BUREAU OF RECLAMATION

2024 Sacramento River Temperature Management Plan

Introduction

Conditions in the Central Valley this winter season have been cold and wet, and consequently, Shasta temperature management will be similar to last year and much improved over the previous few drought years. The Northern Sierra Precipitation 8-Station Index indicates that this year's hydrologic conditions are very close to average for the last 30 years. In mid-May, Shasta Reservoir's cold water pool used to protect winter-run Chinook salmon was projected to be comparable to other average and wetter years such as 2016 and 2018. This Water Year 2024 Sacramento River Temperature Management Plan (Plan) reflects coordination starting in February 2024 to manage operations of Shasta Reservoir for water temperatures on the Sacramento River using conservative assumptions in modeling, taking advantage of opportunities to increase the cold water pool, and managing to real-time conditions. The Plan describes how the U.S. Bureau of Reclamation (Reclamation) plans to operate Shasta Reservoir and the Temperature Control Device (TCD) on Shasta Dam consistent with the 2020 Record of Decision on the Coordinated Long-Term Operation of the Central Valley Project and State Water Project (LTO) in compliance with:

- RPM 1.a. of the 2019 National Marine Fisheries Service (NMFS) Biological Opinion to, in coordination with the Sacramento River Temperature Task Group (SRTTG), consider technical assistance from NMFS regarding the development of an annual temperature management plan and to submit a final temperature management plan to NMFS by May 20 of each year;
- Order 90-5 to consult with the California Department of Fish and Wildlife (CDFW), U.S. Fish and Wildlife Service (USFWS), NMFS, and Western Area Power Administration on the designation of a location upstream of the Red Bluff Diversion Dam where Reclamation will meet a daily average water temperature of 56°F; and
- Order 90-5 to provide an operation plan to the State Water Resources Control Board (SWRCB), Chief of the Division of Water Rights, on Reclamation's strategy to meet the temperature requirement at a location upstream of the Red Bluff Diversion Dam.
- The Interim Operations Plan (IOP), ordered by the US District Court on April 2, 2024, which identified priorities and planning efforts for Shasta cold water pool management to meet operational priorities and species needs. This IOP included establishing a six-agency Shasta Planning Group (SPG) to work iteratively with the technical groups (e.g., SRTTG and USST) to solicit operational guidance and risk assessments and provide policy guidance as necessary.

The temperature management strategy provided by the Plan is based on technical review and recommendations received from Sacramento River Temperature Task Group (SRTTG). The Plan establishes temperature locations and targets through October 31, and estimates winter-run Chinook

salmon egg mortality, dates for operation of the side gates on the TCD, and end of September cold water pool. Reclamation will monitor the cold water pool, compare measured conditions to actual performance during implementation, and provide regular updates through the SRTTG throughout Plan implementation.

Based on the March 90% forecast, Reclamation identified that Water Year 2024 was likely to be a Tier 1 year. In a Tier 1 year, there is more than 2.8 MAF of cold water pool in Shasta Reservoir at the beginning of May, and Reclamation can meet 53.5°F at Sacramento River at Clear Creek (CCR). However, conditions on April 1 along with modeling suggested the potential for a Tier 2 year. In a Tier 2 year, there is insufficient cold water to meet 53.5°F at CCR from May 15 to October 31. Therefore, in early May, with minimal winter-run Chinook salmon observed in the Sacramento River below Keswick Dam, SRTTG recommended delaying the start of the temperature management season until May 24. May 1 hydrology along with updated modeling based on the latest measured reservoir profiles confirmed that 53.5°F at CCR can be maintained for the remainder of the temperature management season.

Modeling Assumptions, Limitations, and Other Uncertainties

A seasonal water temperature forecast describes future expected downstream water temperature. This forecast, or simulation of expected water temperature performance is based on the targets specified in the TMP. Future water temperature is forecasted using computational tools, at various elevations in the reservoirs and downstream in the river. These tools are based on conservative assumptions regarding hydrology, operations, and meteorology. Because this forecast (using conservative estimates in May to estimate what might happen at the end of October) can never exactly predict the actual hydrology, operations, and meteorology, the model results are not expected to precisely match actual water temperatures. The expectation is, however, that forecasted downstream water temperatures generally have an accepted measure of error regardless of the uncertain future conditions. In this case, there are generally two types of simulation error: uncertainty of the future conditions (e.g. inputs such as meteorology) and inherent model error or bias. To better understand the inherent model error or bias, a hindcast evaluation is typically performed. A hindcast, rather than looking forward to forecast, simply uses the actual input/forcing data after it's observed (e.g., hydrology, operations, and meteorology) to determine how well the model reproduced a condition such as actual downstream water temperatures. Reclamation has proposed the use of NOAA-NWS Local Three-Month Temperature Outlooks (L3MTO) and historical meteorology as a means of estimating air temperature expectations for modeling purposes. In coordination with SRTTG, Reclamation has the choice of five exceedance threshold options, varying from those that serve more conservative stream temperature planning (e.g., 10% exceedance) to those that serve more aggressive planning (e.g., 90% exceedance). In past years, SRTTG has recommended the use of a conservative approach that uses the 25% exceedance L3MTO forecast. Therefore, Reclamation's April and May model runs utilized historical 25% exceedance meteorology.

Release Outlook

The Shasta Reservoir release strategy included in this plan and temperature modeling is based on the CVP's May 90% exceedance forecast of operations. This release schedule is intended to guide the monthly average releases from Keswick Dam. Daily releases may vary from these flows to

adjust for real-time operations. The 2024 Sacramento River Spring Pulse Operations Plan (Attachment 1) was used as a guide for Keswick Dam releases in April and May. Trinity River releases below Lewiston Dam were based on a forecasted Wet year type per the 2000 Trinity Record of Decision and diversions through Carr Powerplant were adjusted to balance storage, flow and water temperature goals. Significant uncertainties exist within the forecast that will require intensive real-time operations management throughout the summer to achieve the various goals and targets throughout the system. Reclamation will attempt to minimize the magnitude of July flows, during the peak of winter-run spawning, to the extent they are able. In addition to fisheries benefits (reduced dewatering and slower reduction of the cold water pool), this could conserve Shasta storage in the fall, since less flow will be required to keep late redds watered. Reclamation commits to reporting out on the status of this release outlook, temperature management and overall system operations at the monthly SRTTG meetings. Table 1 describes the monthly forecasted operations for releases and storage targets which were taken from the May 90% CVP forecast of operation (Attachment 2).

Table 1. Monthly forecasted operations for Shasta and Keswick reservoir releases and storage estimates from May 90% exceedance forecast.

Operations Information/Month	May	June	July	August	September
Shasta Releases (TAF)	484	545	761	575	406
Keswick Releases (cfs)	8,200	10,500	13,850	10,500	8,000
Keswick Releases (TAF)	504	625	851	645	476
Spring Creek Power Plant (TAF)	20	80	90	70	70
Shasta End-of-Month Storage (TAF)	4,3215	4,009	3,411	2,999	2,757

Key Areas of Uncertainty

Operational decisions on the upper Sacramento River are influenced by local and CVP and SWP system-wide multi-purpose objectives, including those that are planned and uncertain. Many factors contribute to operational actions including, but not limited to: flood protection, forecasted inflows, facility maintenance schedules, physical/mechanical facility limitations, upstream operations, minimum in-stream flow criteria, public health and safety criteria, downstream Delta regulatory requirements, Delta exports, power generation, recreation, fish hatchery accommodations, temperature management capabilities, and others. In addition, uncertain or unplanned events can also influence real-time operation decisions (e.g., wildfires and equipment malfunctions). To address uncertainty, Reclamation typically uses conservative estimates of future conditions in the modeling assumptions (e.g., hydrology, operations, and meteorology) and projections are updated through the management period.

The release forecast and temperature modeling used for this temperature management plan is based on a number of assumptions that each come with a level of uncertainty. A brief list of these uncertainty areas is listed below:

- Inflow hydrology

- Meteorology
- Reservoir stratification
- Accretions and depletions
- Public health and safety demands
- Infrastructure limitations
- Low River flow challenges
- Trinity River imports and Trinity River temperature management
- Low flow river and reservoir thermodynamics
- Delta water quality
- Spring pulse action timing and magnitude

Temperature Strategy

The Keswick Reservoir release schedule, which includes the planned spring pulse flow action, was developed by Reclamation as part of the May forecast of operations. Reclamation completed HEC-5Q modeling on May 21, 2024 based on the May 90% exceedance forecast. The temperature modeling is presented here and is reflected in resulting biological and water supply performance metrics as shown in Table 2, Table 6, and Attachment 3. Further refinement to the temperature management strategy will occur through coordination with SRTTG and SPG as the temperature management season progresses.

Table 2. Estimated average monthly water temperature in degrees Fahrenheit at Shasta, Keswick, CCR and BSF based on model run of operations with pulse flow action (i.e., pulse flow scenario described in pulse flow operations plan) targeting 53.5 degrees F at CCR and 90% exceedance forecast. HEC-5Q does not perform well after mid-September. Water temperatures may be warmer than these targets and HEC-5Q results.

Month	Shasta	Keswick	CCR	BSF
June	49.9	52.3	53.5	56.0
July	49.9	52.4	53.5	55.4
August	49.4	52.2	53.2	55.1
September	49.3	52.3	53.5	55.5
October	51.0	52.5	53.2	54.5
November	52.5	52.8	53.1	53.5

Trinity River and Clear Creek modeled temperatures are included in Attachment 3.

For comparative purposes, Reclamation also completed a forecast of operations that did not include spring pulse flow actions (Attachment 4). Modeling results for this forecast can be found in Table 3, Table 6, and Attachment 5.

Table 3. Estimated average monthly water temperature in degrees Fahrenheit at Shasta, Keswick, CCR and BSF based on model run of operations without pulse flow action (i.e., baseline scenario described in pulse flow operations plan) targeting 53.5 degrees F at CCR and 90% exceedance forecast. HEC-5Q does not perform well after mid-September. Water temperatures may be warmer than these targets and HEC-5Q results.

