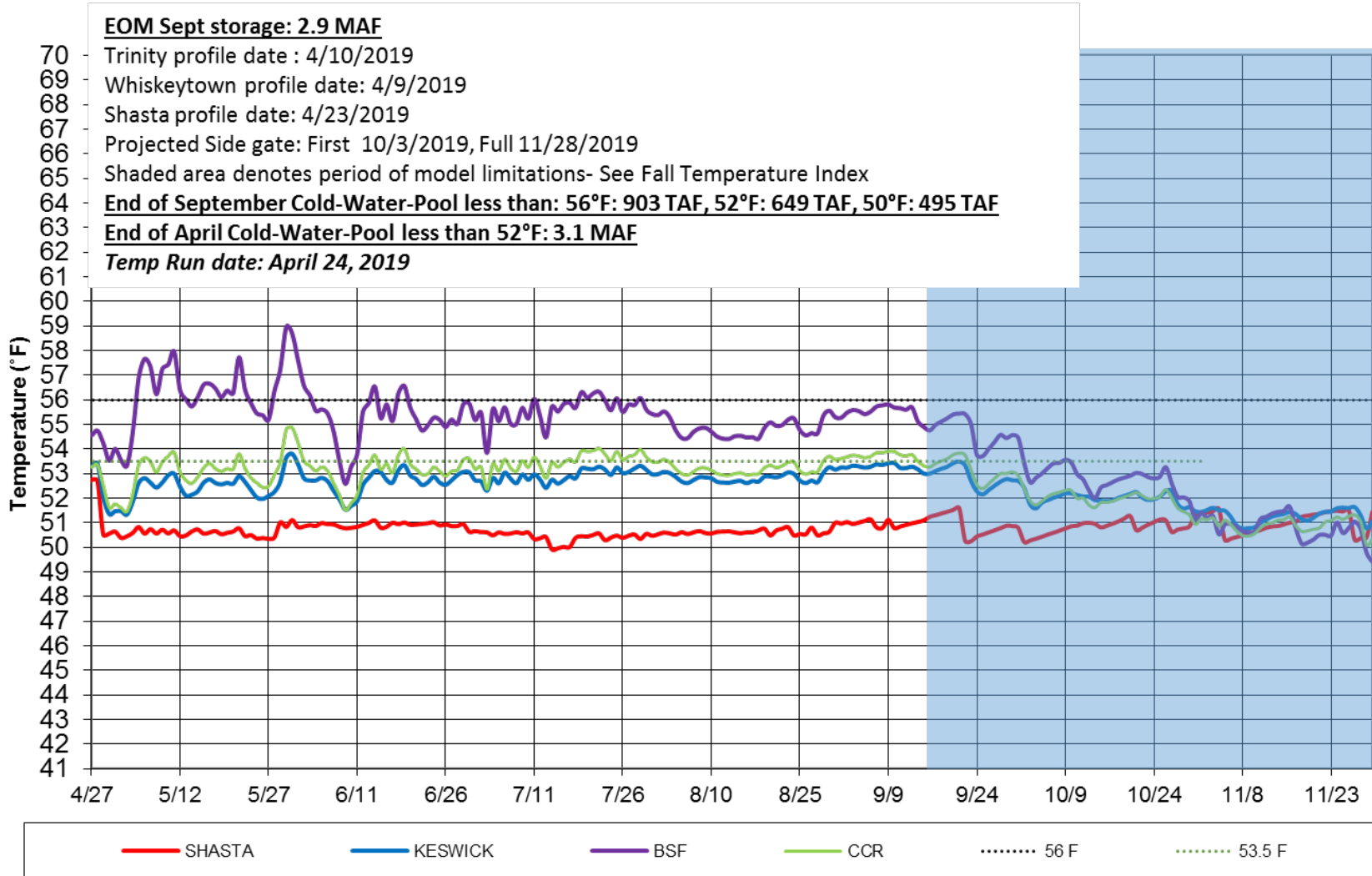


Figure 2. April 2019 simulated Sacramento River temperatures 90% runoff exceedance hydrology and 50% L3MTO meteorology.

Sacramento River Modeled Temperature 2019 April 50%-Exceedance Water Outlook - 25% L3MTO Meteorology

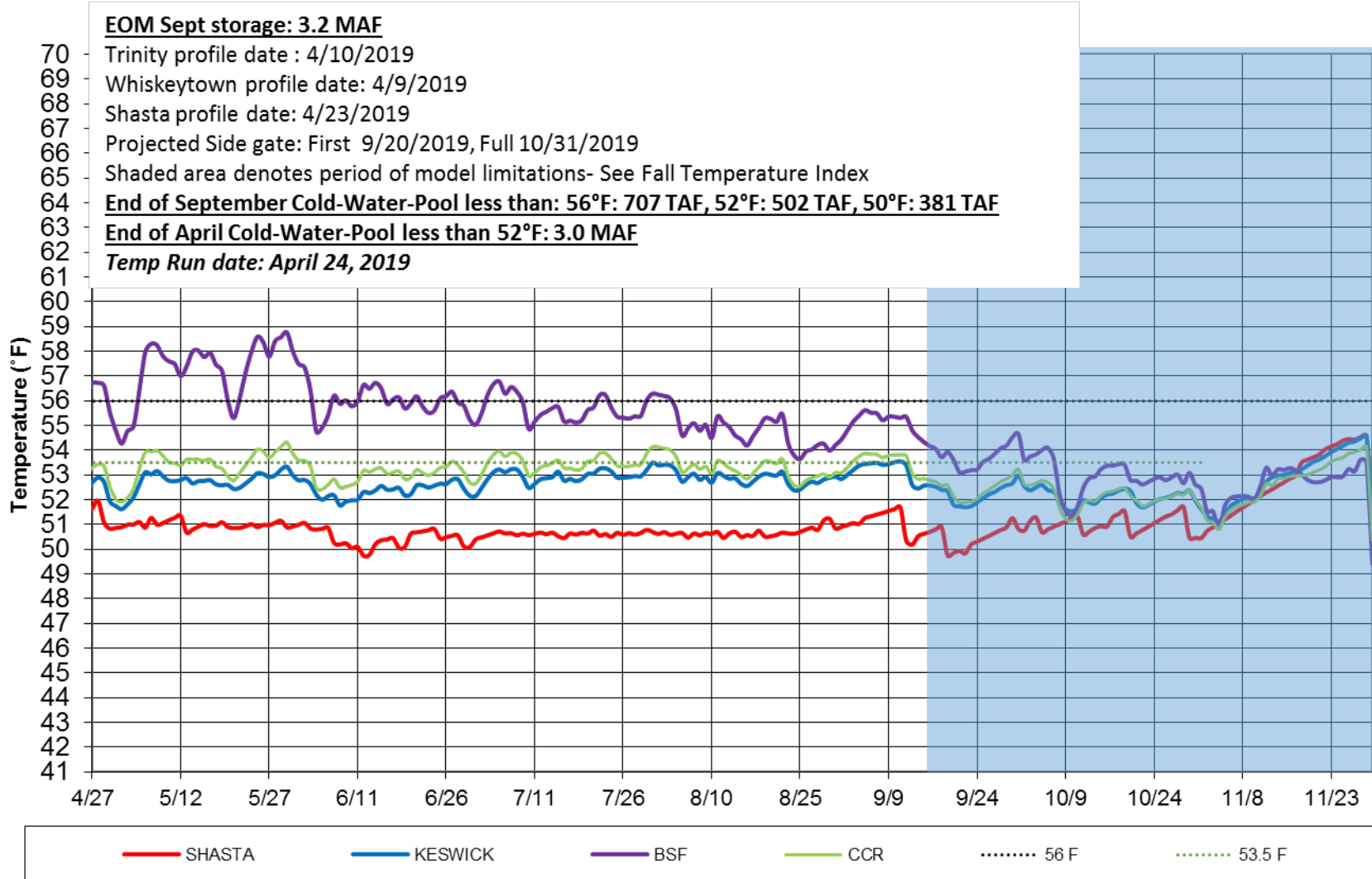


Figure 3. April 2019 simulated Sacramento River temperatures 50% runoff exceedance hydrology and 30% L3MTO meteorology.

Sacramento River Modeled Temperature 2019 April 50%-Exceedance Water Outlook - 50% L3MTO Meteorology