Month	Shasta	Keswick	CCR	BSF
June	49.9	52.4	53.5	55.4
July	49.4	52.1	53.1	55.1
August	49.3	52.3	53.4	55.5
September	50.9	52.4	53.2	54.5
October	52.4	52.7	53.0	53.4
November	49.9	52.4	53.5	56.0

HEC-5Q modeling was performed to determine the location upstream of the Red Bluff Diversion Dam where a daily average water temperature of 56 degrees F could reasonably be met. The strategy of meeting 53.5 degrees F at CCR will likely result in average daily temperatures at or near 56 degrees F at Sacramento River at Balls Ferry (BSF). Reclamation does not propose to operate the TCD explicitly to meet 56 degrees F at BSF under conditions that may require changes to TCD operations that could risk cold water pool resources for use later in the temperature management season. This would cause an unreasonable risk to other goals and objectives. Modeling results for targeting 56 degrees F for BSF can be found in Table 4, Table 6, and Attachment 6.

Table 4. Estimated average monthly water temperature in degrees Fahrenheit at Shasta, Keswick, CCR, and BSF based on model run of operations with pulse flow action (i.e., pulse flow scenario described in pulse flow operations plan) targeting 56 degrees F at Balls Ferry and 90% exceedance forecast. HEC-5Q does not perform well after mid-September. Water temperatures may be warmer than these targets and HEC-5Q results.

Month	Shasta	Keswick	CCR	BSF
June	49.6	52.1	53.3	55.8
July	50.0	52.6	53.6	55.6
August	49.4	52.2	53.2	55.2
September	49.4	52.3	53.5	55.5
October	51.0	52.5	53.3	54.6
November	52.5	52.8	53.2	53.5

For comparative purposes, Reclamation also completed a 50% exceedance forecast of operations with spring pulse flow actions (Attachment 7). Modeling results for this forecast can be found in Table 5, Table 6, and Attachment 8.

Table 5. Estimated average monthly water temperature in degrees Fahrenheit at Shasta, Keswick, CCR, and BSF based on model run of operations with pulse flow action (i.e., pulse flow scenario described in pulse flow operations plan) targeting 53.5 degrees F at CCR and 50% exceedance forecast. HEC-5Q does not perform well after mid-September. Water temperatures may be warmer than these targets and HEC-5Q results.

Month	Shasta	Keswick	CCR	BSF
June	49.3	52.0	53.3	56.1
July	49.0	51.9	53.1	55.4
August	49.2	52.1	53.2	55.2
September	49.6	52.5	53.6	55.6
October	51.1	52.9	53.6	54.7
November	52.5	52.8	53.1	53.4

Table 6. Fish and water performance metrics from biological modeling (Attachment 9).

Metric/Scenario	No Pulse Flow 53.5 deg F CCR (90% Exceedance	With Pulse Flow 53.5 deg F CCR (90% Exceedance)	With Pulse Flow 56 deg F BSF (90% Exceedance)	With Pulse Flow 53.5 deg F CCR (50% Exceedance)
Stage-independent TDM	0.4%	0.4%	0.3%	0.3%
Stage-dependent TDM	0.4%	0.5%	0.4%	0.3%
End of Sept CWP Storage less than 56 deg F (TAF)	893 TAF	863 TAF	863 TAF	975 TAF
First Side Gate Use	August 19	August 19	August 16	July 27
Full Side Gate	September 3	September 3	September 3	September 3
End of September Storage (MAF)	2.81 MAF	2.76 MAF	2.76 MAF	3.05 MAF

Water temperature forecasts indicate favorable temperatures for winter-run chinook salmon egg incubation with TDM estimates less than 1%. Modeled water temperature forecasts also indicate suitable temperatures for spring-run and fall-run Chinook salmon incubation; however, temperature models are more uncertain during the fall period. The SRTTG has an interest in better understanding the needs of fall-run chinook and improving the tools to manage conditions for fall run. Maximizing carryover storage and coldwater pool can improve temperature conditions for fall-run spawning (which historically runs from September through December, peaking in October) and subsequent egg incubation. Minimizing the drop in the stage of the river (from peak summer flows, to fall and winter flows) reduces winter-run redd dewatering, and in turn allows for earlier stabilization of fall flows to minimize fall-run redd dewatering. Development and integration of decision support tools to forecast TDM and redd dewatering, for both runs simultaneously, would benefit future temperature management plans.

Additional modeling results from NOAA Southwest Fisheries Science Center are described in Attachment 10.

Reclamation will continue to coordinate through SRTTG to review these and other model results and may update these TDM estimates based on those discussions.

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Attachment 1: 2024 Sacramento River Spring Pulse Operations Plan

April 15, 2024

Background

As part of the Action for the Long term Operation of the Central Valley Project and State Water Project, Reclamation expects to release spring pulse flows of up to 150 thousand acre-feet (TAF) in coordination with the Upper Sacramento Scheduling Team when the projected total May 1 Shasta Reservoir storage indicates a likelihood of sufficient cold water to support summer cold water pool management, and the pulse does not interfere with the ability to meet performance objectives or other anticipated operations of the reservoir. The purpose of the pulse flow is to improve survival rates of outmigrating juvenile spring-run Chinook salmon smolts though the Sacramento River. For more information, refer to Proposed Action 4.10.1.2 Spring Pulse Flows and 4.10.1.4 Cold Water Pool Management which includes information on relationships between Shasta Storage and water temperatures at Clear Creek (CCR).

Reclamation has been coordinating with U.S. Fish and Wildlife Service, National Marine Fisheries Service, California Department of Fish and Wildlife, California Department of Water Resources, Sacramento River Settlement Contractors, Yurok Tribe, Hoopa Valley Tribe, Western Area Power Administration, and the State Water Resource Control Board. During winter 2021, the Upper Sacramento Scheduling Team met to develop a Pulse Flow Study Plan. The Study Plan included the information necessary for considering a seasonal pulse flow and a Fish Monitoring Plan (See Attachment for more information). Following the Guidance Document for the Upper Sacramento River Spring Pulse Flow & Upper Sacramento River Scheduling Team, each year a Pulse Flow Operation Plan will be developed based on the Study Plan and Fish Monitoring Plan and presented to the Sacramento River Temperature Task Group in support of the Proposed Action.

Forecasted and Current Conditions

Reclamation anticipates that a projected May 1 storage greater than 4 million acre feet (MAF) provides sufficient cold water pool management for Tier 1 and may release the spring pulse if it does not impact the ability to meet project objectives. Currently Shasta storage exceeds 4 MAF. Total May 1 Shasta Reservoir storage is predicted to be 4.143 MAF based on the March 90% forecast and 4.290 MAF based on the March 50% exceedance forecast. To date in 2024, actual conditions have more closely followed the 50% forecasts.

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.

Chinook Salmon Benefits and Action Effectiveness

Optimal timing for implementation of a managed pulse release from Keswick Reservoir to improve outmigration survival of spring-run Chinook salmon smolt, was discussed during the USST meetings. Late April and early May are likely to have the greatest benefits for smolt survival in most years. Factors considered to determine optimal timing were peak period of water deliveries to benefit areas further downstream, attraction pulse flows in Clear Creek, and smolt timing of Delta entry. Based on weekly passage at the Red Bluff Diversion Dam (RBDD), peak spring-run migration occurs between October and April with the majority of passage occurring by mid-April. Spring-run juveniles from Mill and Deer Creeks generally migrate later than spring-run juveniles observed in the rotary screw traps at RBDD. Spring-run smolts, which outmigrate later in the season, are expected to have a disproportionately large contribution to the returning adult population; yet they also typically experience the worse outmigration conditions due to their later outmigration timing. To support the outmigration success of this year's spring-run smolts, April and May pulse releases may provide the greatest species benefit. In addition, the timing of these pulses may also benefit the approximately 3 million Coleman National Fish Hatchery (CNFH) fall Chinook, which will be released in the next week. To evaluate the effectiveness of the spring pulse, juvenile fall chinook salmon from CNFH will be acoustically tagged and tracked as described in the Study Plan. Initial real-time results for this year's Pulse Flow Study as well as previous years are posted to: CalFishTrack (noaa.gov). Final results will be posted to: Central Valley Enhanced Acoustic Tagging Project (noaa.gov) and will also be reported in the Shasta Winter Storage Rebuilding and Spring Pulse Flow Seasonal Report.

Pulse Flow Scenarios

The Upper Sacramento Scheduling Team representatives proposed a set of pulse flow scenarios. All scenarios (with the exception of the no action alternative) have a pulse volume less than 150 TAF, utilize 15% ramping rates, and achieve a pulse magnitude of at least 11,000 cfs at Wilkins Slough. All scenarios have forecasted end of May Shasta storage greater than 4.0 MAF based on the March 50% forecast. A beginning of May Shasta storage of 2.8 MAF is associated with Tier 1 year (2020 ROD Long-term Operations of CVP and SWP). A Tier 1 year is the best temperature management category in which it is suggested that 53.5 degrees F at CCR can be maintained from May 15 to October 31.

On March 28, 2024, Upper Sacramento Scheduling Team representatives reviewed the scenarios described in survival_per_scenario_20240327.pdf and recommended an adaptable approach given the uncertainty with the forecasted conditions. Participants were interested in scenarios that consisted of up to 3 pulses. Participants were interested in continuing to review real-time conditions and provide additional input on flow releases. Ideally, pulse flows would start after flows at Wilkins Slough stabilize in the 5,000 to 10,000 cfs range. Additional constraints and considerations were discussed, including ACID dam needs, power impacts, delta needs (initial estimate is that delta will need 20 days of higher flow in April), and potential effects to Clear Creek Pulse Flow. For more information, see the USST meeting notes.

On April 11, 2024, the agencies in USST met and reviewed the new information. The new information included Scenarios M1 through M9 in the excel file titled Spring Pulse Flow Apr8 2024 which was developed from the input received during the April 4th, 2024, USST Meeting. Survival estimates benefits using Michel et al. 2021 flow threshold model for these scenarios ranged from 5-15% using all years of passage data (2006-2019; Figure 3) and 3 to 8% using passage estimates for normal and wet years of passage data (2006, 2011, 2017, 2019; Figure 4). Additionally, juvenile chinook salmon survival estimates for ~160 scenarios were simulated using the baseline flows for Keswick and Wilkins Slough described in Spring Pulse Flow Apr8 2024 excel file. The updated modelled juvenile Chinook salmon survival for the top 10 survival scenarios was estimated to be approximately 15 – 17% above the baseline (see survival_per_scenario_20240410_w_KES.pdf).