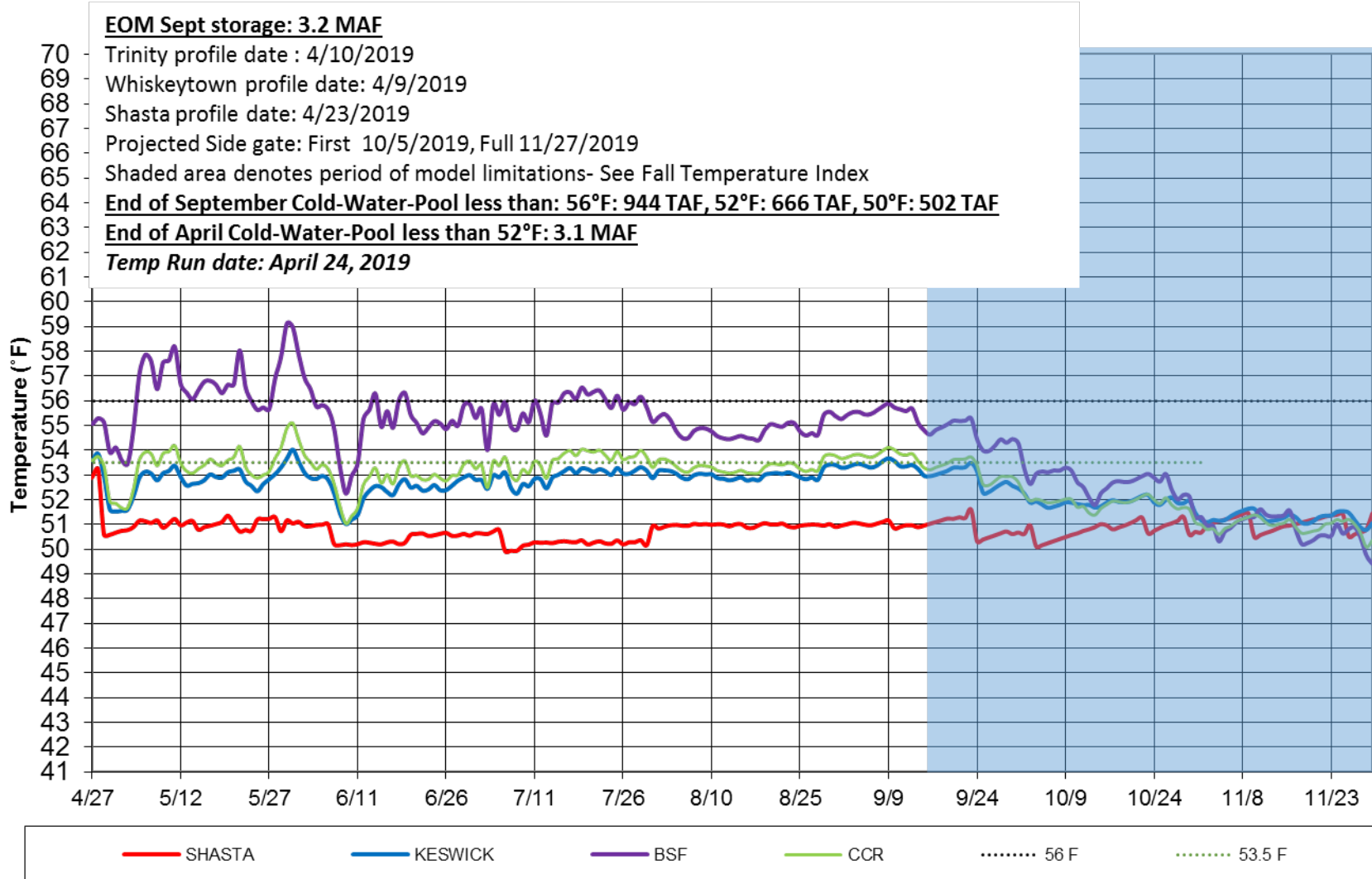


Figure 4. April 2019 simulated Sacramento River temperatures 50% runoff exceedance hydrology and 50% L3MTO meteorology

Figure 5-7 Model Performance and Fall Temperature Index:

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.

Sacramento River - Lake Shasta
 Early Fall Water Temperature - Keswick (KWK)

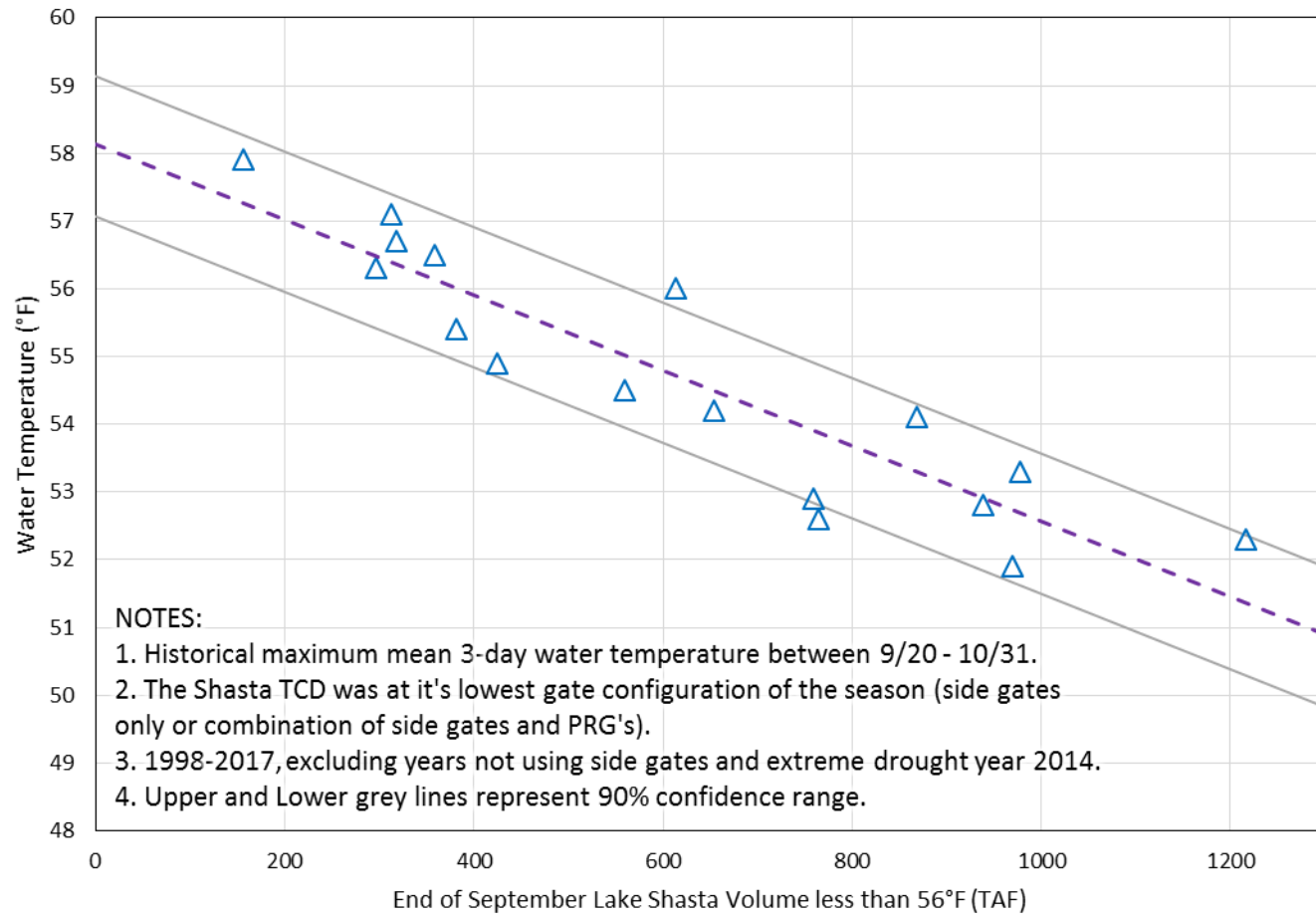


Figure 5. Historical relationship between Lake Shasta cold-water-pool characteristics and early fall Keswick water temperature.

Sacramento River - Lake Shasta
Early Fall Water Temperature - Sac River above Clear Creek (CCR)

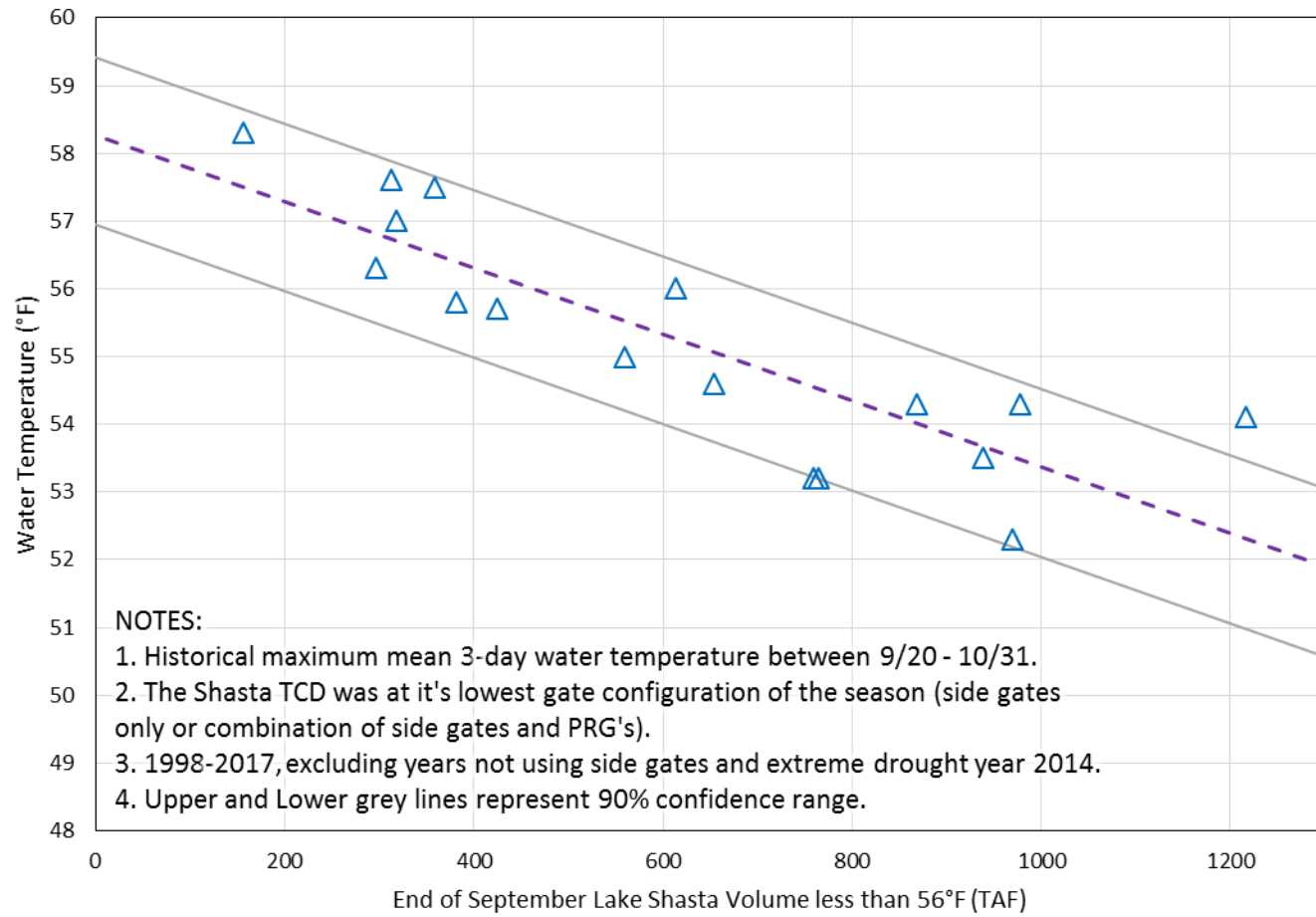


Figure 6. Historical relationship between Lake Shasta cold-water-pool characteristics and early fall Sacramento River above Clear Creek confluence water temperature.