USST and SRTTG representatives expressed support for three pulse flows resembling the M6 scenario from Spring Pulse Flow Apr8 2024 and X4.4o6.4o8.4 scenario from survival_per_scenario_20240410_w_KES.pdf. These scenarios consist of 3, 4-day pulses in Weeks 4 (April 22), Week 6 (May 6), and Week 8 (May 20). Some USST participants were interested in continuing to evaluate the scenarios if conditions change. Although survival estimates for some scenarios were greater than M6, M6 was preferrable to other scenarios as it provides a week in between pulse flows to better understand the mechanisms behind the pulse flows and juvenile salmonid survival. Another consideration is that the flow threshold survival model does not account for number fish available to migrate, so pulse flows scheduled closer together may not have additive benefits. In addition, temperature modelling of planned scenarios will be included in the 2024 Sacramento River Temperature Management Plan.

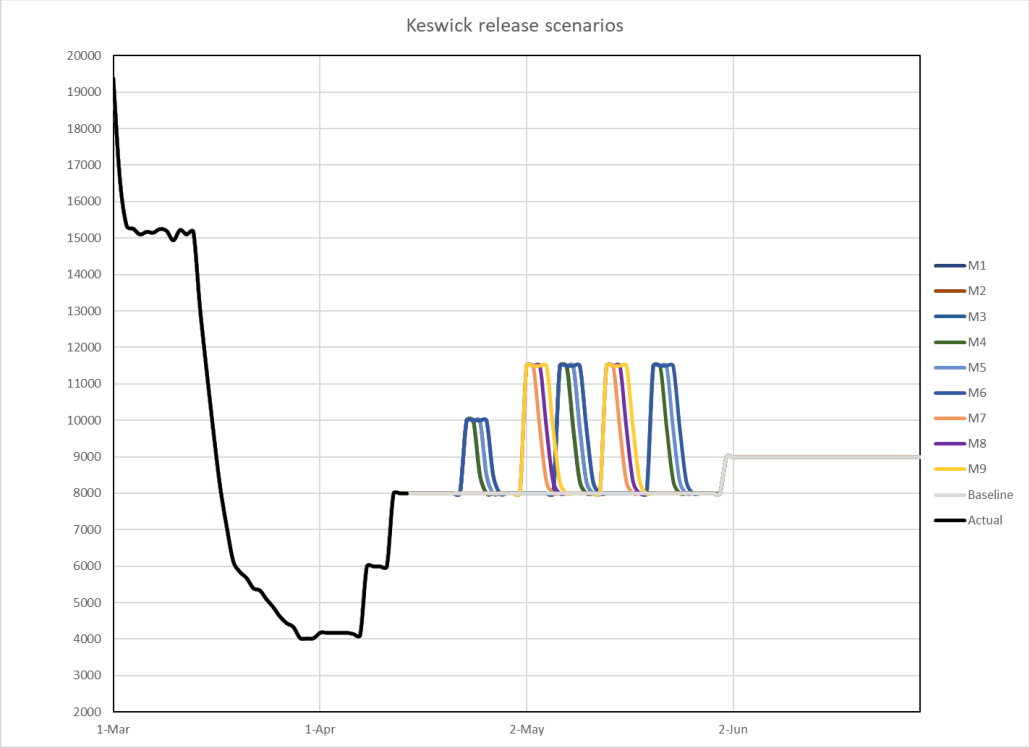

Figure 1. Proposed spring pulse flow scenarios for water year 2024 and associated flow below Keswick in cubic feet per second (cfs).

Figure 1 is a line graph of proposed Keswick release scenarios from March 1 until July 2024. The graph shows the actual, baseline, and nine different modeled scenarios with different colored lines.

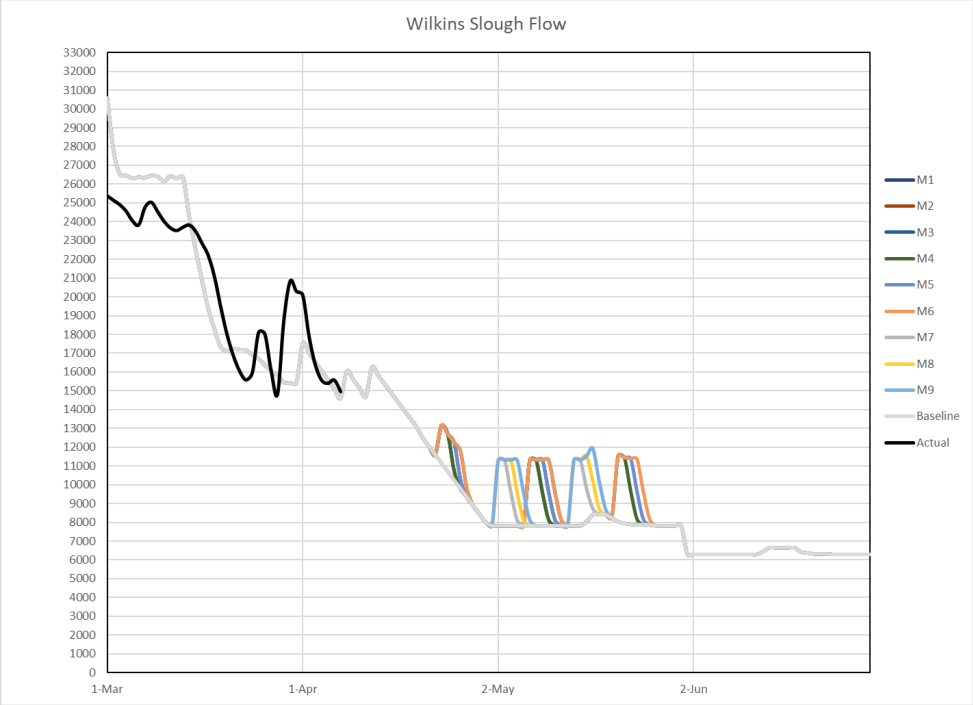

Figure 2. Proposed spring pulse flow scenarios for water year 2024 and associated flow at Wilkins Slough in cubic feet per second (cfs).

Figure 2 is a line graph of proposed Keswick release scenarios from March 1 until July 2024. The graph shows the actual, baseline, and nine different modeled scenarios with different colored lines.

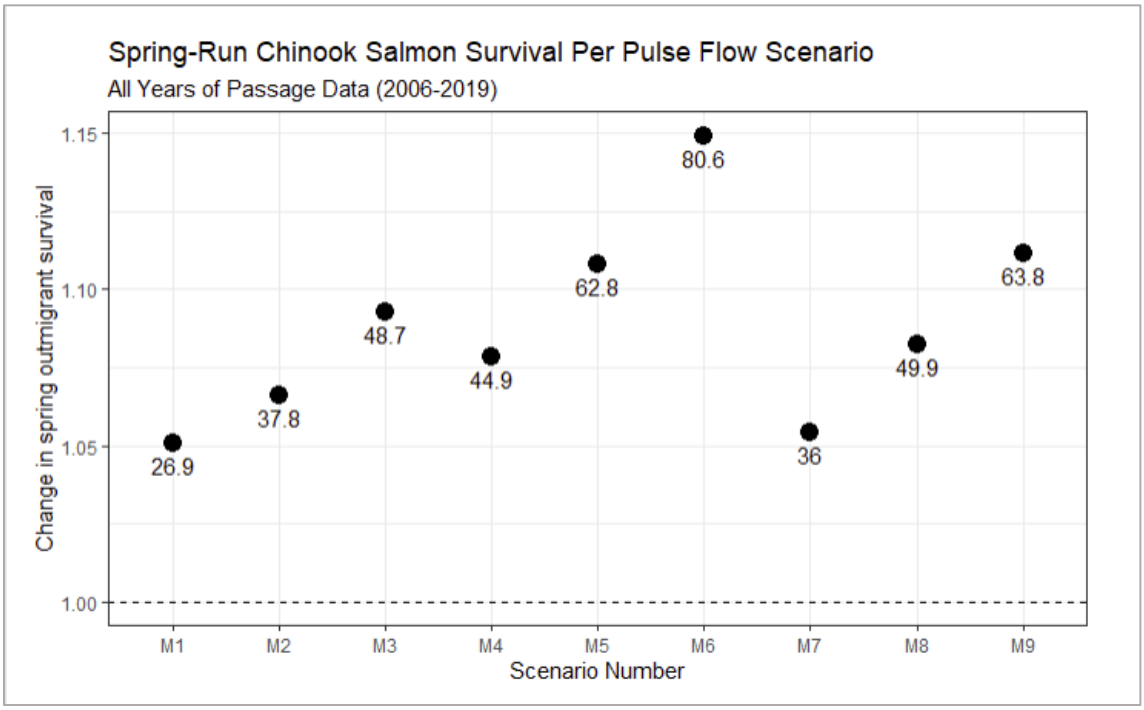

Figure 3. Percent Change in spring Chinook survival per pulse flow scenario with water cost per thousands of acre-feet (TAF; point labels) for all years of passage data (2006-2019).

Figure 3 is a scatter plot of the percent change in outmigrant Spring-run Chinook salmon survival for different modeled flow scenarios. It includes the water cost per thousands of acre-feet from 2006 until 2019.