Sacramento River - Lake Shasta
 Early Fall Water Temperature - Balls Ferry (BSF)

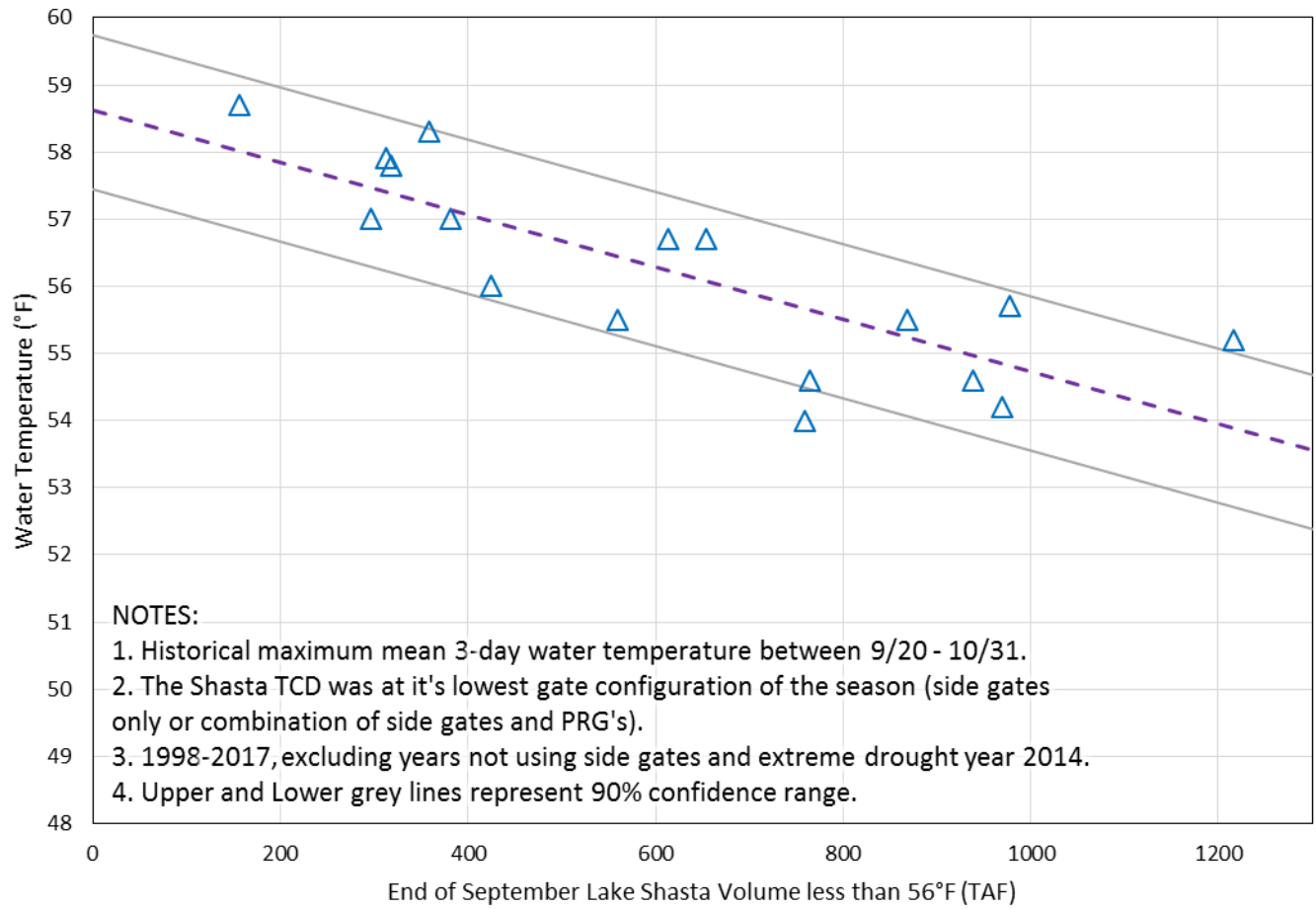
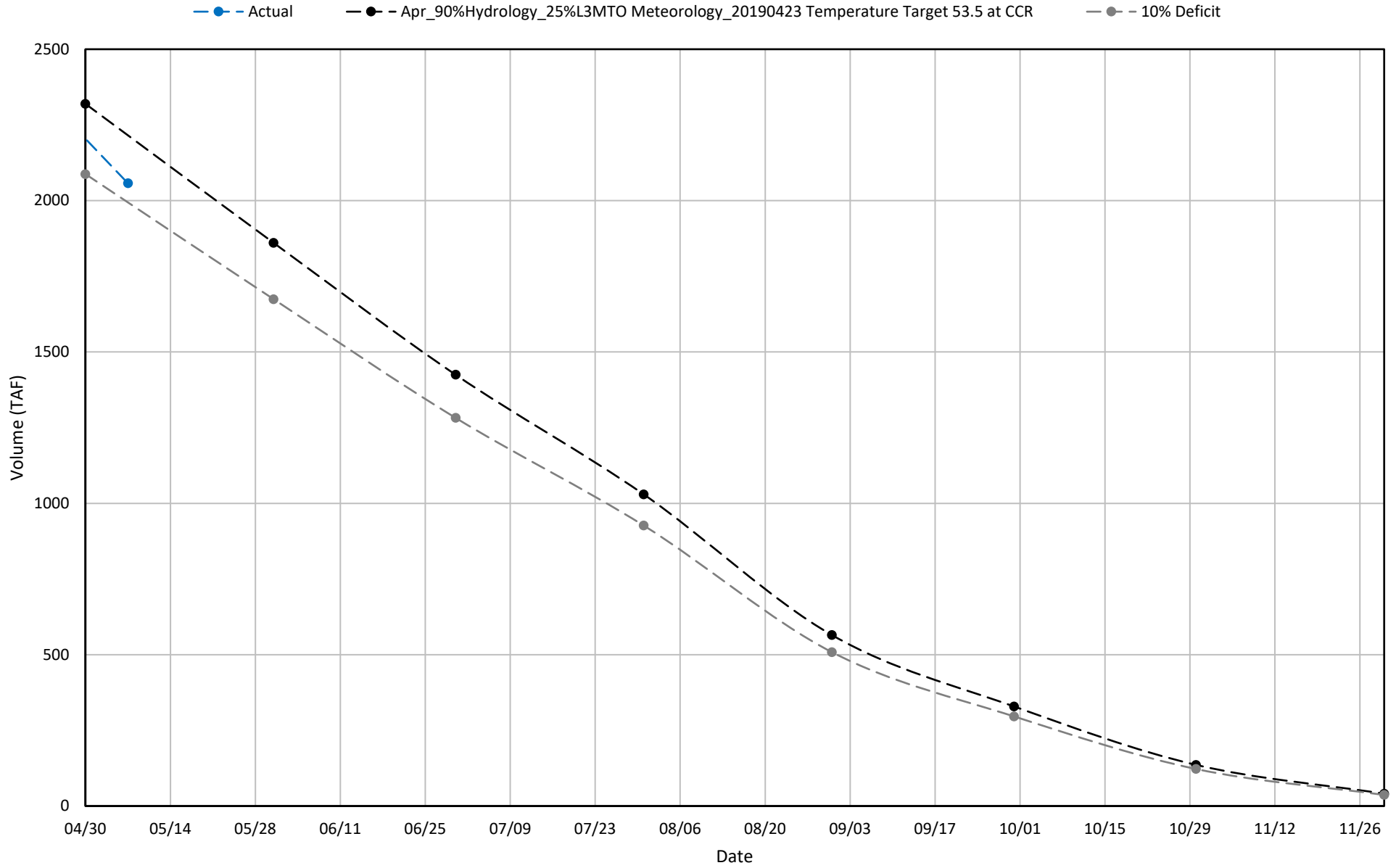


Figure 7. Historical relationship between Lake Shasta cold-water-pool characteristics and early fall Balls Ferry water temperature.

2019 Shasta Cold Water Pool Volume $\leq 49^{\circ}\text{F}$



Enclosure 3



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.

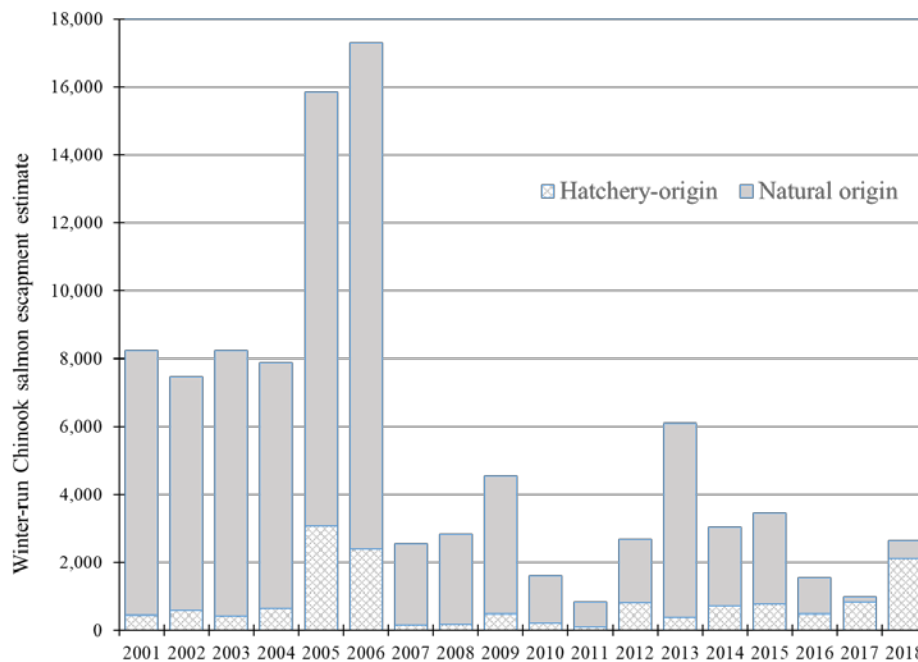


Figure 1. Winter-run Chinook salmon escapement from 2001-2018, with proportion hatchery origin and natural origin.

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.