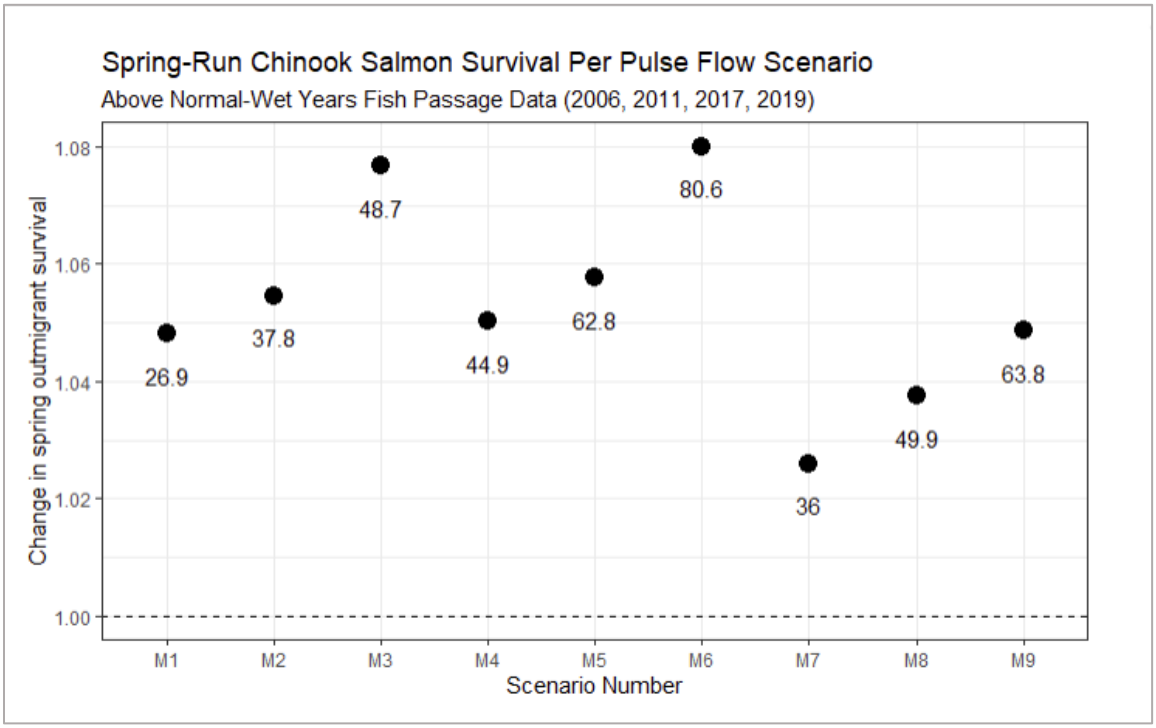

Figure 4. Percent Change in spring Chinook survival per pulse flow scenario with water cost per thousands of acre-feet (TAF; point labels) for above normal and wet years of passage data (2006, 2011, 2017, 2019).

Figure 4 is a scatter plot of the percent change in outmigrant Spring-run Chinook salmon survival for each flow scenario. It includes the water cost per thousands of acre-feet for the above normal and wet years 2006, 2011, 2017, and 2019.

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Attachment 2

Estimated CVP Operations 90% Exceedance

Storages

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

Facility	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apt
Trinity	2073	2117	2020	1885	1762	1633	1610	1606	1627	1639	1675	1739	1813
Trinity Elev.	N/A	2349	2342	2333	2324	2314	2312	2312	2313	2314	2317	2322	2328
Whiskeytown	237	238	238	238	238	238	206	206	206	206	206	206	238
Whiskeytown Elev.	N/A	1209	1209	1209	1209	1209	1199	1199	1199	1199	1199	1199	1209
Shasta	4364	4325	4009	3411	2999	2757	2663	2672	2744	2814	2969	3239	3442
Shasta Elev.	N/A	1059	1048	1025	1008	997	992	993	996	999	1006	1018	1026
Folsom	849	966	904	648	452	417	365	333	319	305	332	431	563
Folsom Elev.	N/A	465	459	434	410	405	398	393	390	388	393	407	424
New Melones	2056	2068	2044	1985	1929	1885	1821	1827	1835	1839	1842	1862	1748
New Melones Elev.	N/A	1058	1056	1051	1046	1042	1036	1036	1037	1037	1038	1040	1029
Fed. San Luis	821	677	391	262	186	238	198	240	404	579	537	589	507
Fed. San Luis Elev.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total	10400	10391	9606	8430	7566	7168	6863	6884	7135	7383	7561	8066	8311

State End of the Month Reservoir Storage (TAF)

Facility	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Oroville	3461	3519	3408	2837	2330	1829	1628	1540	1513	1551	1638	1809	1879
Oroville Elev.	N/A	899	892	852	812	766	745	735	732	736	746	764	771
State San Luis	539	428	289	453	625	869	959	1092	1245	1276	1284	1282	1238
State San Luis Elev.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total San Luis (TAF)	1360	1105	680	715	811	1107	1157	1332	1649	1854	1822	1872	1745
Total San Luis Elev.	N/A	463	419	423	433	463	468	484	512	529	526	531	520

Monthly River Releases (TAF/cfs)

Facility	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Trinity (TAF)	N/A	215	107	45	53	52	23	18	18	18	17	18	32
Trinity (cfs)	N/A	3,500	1,800	735	857	870	373	300	300	300	300	300	540
Clear Creek (TAF)	N/A	18	13	9	9	9	12	12	12	12	11	22	12
Clear Creek (cfs)	N/A	296	224	150	150	150	200	200	200	200	200	363	200
Sacramento (TAF)	N/A	504	625	851	645	476	338	238	246	246	222	246	238
Sacramento (cfs)	N/A	7300	10500	13850	10500	8000	5500	4000	4000	4000	4000	4000	4000
American (TAF)	N/A	246	208	345	283	113	93	75	77	77	76	77	74
American (cfs)	N/A	4000	3500	5616	4599	1893	1506	1263	1250	1250	1377	1201	1250
Stanislaus (TAF)	N/A	76	89	15	15	15	48	12	12	14	12	12	91
Stanislaus (cfs)	N/A	1242	1200	250	250	250	774	200	200	226	221	200	1537
Feather (TAF)	N/A	215	107	479	452	556	215	104	108	77	111	108	143
Feather (cfs)	N/A	3500	1800	7800	7350	9350	3500	1750	1750	1250	2000	1750	2400

Trinity Diversions (TAF)

Diversion Facility	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Carr PP	N/A	24	91	100	81	80	8	6	1	1	1	3	29
Spring Creek PP	N/A	20	80	90	70	70	30	0	0	0	0	0	0

Delta Summary (TAF)

Facility	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Tracy	N/A	123	150	259	229	260	100	128	220	225	45	150	57
USBR Banks	N/A	0	0	18	18	18	0	0	0	0	0	0	0
Contra Costa	N/A	12.0	10.0	11.0	12.0	13.0	14.0	14.0	14.0	13.0	14.0	12.0	12.0
Total USBR	N/A	135	160	288	259	291	114	142	234	238	59	162	69
State Export	N/A	37	79	393	397	396	234	233	220	155	110	85	62
Total Export	N/A	172	239	681	656	687	348	375	454	393	169	247	132
COA Balance	N/A	0	38	33	33	-37	5	33	33	33	32	-66	-66
Vernalis (TAF)	N/A	322	179	54	52	57	107	74	75	77	82	98	148
Vernalis (cfs)	N/A	5243	3013	884	852	956	1734	1242	1225	1251	1482	1599	2496
Old/Middle River calc.	N/A	-383	-2,328	-8,722	-8,424	-9,052	- 4,169	-4,885	- 5,726	- 4,950	- 2,267	-2,964	-1,170

Facility	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Computed DOI	N/A	18089	7884	8004	6539	7497	7499	4505	6507	7890	11400	11403	22592
Excess Outflow	N/A	5531	0	0	0	0	0	0	2001	3384	0	0	13095
% Export/ Inflow	N/A	11%	25%	47%	50%	53%	37%	52%	50%	46%	20%	26%	8%
% Export/ Inflow std.	N/A	35%	35%	65%	65%	65%	65%	65%	65%	65%	45%	35%	35%

Hydrology

Statistic	Trinity	Shasta	Folsom	New Melones
Water Year Inflow (TAF)	1567	5604	2413	1095
Year to Date + Forecasted % of mean	130%	101%	89%	104%

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.

BUREAU OF RECLAMATION

Attachment 3

Sacramento River Temperature Modeling

Facility Temperature Outlook in Degrees Fahrenheit

Month	Shasta (deg F)	Keswick (deg F)	CCR (deg F)	BSF (deg F)	Igo (deg F)	Trinity (deg F)	Lewiston (deg F)
June	49.9	52.3	53.5	56.0	53.1	45.3	48.2
July	49.9	52.4	53.5	55.4	56.7	45.6	49.8
August	49.4	52.2	53.2	55.1	57.4	45.7	49.2
September	49.3	52.3	53.5	55.5	57.0	45.9	49.0
October	51.0	52.5	53.2	54.5	55.2	46.0	49.9
November	52.5	52.8	56.4	53.5	53.4	46.0	48.0

Run date: 5/21/24

EOM September Storage: 2.76 MAF (w/pulse)