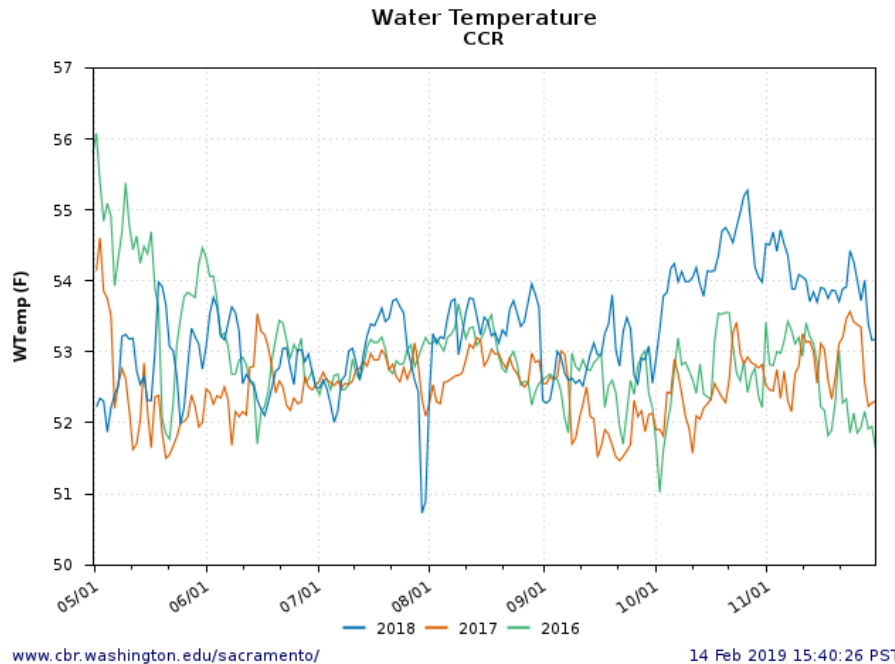


Figure 2. Water temperatures at the CCR California Data Exchange Center gaging station in 2016-2018. Source: www.cbr.washington.edu/sacramento/.

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.

Summary and Expectations

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

Electronic copy only:

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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	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

Water Year Inflow (TAF)	Trinity	Shasta	Folsom	New Melones
Year to Date + Forecasted	1506	6,804	3,598	1483
% 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.

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	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)

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

Water Year Inflow (TAF)	Trinity	Shasta	Folsom	New Melones
Year to Date + Forecasted	1592	7,119	3,967	1661
% 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.

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.

Sacramento River Modeled Temperature 2019 April 90%-Exceedance Water Outlook - 25% L3MTO Meteorology

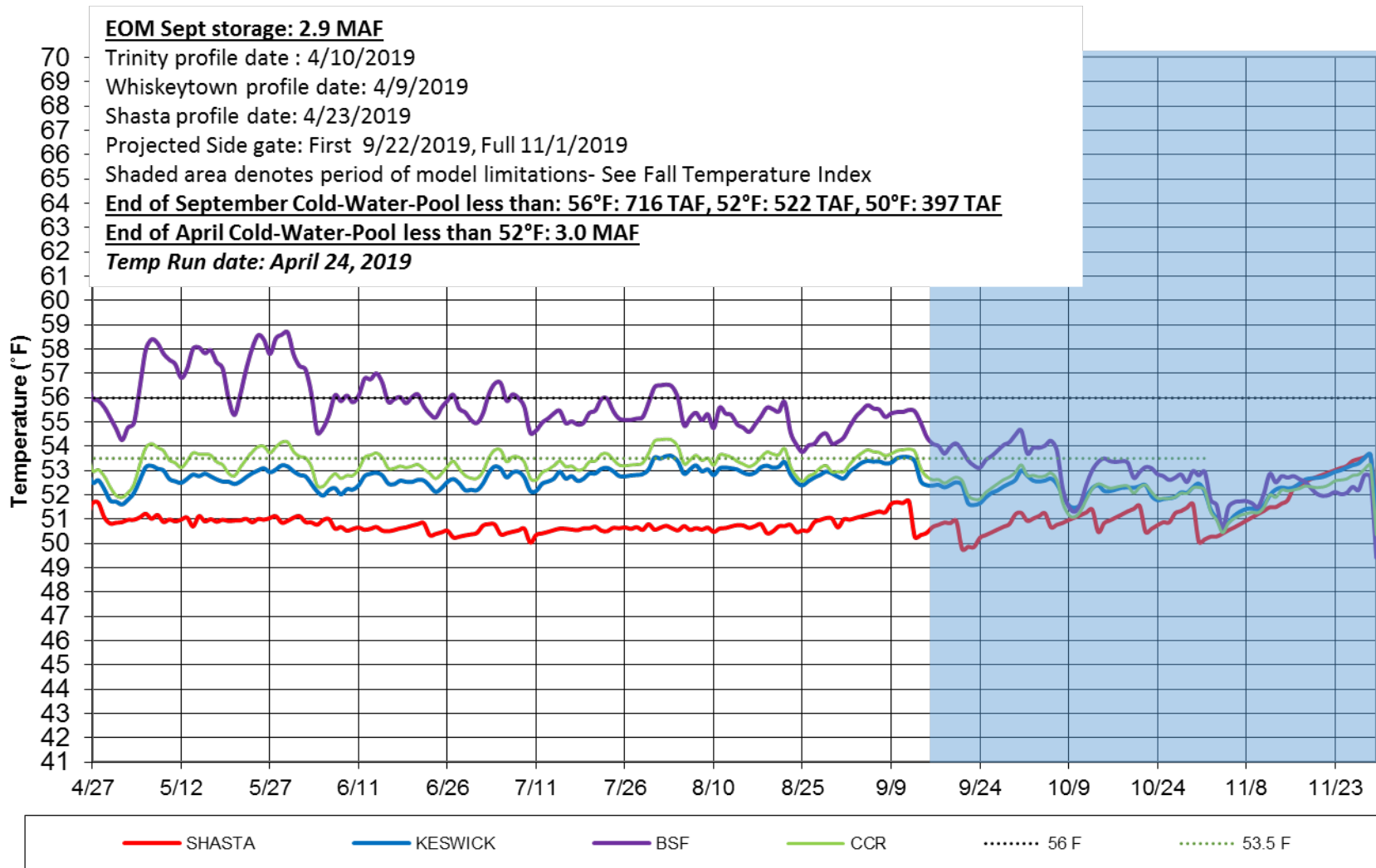


Figure 1. April 2019 simulated Sacramento River temperatures 90% runoff exceedance hydrology and 25% L3MTO meteorology.

Sacramento River Modeled Temperature 2019 April 90%-Exceedance Water Outlook - 50% L3MTO Meteorology

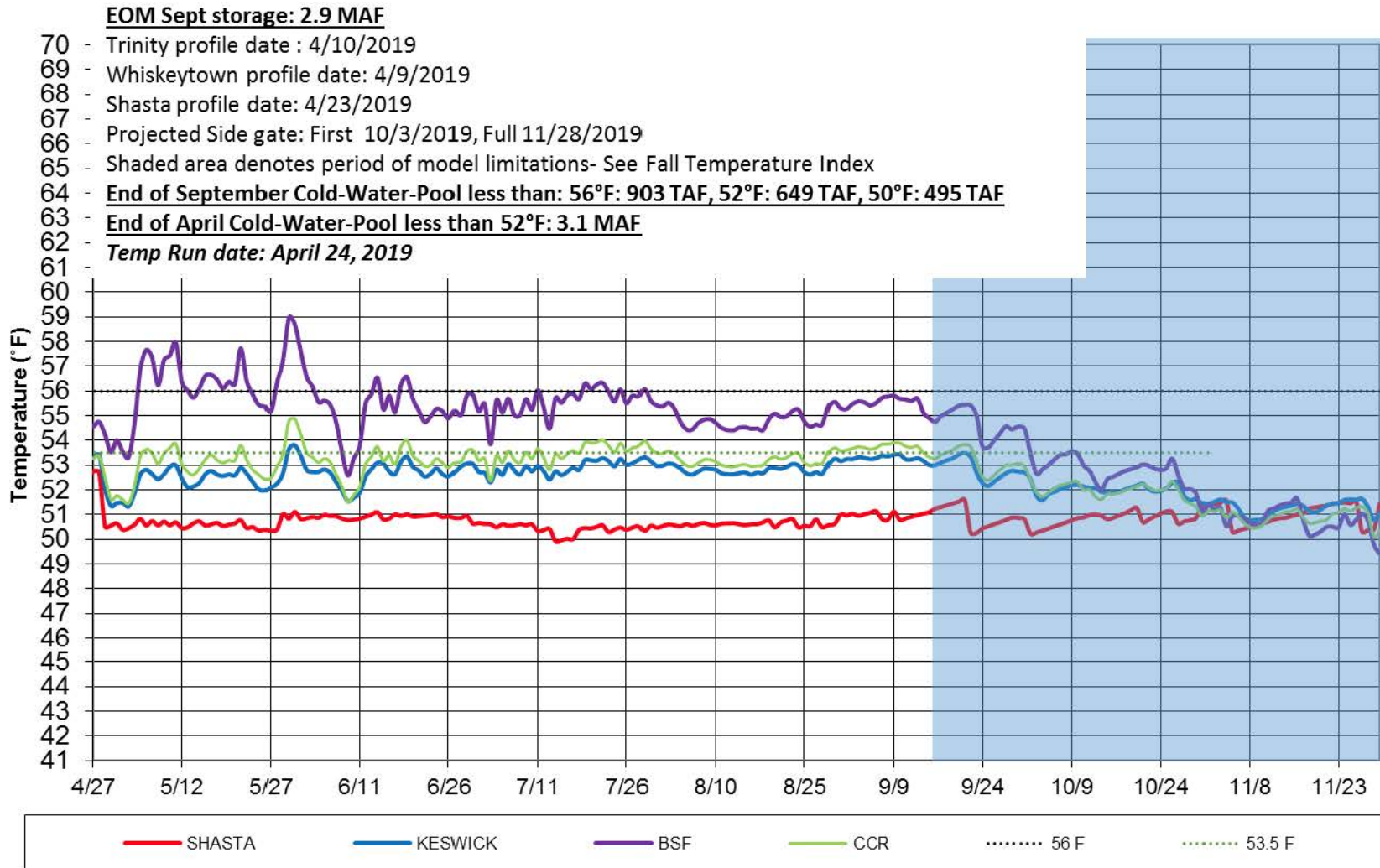


Figure 2. April 2019 simulated Sacramento River temperatures 90% runoff exceedance hydrology and 50% L3MTO meteorology.