Trinity profile date: 5/2/24

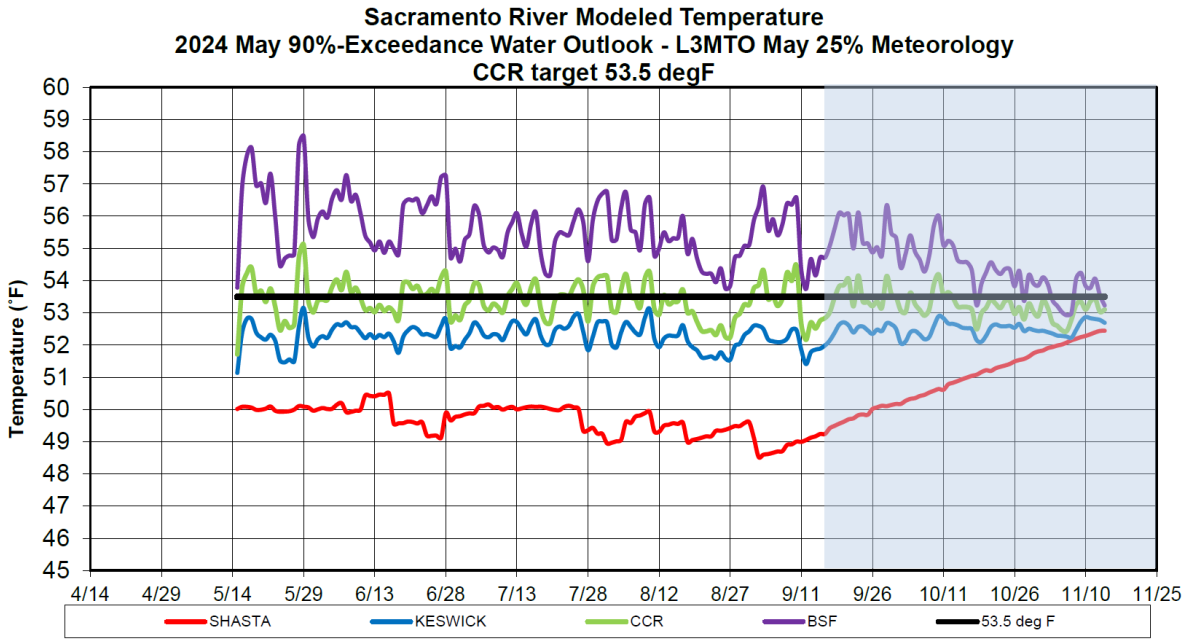
Whiskeytown profile date: 5/7/24

Shasta profile date: 5/15/24

Projected side gates: First Aug 19 Full Sep 3

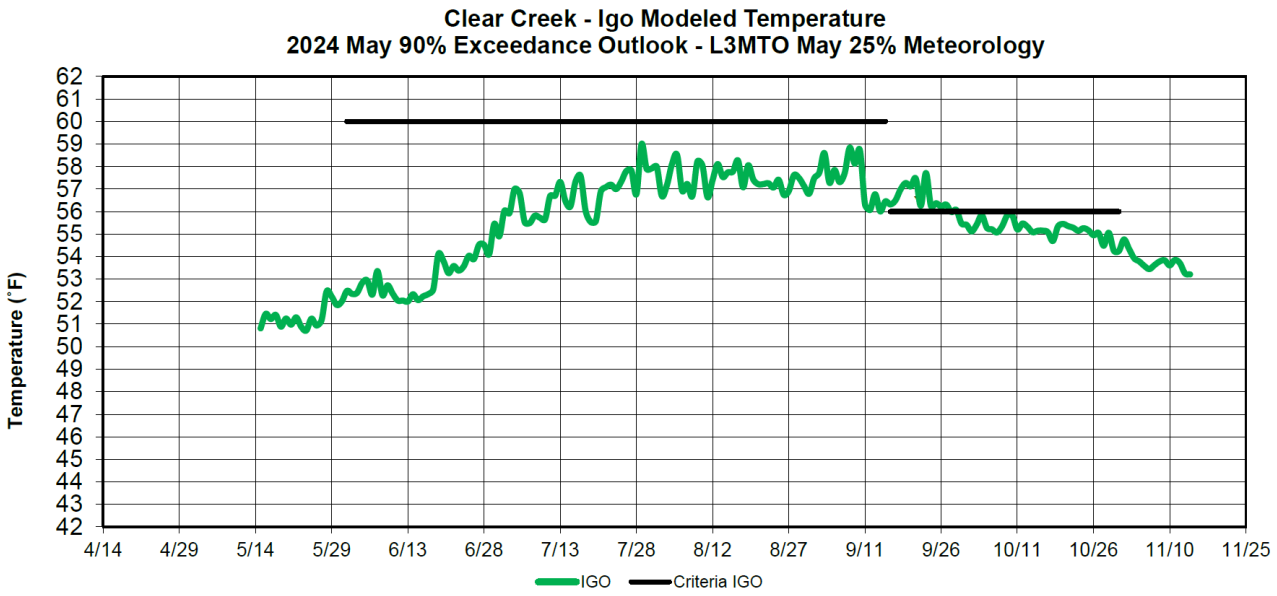
Shaded area denotes period of model limitations – see Fall Temperature Index

End of September Cold-Water-Pool less than 56 degrees Fahrenheit: 863 TAF



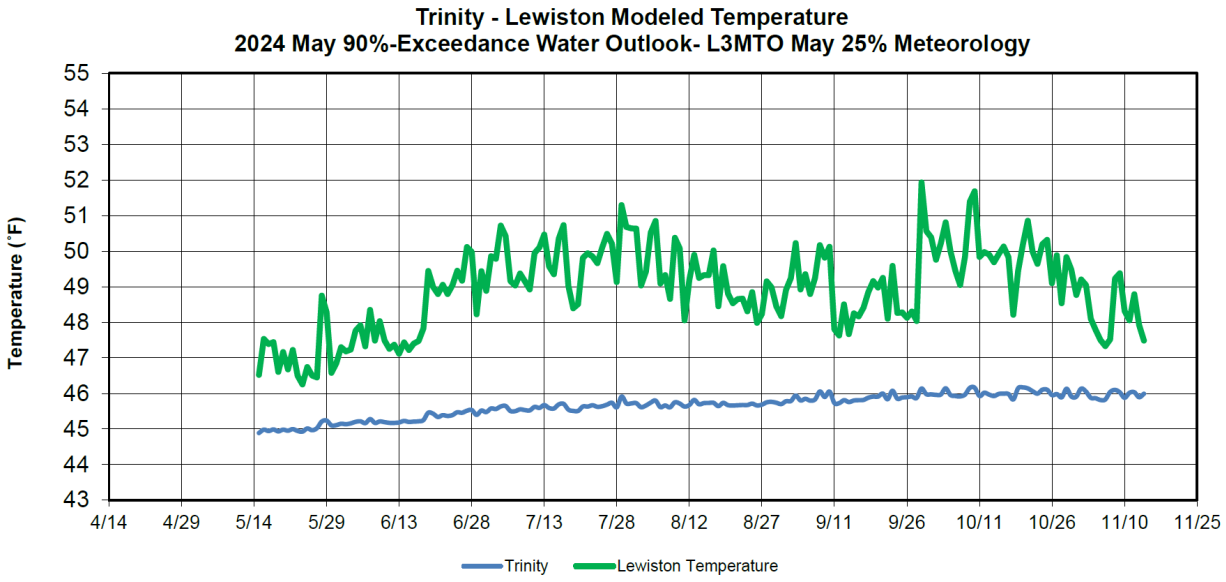
Sacramento River Modeled Temperature – May 2024 90%-Exceedance Water Outlook – L3MTO 25% Meteorology

This figure shows Sacramento River modeled temperature in degrees Fahrenheit at Shasta and Keswick Dams, and above Clear Creek from 4/14 to 11/25 in percent exceedances. It also shows the desired degree of 53.5 degrees Fahrenheit.



Clear Creek Igo Modeled Temperature – May 2024 90%-Exceedance Outlook – L3MTO 25% Meteorology

This figure is a line graph showing Igo modeled temperature in degrees Fahrenheit from 04/14 to 11/25.



Trinity-Lewiston Modeled Temperature – May 2024 90%-Exceedance Water Outlook – L3MTO 25% Meteorology

This figure is a line graph showing Trinity and Lewiston modeled temperature in degrees Fahrenheit from 04/14 to 11/25.

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Attachment 4

Estimated CVP Operations 90% Exceedance

Storages

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

Facility	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Trinity	2073	2117	2020	1885	1762	1633	1610	1606	1627	1639	1675	1739	1813
Trinity Elev.	N/A	2349	2342	2333	2324	2314	2312	2312	2313	2314	2317	2322	2328
Whiskeytown	237	238	238	238	238	238	206	206	206	206	206	206	238
Whiskeytown Elev.	N/A	1209	1209	1209	1209	1209	1199	1199	1199	1199	1199	1199	1209
Shasta	4364	4381	4064	3466	3053	2812	2717	2726	2798	2869	3024	3293	3496
Shasta Elev.	N/A	1061	1050	1027	1010	999	995	995	999	1002	1009	1020	1029
Folsom	849	966	898	642	446	411	360	327	314	300	326	422	554
Folsom Elev.	N/A	465	459	433	410	405	397	392	390	387	392	406	423
New Melones	2056	2068	2062	2003	1947	1903	1838	1845	1853	1857	1859	1880	1766
New Melones Elev.	N/A	1058	1058	1053	1047	1043	1037	1038	1039	1039	1039	1041	1030
Fed. San Luis	891	747	461	332	256	308	358	412	466	636	593	550	468
Fed. San Luis Elev.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total	10470	10516	9743	8567	7702	7304	7089	7122	7264	7506	7683	8090	8335

State End of the Month Reservoir Storage (TAF)

Facility	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Oroville	3461	3519	3408	2837	2330	1829	1628	1540	1513	1551	1638	1809	1879
Oroville Elev.	N/A	899	892	852	812	766	745	735	732	736	746	764	771
State San Luis	539	428	247	411	583	826	807	928	1140	1175	1185	1281	1237
State San Luis Elev.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total San Luis (TAF)	1430	1175	708	743	839	1134	1165	1340	1606	1811	1778	1831	1705
Total San Luis Elev.	N/A	470	422	426	436	466	469	485	508	526	523	527	517

Monthly River Releases (TAF/cfs)

Facility	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Trinity (TAF)	N/A	215	107	45	53	52	23	18	18	18	17	18	32
Trinity (cfs)	N/A	3,500	1,800	735	857	870	373	300	300	300	300	300	540
Clear Creek (TAF)	N/A	18	13	9	9	9	12	12	12	12	11	22	12
Clear Creek (cfs)	N/A	296	224	150	150	150	200	200	200	200	200	363	200
Sacramento (TAF)	N/A	449	625	851	645	476	338	238	246	246	222	246	238
Sacramento (cfs)	N/A	7300	10500	13850	10500	8000	5500	4000	4000	4000	4000	4000	4000
American (TAF)	N/A	246	214	345	283	113	92	75	77	77	76	77	74
American (cfs)	N/A	4000	3598	5616	4599	1893	1500	1263	1250	1250	1377	1250	1250
Stanislaus (TAF)	N/A	76	71	15	15	15	48	12	12	14	12	12	91
Stanislaus (cfs)	N/A	1242	1200	250	250	250	774	200	200	226	221	200	1537
Feather (TAF)	N/A	215	107	479	452	556	215	104	108	77	111	108	143
Feather (cfs)	N/A	3500	1800	7800	7350	9350	3500	1750	1750	1250	2000	1750	2400

Trinity Diversions (TAF)

Diversion Facility	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Carr PP	N/A	24	91	100	81	80	8	6	1	1	1	3	29
Spring Creek PP	N/A	20	80	90	70	70	30	0	0	0	0	0	0

Delta Summary (TAF)

Facility	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Tracy	N/A	123	150	259	229	260	190	140	110	220	44	55	57
USBR Banks	N/A	0	0	18	18	18	0	0	0	0	0	0	0
Contra Costa	N/A	12.0	10.0	11.0	12.0	13.0	14.0	14.0	14.0	13.0	14.0	12.0	12.0
Total USBR	N/A	135	160	288	259	291	204	154	124	233	58	67	69
State Export	N/A	37	37	393	397	396	125	221	278	160	111	183	62
Total Export	N/A	172	197	681	656	687	329	375	402	393	169	250	132
COA Balance	N/A	0	6	0	0	-69	-69	-53	-53	-53	-52	-53	-53
Vernalis (TAF)	N/A	322	131	54	52	57	107	74	75	77	82	98	148
Vernalis (cfs)	N/A	5243	2209	884	852	956	1734	1242	1225	1251	1482	1599	2496
Old/Middle River calc.	N/A	-383	-2146	-8722	-8424	-9052	-3931	-4885	-5074	-4950	-2267	-3002	-1170

Facility	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Computed DOI	N/A	17195	7884	8004	6539	7497	7808	4505	7353	7890	11400	11403	22592
Excess Outflow	N/A	4636	0	0	0	0	309	0	2847	3384	0	0	13095
% Export/Inflow	N/A	12%	21%	47%	50%	53%	35%	52%	44%	46%	20%	26%	8%
% Export/inflow std.	N/A	35%	35%	65%	65%	65%	65%	65%	65%	65%	45%	35%	35%

Hydrology

Statistic	Trinity	Shasta	Folsom	New Melones
Water Year Inflow (TAF)	1567	5,604	2,413	1095
Year to Date + Forecasted % of mean	130%	101%	89%	104%

CVP actual operations do not follow any forecasted operation or outlook; actual operations are based on real-time conditions.