Sacramento River Modeled Temperature 2019 April 50%-Exceedance Water Outlook - 25% L3MTO Meteorology

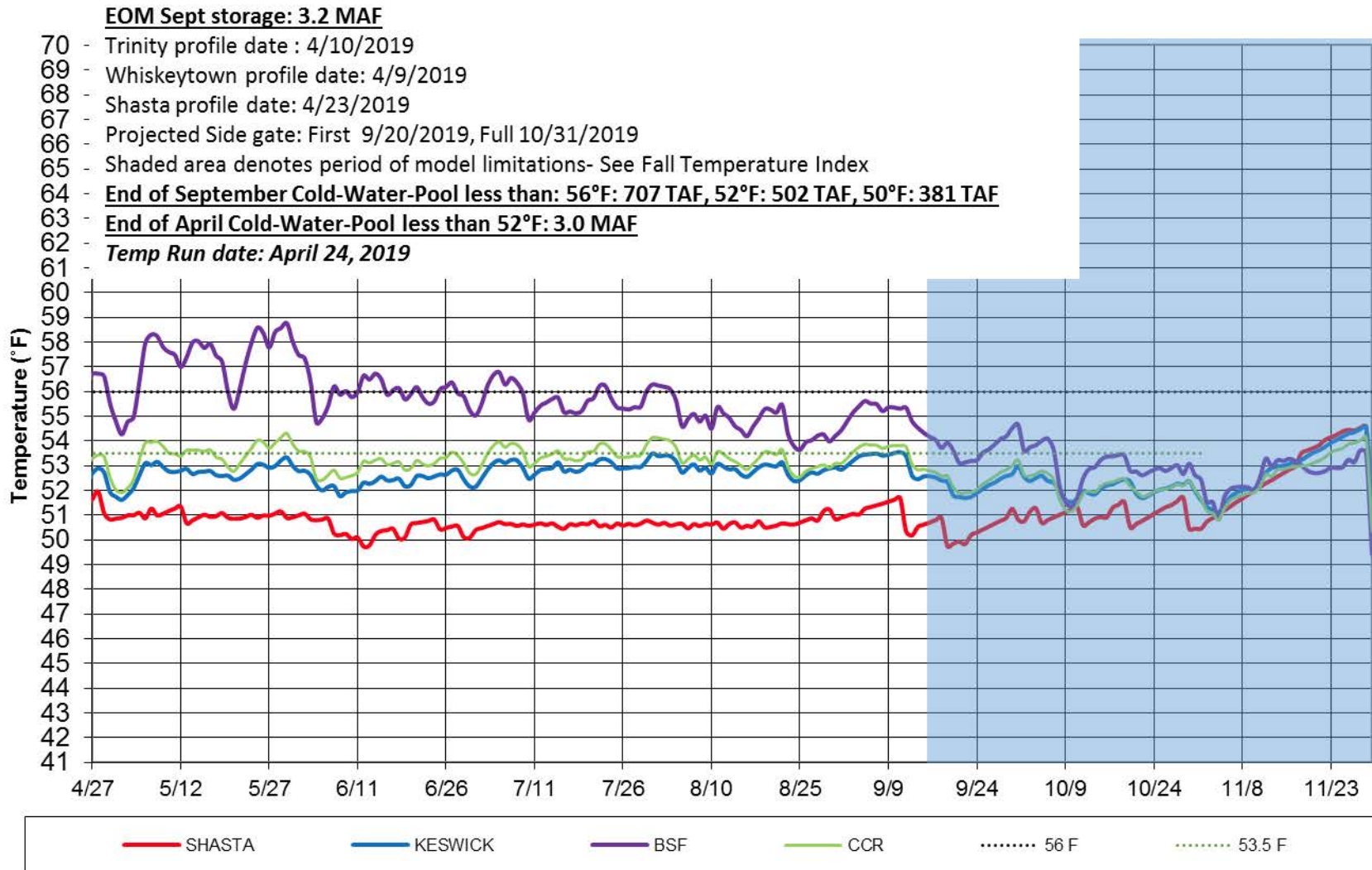


Figure 3. April 2019 simulated Sacramento River temperatures 50% runoff exceedance hydrology and 30% L3MTO meteorology.

Sacramento River Modeled Temperature 2019 April 50%-Exceedance Water Outlook - 50% L3MTO Meteorology

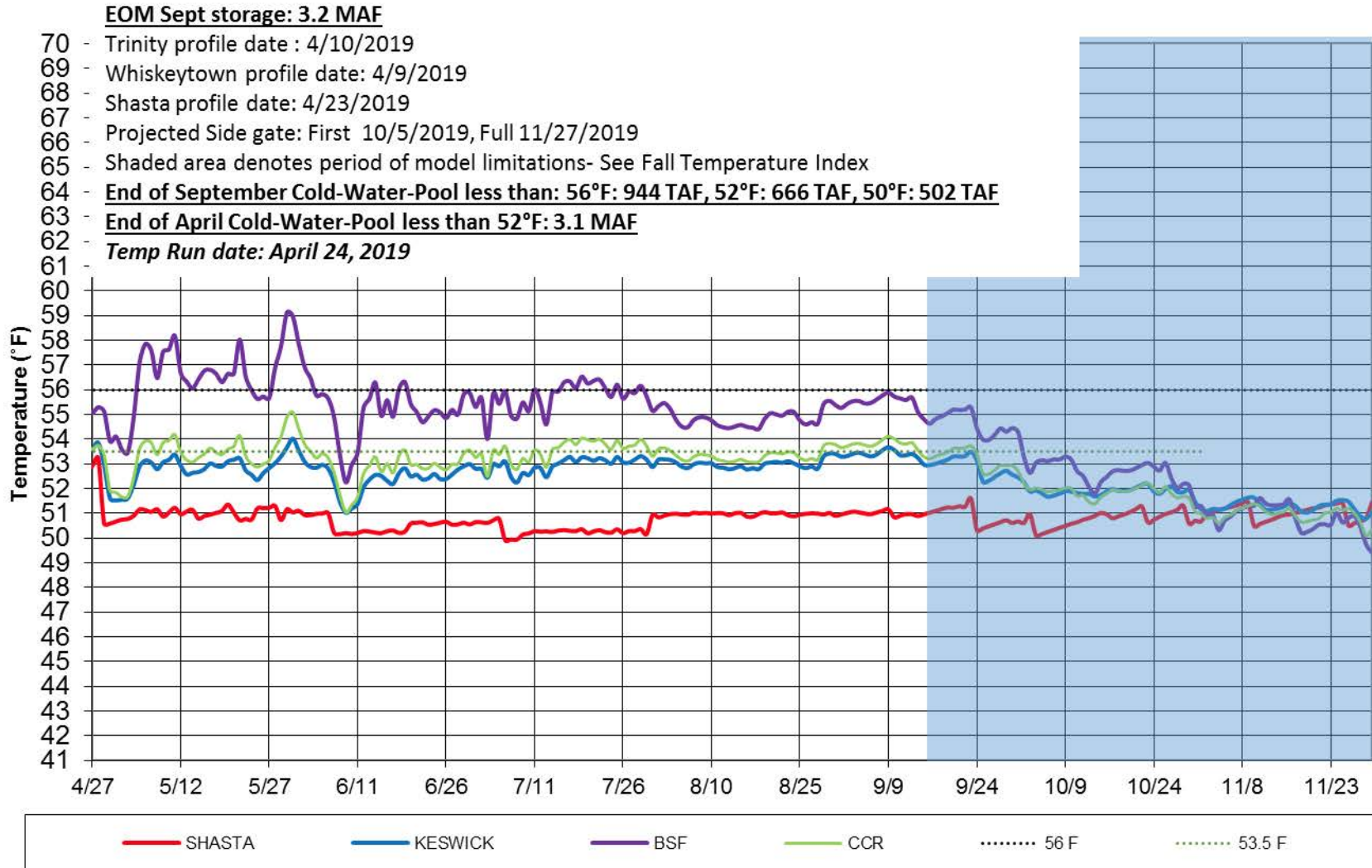


Figure 4. April 2019 simulated Sacramento River temperatures 50% runoff exceedance hydrology and 50% L3MTO meteorology

Figure 5-7 Model Performance and Fall Temperature Index:

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.

Sacramento River - Lake Shasta
Early Fall Water Temperature - Keswick (KWK)

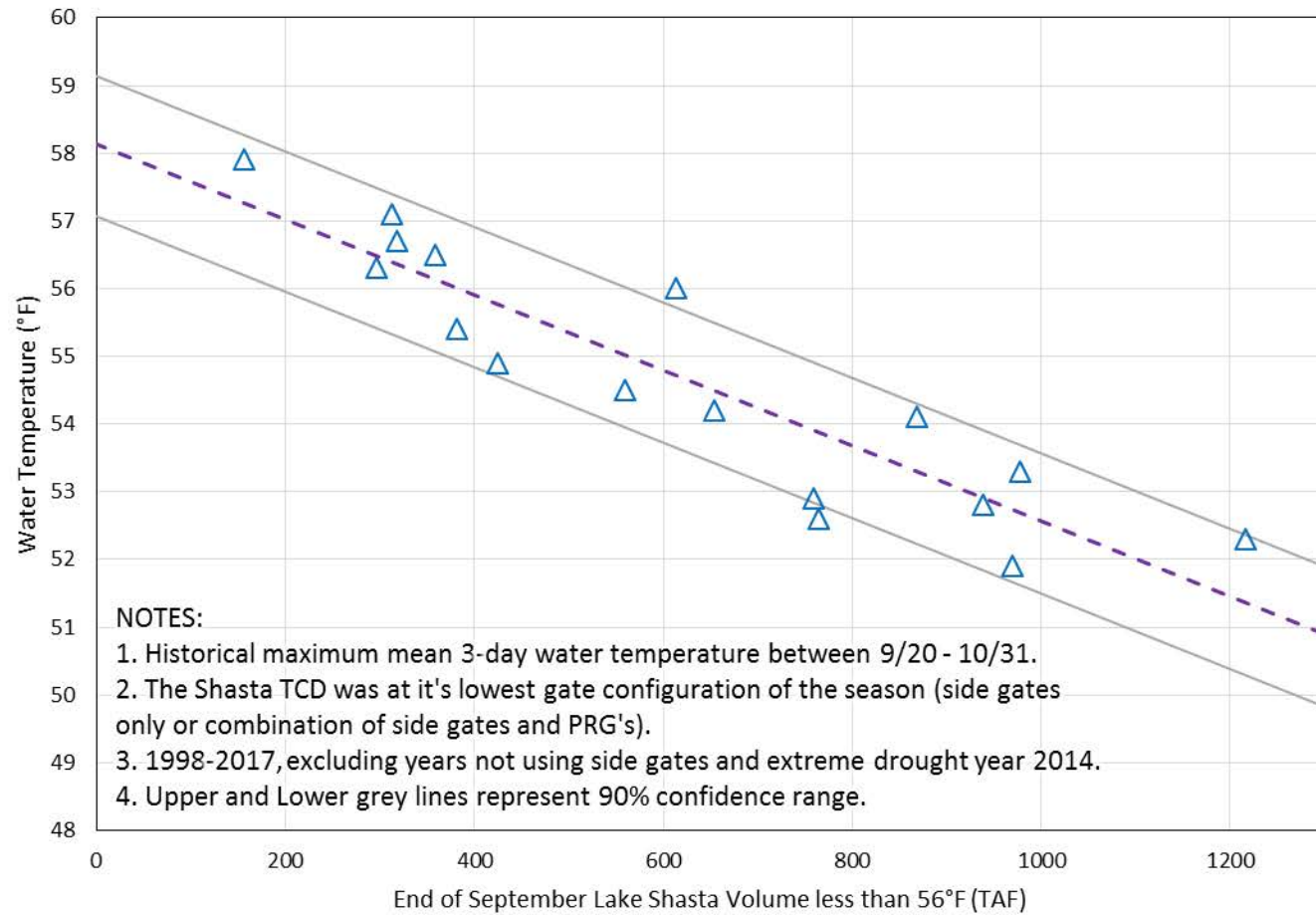


Figure 5. Historical relationship between Lake Shasta cold-water-pool characteristics and early fall Keswick water temperature.