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CVP releases or export values represent monthly averages.

CVP Operations are updated monthly as new hydrology information is made available December through May.

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Attachment 5

Sacramento River Temperature Modeling

Facility Temperature Outlook in Degrees Fahrenheit

Month	Shasta (deg F)	Keswick (deg F)	CCR (deg F)	BSF (deg F)	Igo (deg F)	Trinity (deg F)	Lewiston (deg F)
June	49.9	52.3	53.5	56.0	53.1	45.3	48.2
July	49.9	52.4	53.5	55.4	56.7	45.6	49.8
August	49.4	52.2	53.1	55.1	57.4	45.7	49.2
September	49.3 A	52.3 A	53.4 A	55.5	57.0	45.9	49.0
October	51.0 A	52.5 A	53.2 A	54.5	55.2	46.0	49.9
November	52.5 A	52.8 A	53.0 A	53.4	53.1	46.0	48.0

Legend

A = Denotes period of model limitations.

Run date: 5/21/24

EOM September Storage: 2.8 MAF (no pulse)

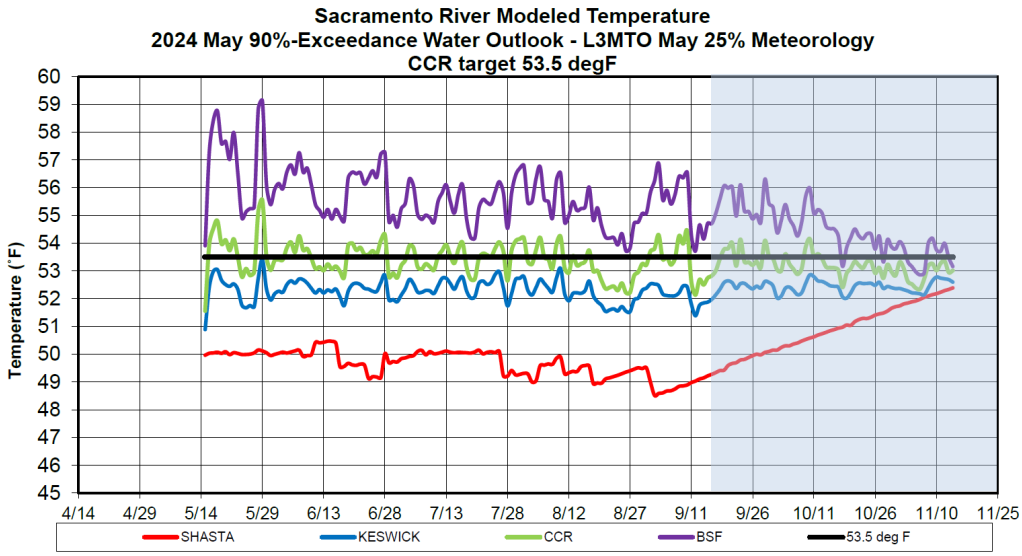
Trinity profile date: 5/2/24

Whiskeytown profile date: 5/7/24

Shasta profile date: 5/15/24

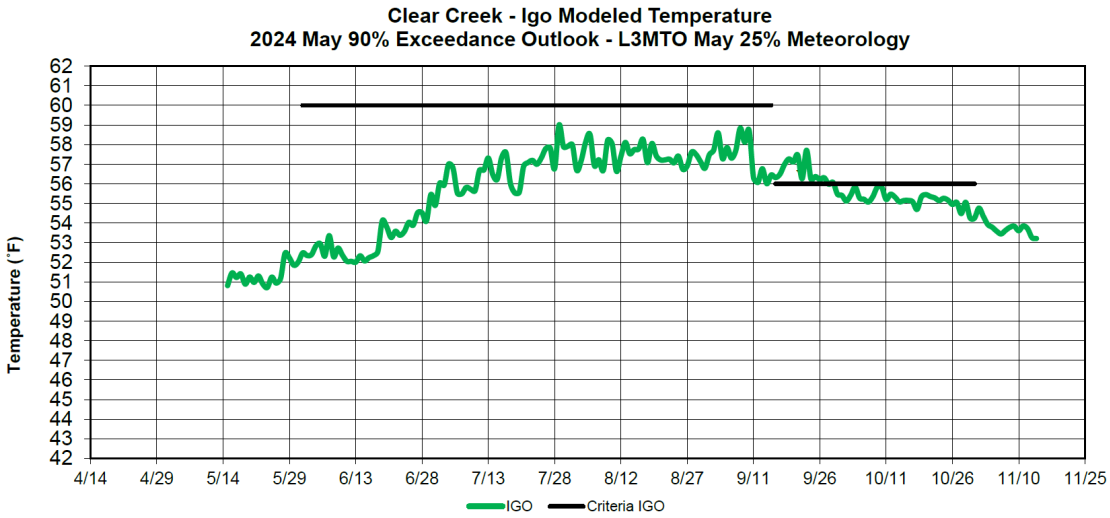
Projected side gates: First August 19 Full September 3

End of September Cold-Water-Pool less than 56 degrees Fahrenheit: 893 TAF



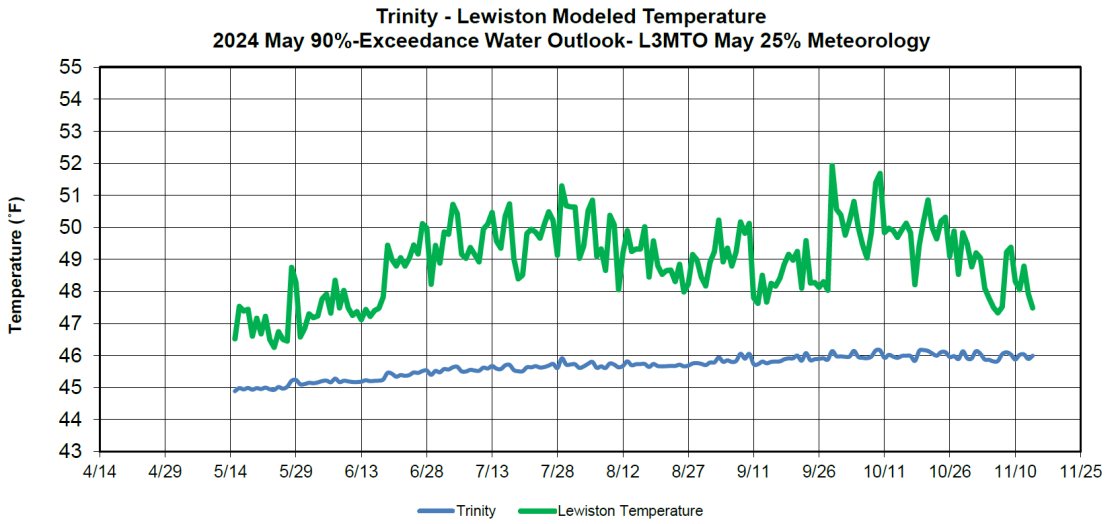
Sacramento River Modeled Temperature – May 2024 90%-Exceedance Water Outlook Historical 25% Meteorology.

This figure shows Sacramento River modeled temperature in degrees Fahrenheit at Shasta and Keswick Dams, and above Clear Creek from 4/14 to 11/25 in percent exceedances. It also shows the desired degree range between 53.5 and 56 degrees Fahrenheit.



Clear Creek Igo Modeled Temperature – May 2024 90%-Exceedance Water Outlook Historical 25% Meteorology.

This figure is a line graph showing Igo modeled temperature in degrees Fahrenheit at from 04/14 to 11/25.



Trinity-Lewiston Modeled Temperature – May 2024 90%-Exceedance Water Outlook Historical 25% Meteorology.

This figure is a line graph showing Trinity - Lewiston modeled temperature in degrees Fahrenheit at from 04/14 to 11/25.

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Attachment 6

Sacramento River Temperature Modeling

Facility Temperature Outlook in Degrees Fahrenheit

Month	Shasta	Keswick	CCR	BSF	Igo	Trinity	Lewiston
June	49.6	52.1	53.3	55.8	53.1	45.3	48.2
July	50.0	52.6	53.6	55.6	56.7	45.6	49.8
August	49.4	52.2	53.2	55.2	57.4	45.7	49.2
September	49.4 A	52.3 A	53.5 A	55.5 A	57.0	45.9	49.0
October	51.0 A	52.5 A	53.3 A	54.6 A	55.2	46.0	49.9
November	52.5 A	52.8 A	53.2 A	53.5 A	53.1	46.0	48.0

Legend

A = Denotes period of model limitations.