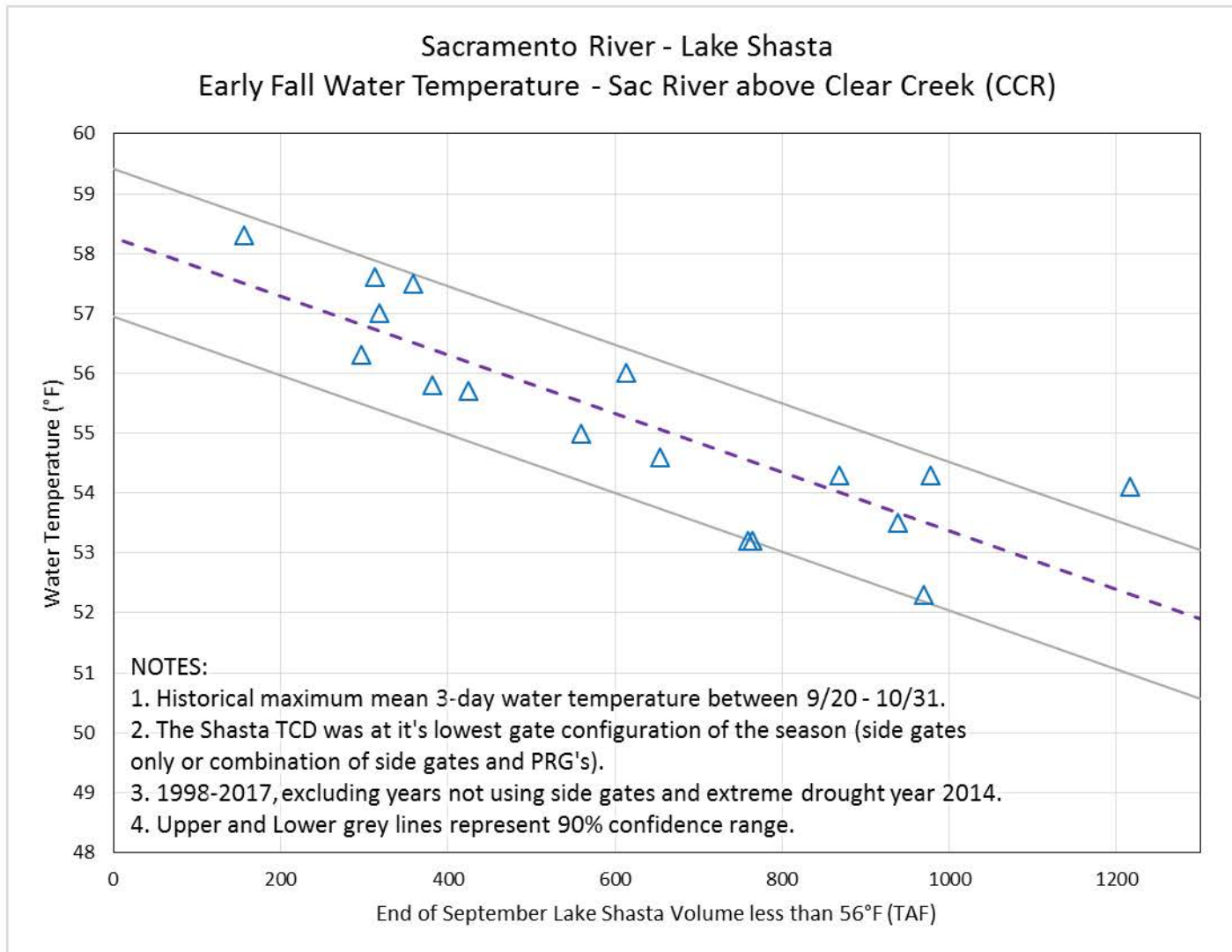


Figure 6. Historical relationship between Lake Shasta cold-water-pool characteristics and early fall Sacramento River above Clear Creek confluence water temperature.

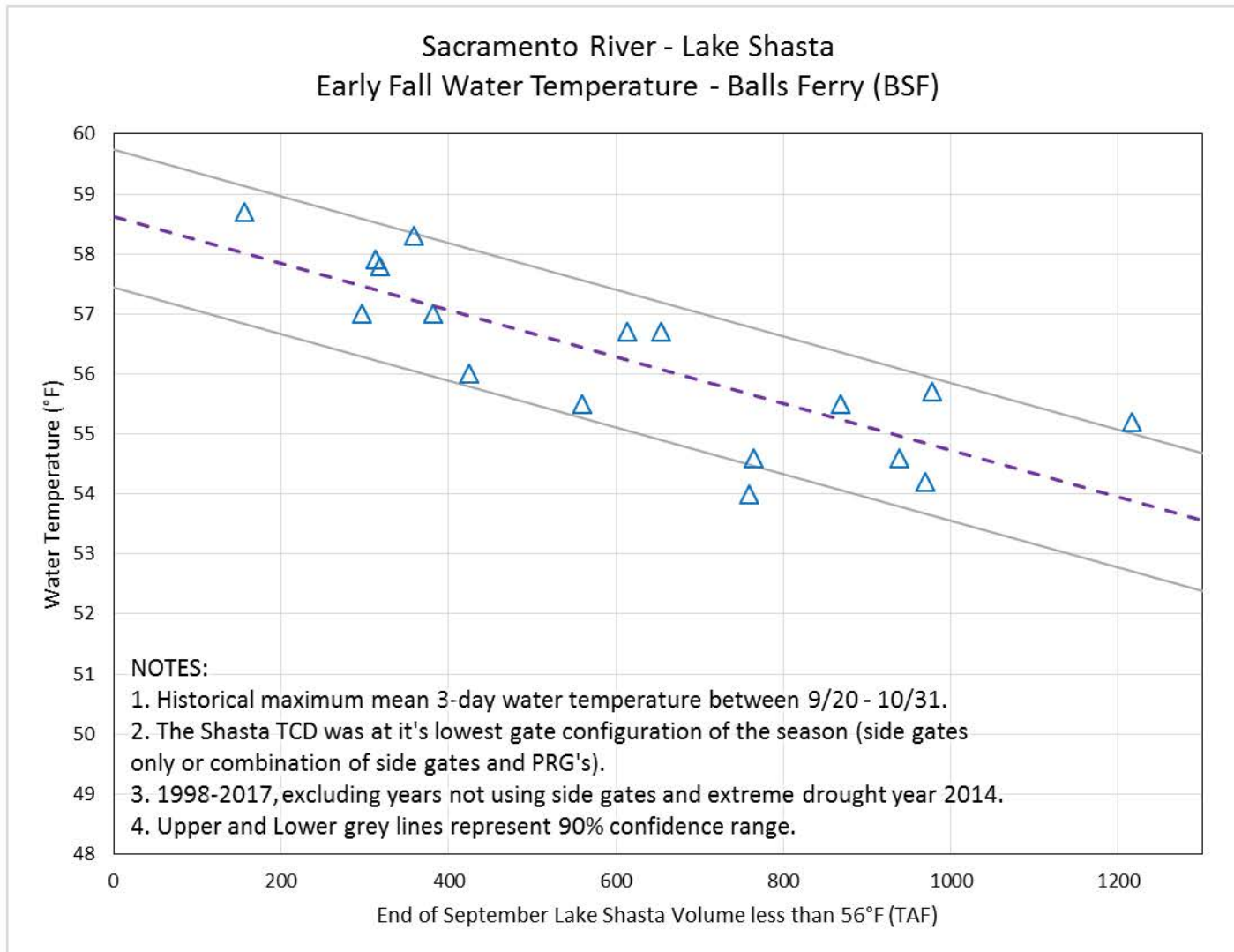
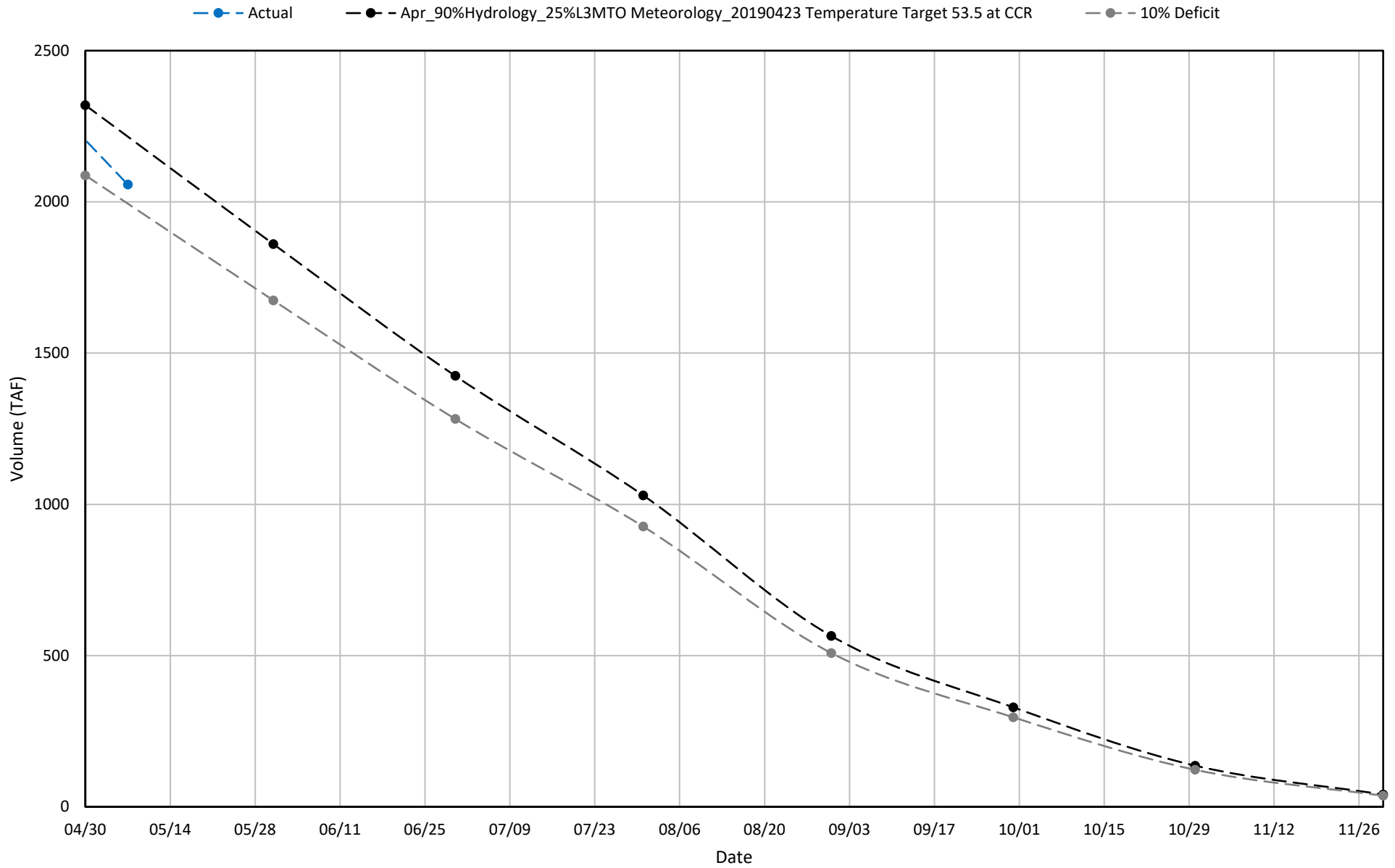


Figure 7. Historical relationship between Lake Shasta cold-water-pool characteristics and early fall Balls Ferry water temperature.

2019 Shasta Cold Water Pool Volume $\leq 49^{\circ}\text{F}$



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/>

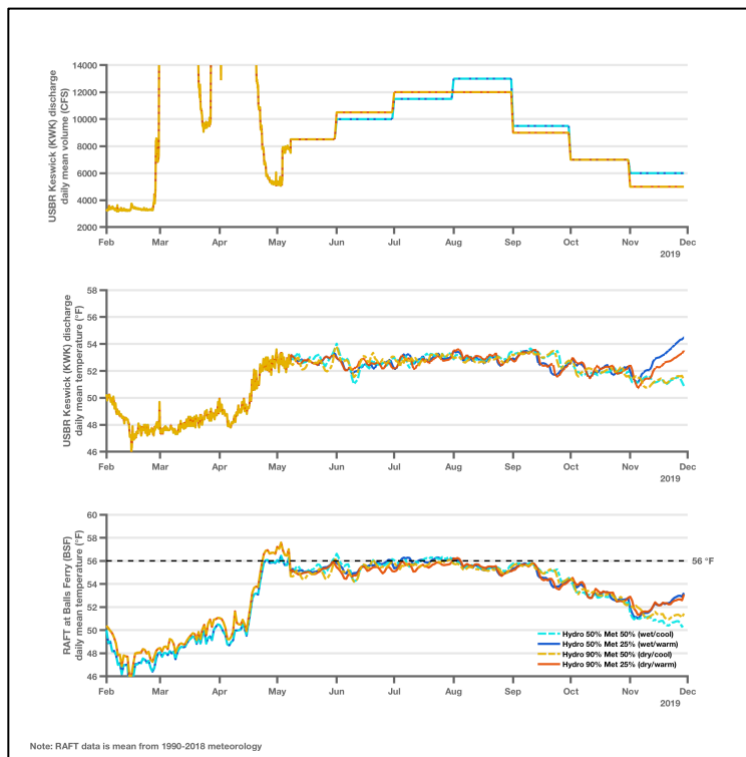


Figure 1: Summary plots showing differences in Keswick discharge volume and temperature, and Balls Ferry RAFT predicted temperature for four scenarios assessed.

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

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

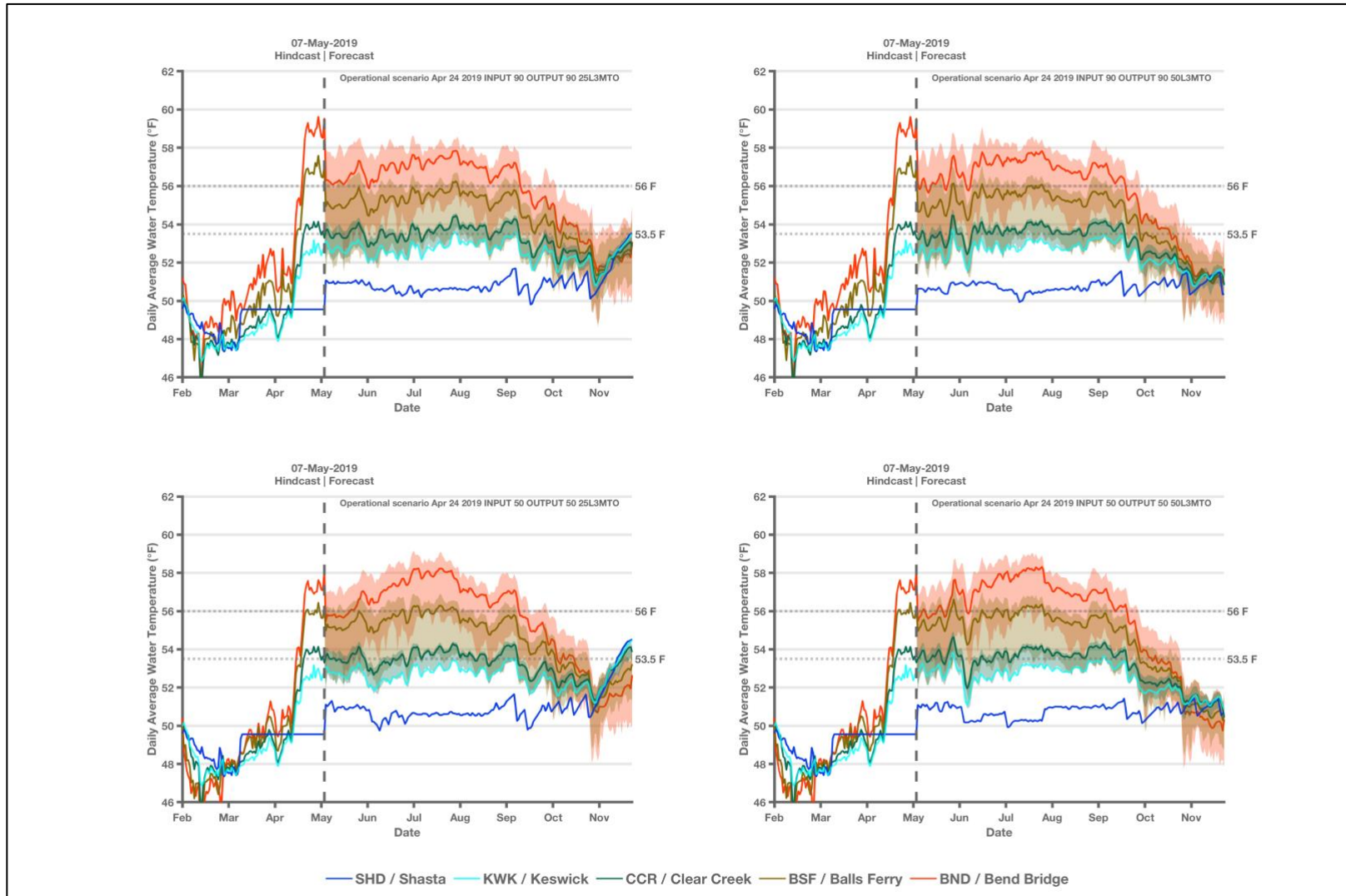


Figure 2: Estimated daily average water temperature produced by scenario input (Shasta and Keswick) and the RAFT model (Clear Creek, Balls Ferry, and Bend Bridge) under the four April 24th 2019 scenarios. **NOTE: Shasta temperature gauge has been off-line since March.**