Run date: 5/21/24

EOM September Storage: 2.76 MAF (with pulse)

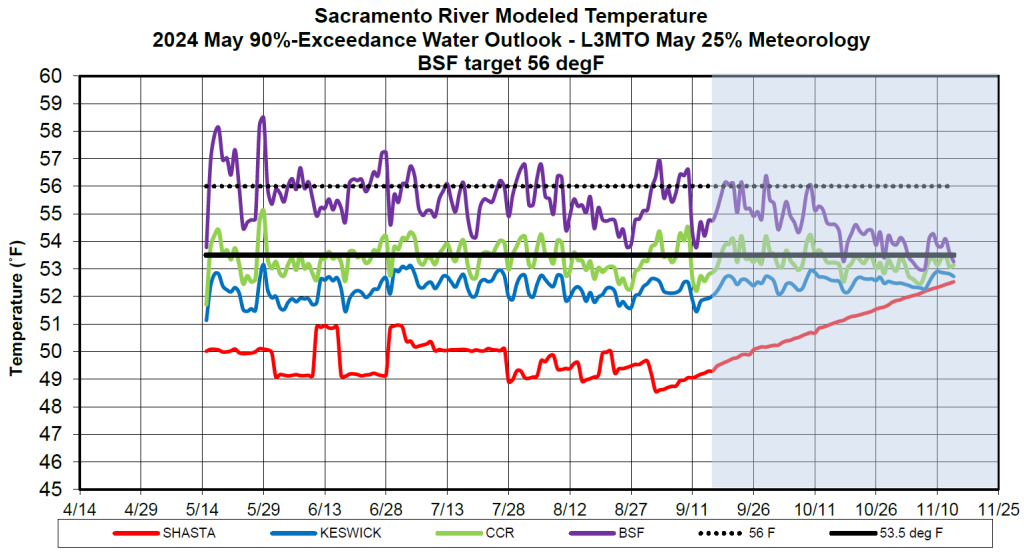
Trinity profile date: 5/2/24

Whiskeytown profile date: 5/7/24

Shasta profile date: 5/15/24

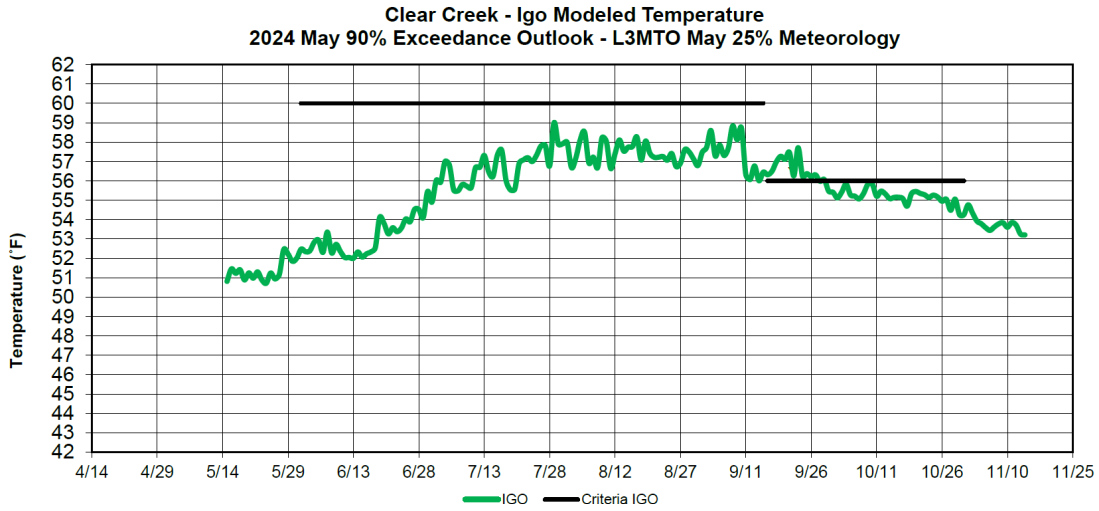
Projected side gates: First August 16 Full September 3

End of September Cold-Water-Pool less than 56 degrees Fahrenheit: 863 TAF



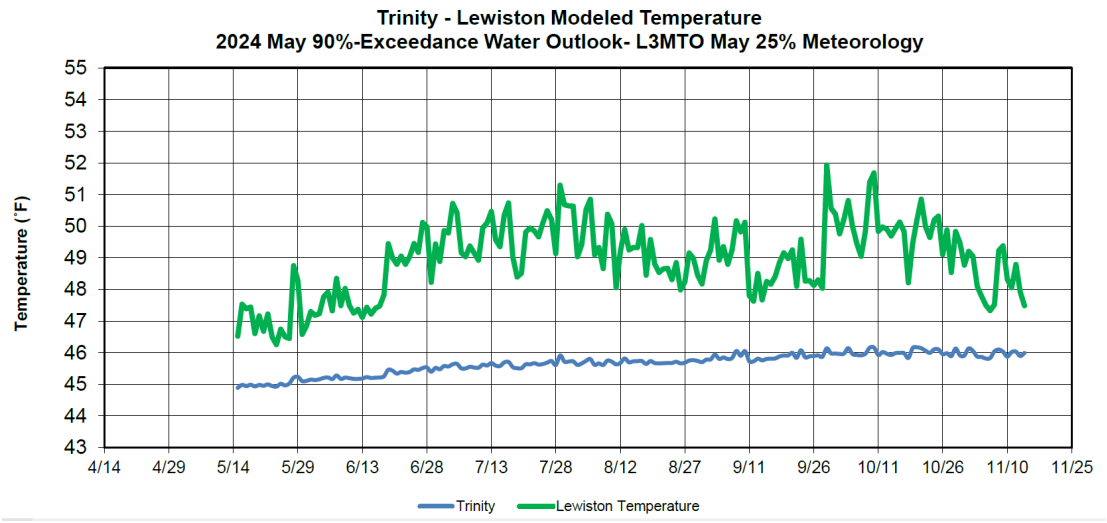
Sacramento River Modeled Temperature – May 2024 90%-Exceedance Water Outlook Historical 25% Meteorology Balls Ferry Target 56 degrees Fahrenheit.

This figure shows Sacramento River modeled temperature in degrees Fahrenheit at Shasta and Keswick Dams, and above Clear Creek from 4/14 to 11/25 in percent exceedances. It also shows the desired degree range between 53.5 and 56 degrees Fahrenheit.



Clear Creek Igo Modeled Temperature – May 2024 90%-Exceedance Water Outlook Historical 25% Meteorology.

This figure is a line graph showing Igo modeled temperature in degrees Fahrenheit at from 04/14 to 11/25.



Trinity-Lewiston Modeled Temperature – May 2024 90%-Exceedance Water Outlook Historical 25% Meteorology.

This figure is a line graph showing Trinity - Lewiston modeled temperature in degrees Fahrenheit at from 04/14 to 11/25.

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Attachment 7

Estimated CVP Operations 50% Exceedance

Storages

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

Facility	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Trinity	2073	2127	2053	1949	1817	1698	1648	1655	1693	1756	1868	1996	2100
Trinity Elev.	0	2350	2345	2337	2328	2319	2315	2316	2319	2323	2332	2341	2348
Whiskeytown	237	238	238	238	238	238	206	206	206	206	206	206	238
Whiskeytown Elev.	N/A	1209	1209	1209	1209	1209	1199	1199	1199	1199	1199	1199	1209
Shasta	4364	4325	4098	3635	3277	3045	2969	2998	3104	3436	3725	4054	4235
Shasta Elev.	N/A	1059	1051	1034	1020	1010	1006	1008	1012	1026	1037	1050	1056
Folsom	849	966	961	773	622	564	521	508	514	559	622	811	956
Folsom Elev.	N/A	465	465	447	431	424	419	418	418	424	431	450	464
New Melones	2056	2068	2112	2059	2006	1963	1912	1924	1941	1976	1962	1962	1934
New Melones Elev.	N/A	1058	1062	1058	1053	1049	1044	1045	1047	1050	1049	1049	1046
Federal San Luis	823	670	431	282	220	258	305	457	625	831	880	880	792
Federal San Luis Elev.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total	10402	10394	9893	8937	8180	7767	7562	7748	8082	8764	9263	9909	10255

State End of the Month Reservoir Storage (TAF)

Facility	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Oroville	3461	3526	3434	2955	2475	2056	1772	1720	1692	1903	2255	2595	2943
Oroville Elev.	N/A	900	894	861	824	788	760	755	752	773	806	834	860
State San Luis	539	424	315	473	619	840	970	1131	1105	1103	1103	1103	1030
State San Luis Elev.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total San Luis (TAF)	1362	1094	746	755	838	1099	1275	1589	1729	1934	1983	1983	1822
Total San Luis Elev.	N/A	462	426	427	436	463	479	507	519	536	540	540	526

Monthly River Releases (TAF/cfs)

Facility	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Trinity (TAF)	N/A	215	107	45	53	52	23	18	18	18	17	18	80
Trinity (cfs)	N/A	3,500	1,800	735	857	870	373	300	300	300	300	300	1,347
Clear Creek (TAF)	N/A	18	14	9	9	9	12	12	12	12	11	22	12
Clear Creek (cfs)	N/A	291	242	150	150	150	200	200	200	200	200	363	200
Sacramento (TAF)	N/A	504	565	738	615	476	369	268	277	277	472	492	428
Sacramento (cfs)	N/A	8200	9500	12000	10000	8000	6000	4500	4500	4500	8500	8000	7200
American (TAF)	N/A	246	196	284	246	143	123	105	108	108	200	123	280
American (cfs)	N/A	4000	3300	4621	4000	2406	2008	1772	1750	1750	3600	2000	4700
Stanislaus (TAF)	N/A	76	54	15	15	15	39	12	12	13	83	92	91
Stanislaus (cfs)	N/A	1242	900	250	250	250	635	200	200	219	1500	1500	1537
Feather (TAF)	N/A	307	85	479	479	497	255	104	108	108	97	108	104
Feather (cfs)	N/A	5000	1430	7800	7800	8350	4150	1750	1750	1750	1750	1750	1750

Trinity Diversions (TAF)

Diversion Facility	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Carr PP	N/A	23	68	79	80	69	38	5	1	1	1	1	20
Spring Creek PP	N/A	20	60	70	70	60	60	0	4	23	34	16	0

Delta Summary (TAF)

Facility	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Tracy	N/A	123	210	265	265	260	189	240	225	260	140	105	57
USBR Banks	N/A	0	0	20	20	20	0	0	0	0	0	0	0
Contra Costa	N/A	12.7	9.8	11.1	12.7	14.0	14.0	16.0	18.0	14.0	14.0	12.7	12.7
Total USBR	N/A	136	220	296	298	294	203	256	243	274	154	118	70
State Export	N/A	38	120	406	386	389	288	274	50	123	102	86	33
Total Export	N/A	174	340	702	684	683	491	530	293	397	256	204	103
COA Balance	N/A	0	41	72	57	48	41	41	41	41	41	41	41
Vernalis (TAF)	N/A	352	204	80	71	74	117	99	103	118	307	329	255
Vernalis (cfs)	N/A	5718	3421	1307	1161	1242	1904	1662	1680	1927	5534	5355	4278

Facility	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Old/Middle River calc.	N/A	-191	-3,449	-8,796	-8,631	-8,872	-5,883	-6,702	-3,504	-4,695	-1,650	-732	8
Computed DOI	N/A	26434	9195	8004	6539	7497	7499	4505	13323	16820	32653	31559	22256
Excess Outflow	N/A	13876	0	0	0	0	0	0	8817	10818	21252	20155	10859
% Export/Inflow	N/A	8%	31%	47%	50%	51%	45%	60%	25%	28%	12%	9%	6%
% Export/inflow std.	N/A	35%	35%	65%	65%	65%	65%	65%	65%	65%	45%	35%	35%

Hydrology

Statistic	Trinity	Shasta	Folsom	New Melones
Water Year Inflow (TAF)	1577	5,740	2,483	1,138
Year to Date + Forecasted % of mean	131%	104%	91%	108%

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.