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

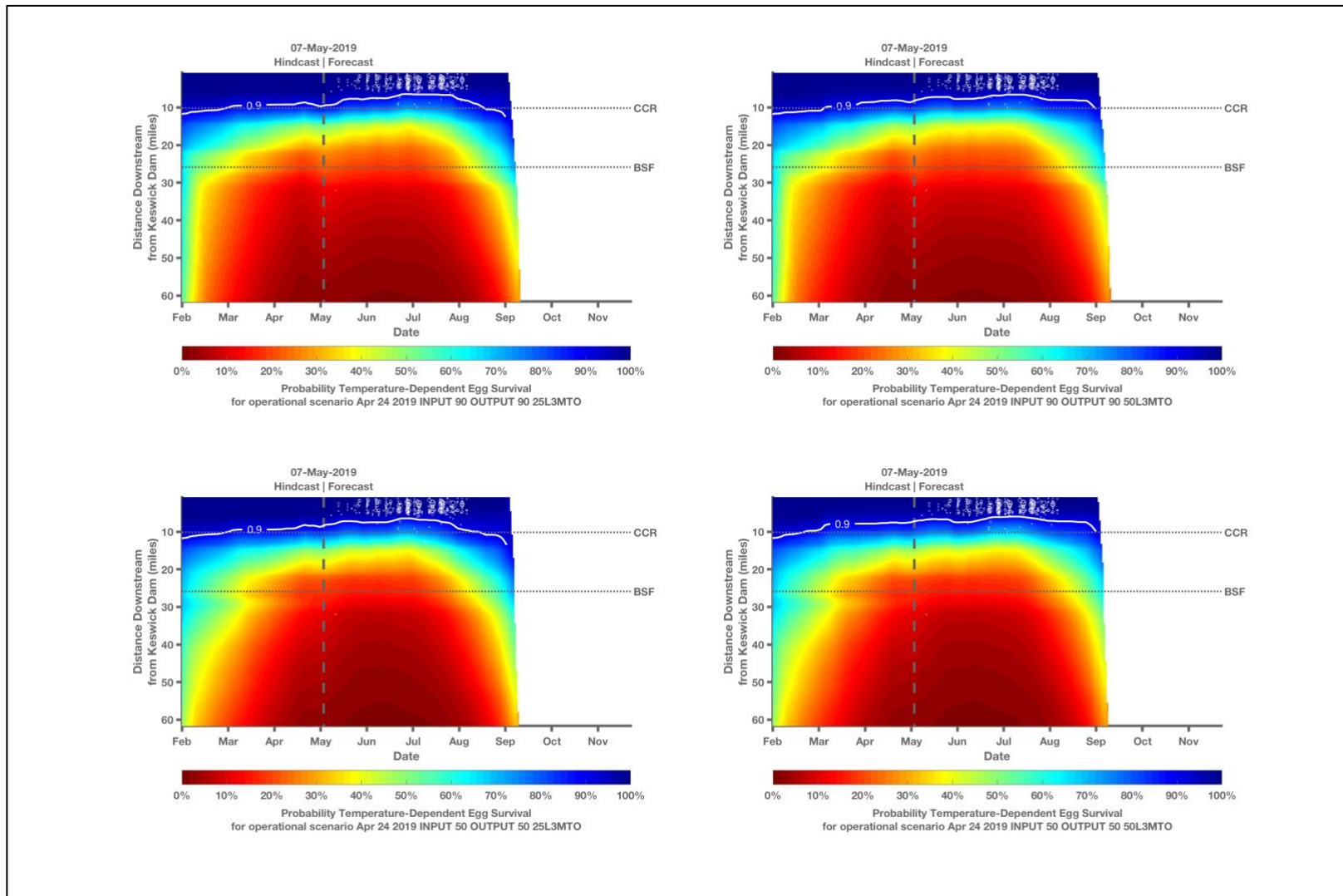


Figure 3: Estimated temperature-dependent egg survival produced by the NMFS temperature mortality model under the four April 24th 2019 scenarios.

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

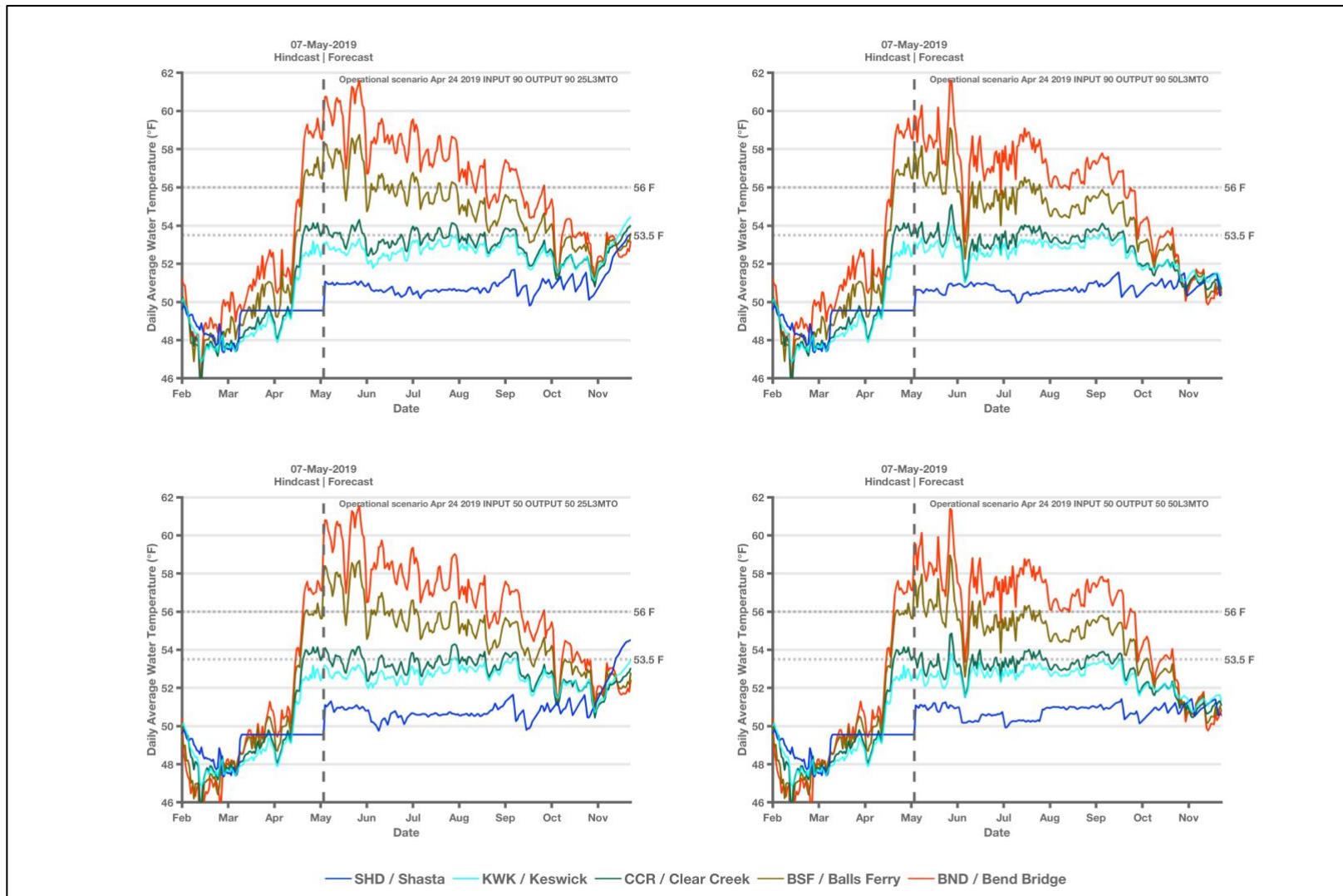


Figure 4: Estimated daily average water temperature produced by scenario input (Shasta, Keswick, Clear Creek, Balls Ferry, and Bend Bridge) under the four April 24th 2019 scenarios using HEC-5Q output. NOTE: Shasta temperature gauge has been off-line since March.

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

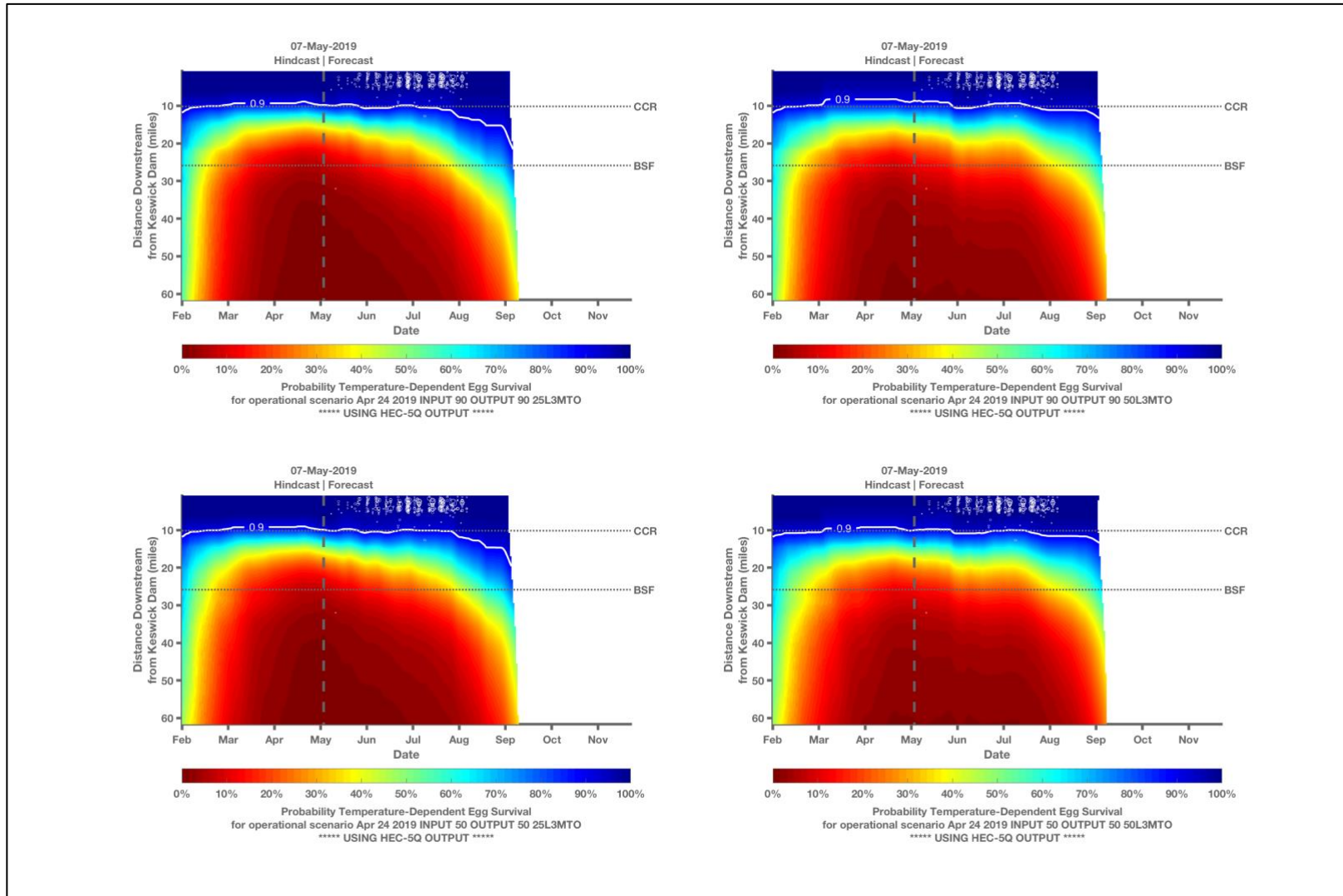


Figure 4: Estimated temperature-dependent egg survival produced by the NMFS temperature mortality model under the four April 24th 2019 scenarios using HEC-5Q output. To generate temperatures between HEC-5Q model nodes (KESWICK, CLEAR_CR, BALL_FERRY, JELLYS_FERRY, BEND_BR, and RED_BLIFF) linear interpolation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

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

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