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Attachment 8

Sacramento River Temperature Modeling

Facility Temperature Outlook in Degrees Fahrenheit

Month	Shasta (deg F)	Keswick (deg F)	CCR (deg F)	BSF (deg F)	Igo (deg F)	Trinity (deg F)	Lewiston (deg F)
June	49.3	52.0	53.3	56.1	52.8	45.3	48.5
July	49.0	51.9	53.1	55.4	56.5	45.6	50.2
August	49.2	52.1	53.2	55.2	57.5	45.7	49.2
September	49.6 A	52.5 A	53.6 A	55.6	57.2	45.8	49.0
October	51.1 A	52.9 A	53.6 A	54.7	54.9	45.9	48.5
November	52.5 A	52.8 A	53.1 A	53.4	52.7	45.9	48.1

Legend

A = Denotes period of model limitations.

Run date: 5/21/24

EOM September Storage: 3.05 MAF (with pulse)

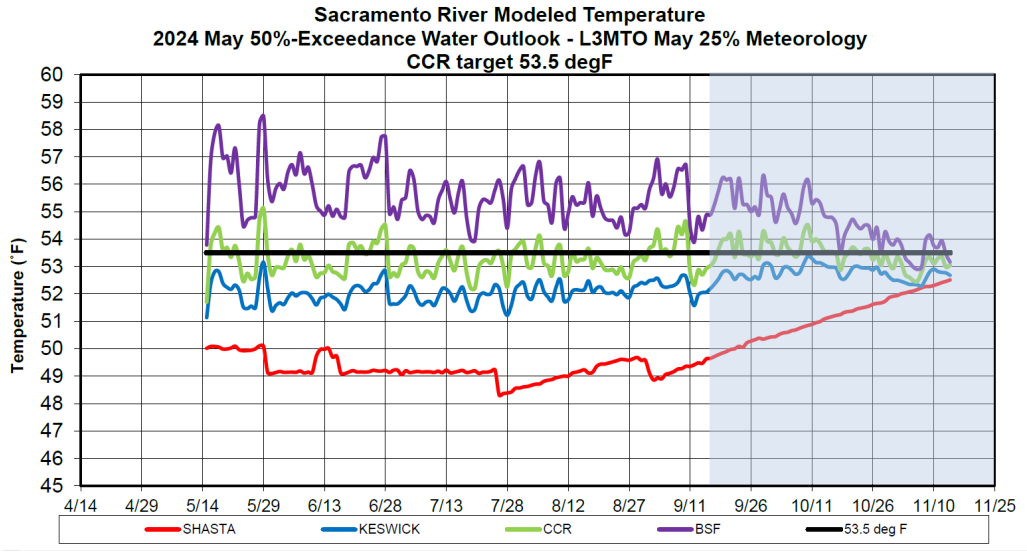
Trinity profile date: 5/2/24

Whiskeytown profile date: 5/7/24

Shasta profile date: 5/15/24

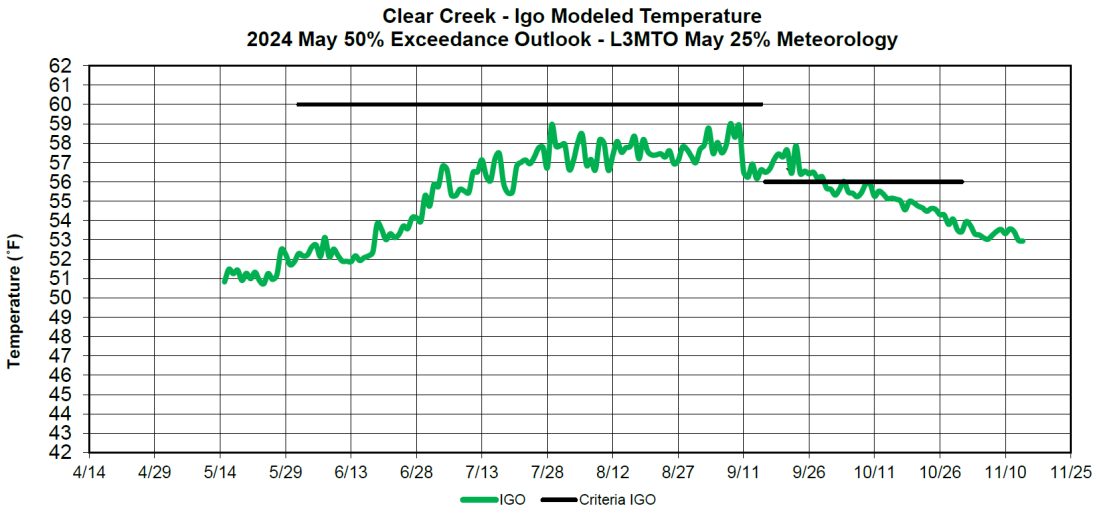
Projected side gates: First July 27 Full September 3

End of September Cold-Water-Pool less than 56 degrees Fahrenheit: 975 TAF



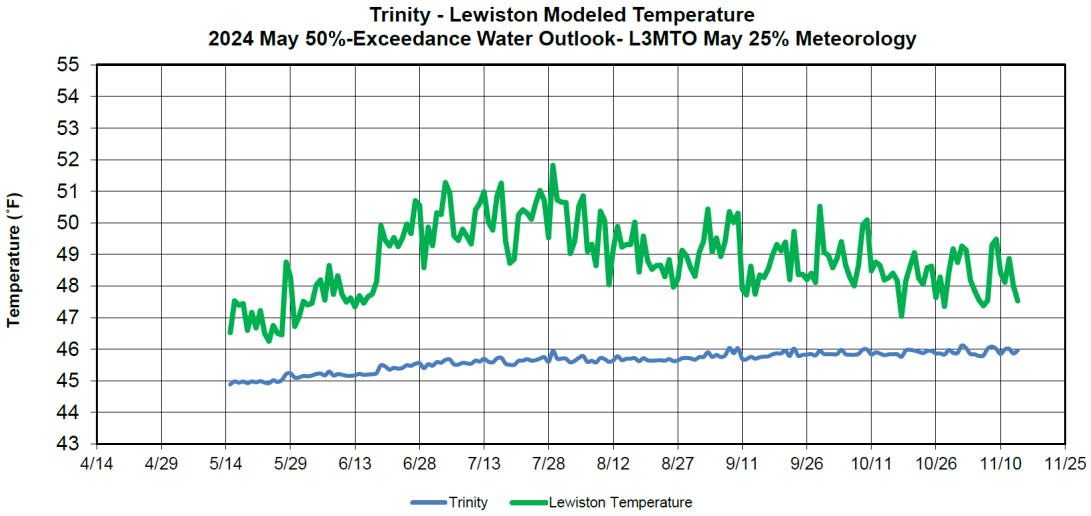
Sacramento River Modeled Temperature – May 2024 50%-Exceedance Water Outlook Historical 25% Meteorology.

This figure shows Sacramento River modeled temperature in degrees Fahrenheit at Shasta and Keswick Dams, and above Clear Creek from 4/14 to 11/25 in percent exceedances. It also shows the desired degree range between 45 and 60 degrees Fahrenheit.



Clear Creek Igo Modeled Temperature – May 2024 50%-Exceedance Water Outlook Historical 25% Meteorology.

This figure is a line graph showing Igo modeled temperature in degrees Fahrenheit at from 04/14 to 11/25.



Trinity-Lewiston Modeled Temperature – May 2024 50%-Exceedance Water Outlook Historical 25% Meteorology.

This figure is a line graph showing Trinity-Lewiston modeled temperature in degrees Fahrenheit at from 04/14 to 11/25.

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Attachment 9.

Biological Modeling

Spatially-explicit daily average Sacramento River water temperatures forecasts from the HEC-5Q model results are used as inputs to generate temperature-dependent egg mortality estimates. For this period, actual temperatures until May 20, 2024, and modeled temperatures after that, on the Sacramento River at Keswick Dam, above Highway 44, above Clear Creek, and Balls Ferry bridge, and interpolated temperatures at other locations are used to estimate temperatures at river miles where simulated winter-run redds were located.

Temperature-dependent egg mortality estimates are calculated by modeling a redd's lifetime based on the days required to cross a known cumulative degree-day threshold and estimating mortality as an increasing function of temperature past a temperature threshold. Martin et al (2017) was used to estimate stage independent mortality whereby a single temperature threshold is used from spawning and incubation through emergence for normal operations (Figure 1), Pulse Flow operations (Figure 2), Pulse Flow and 56°F at Balls Ferry Bridge operations (Figure 3), and for 50% forecast with Pulse Flow operations (Figure 4). Anderson et al. (2021) was used to estimate stage-dependent mortality targeting different temperatures before, during, and after the most sensitive stages during egg incubation for normal operations (Figure 5), Pulse Flow operations (Figure 6) Pulse Flow and 56°F at Balls Ferry Bridge (Figure 7), and for 50% forecast with Pulse Flow operations (Figure 8). The methods are applied to a set of simulated redds representative of redd construction timing and location from 2013-2022 and the results summarized on a population level for comparison. Further information about the model's assumptions have been documented in Table 1 below.

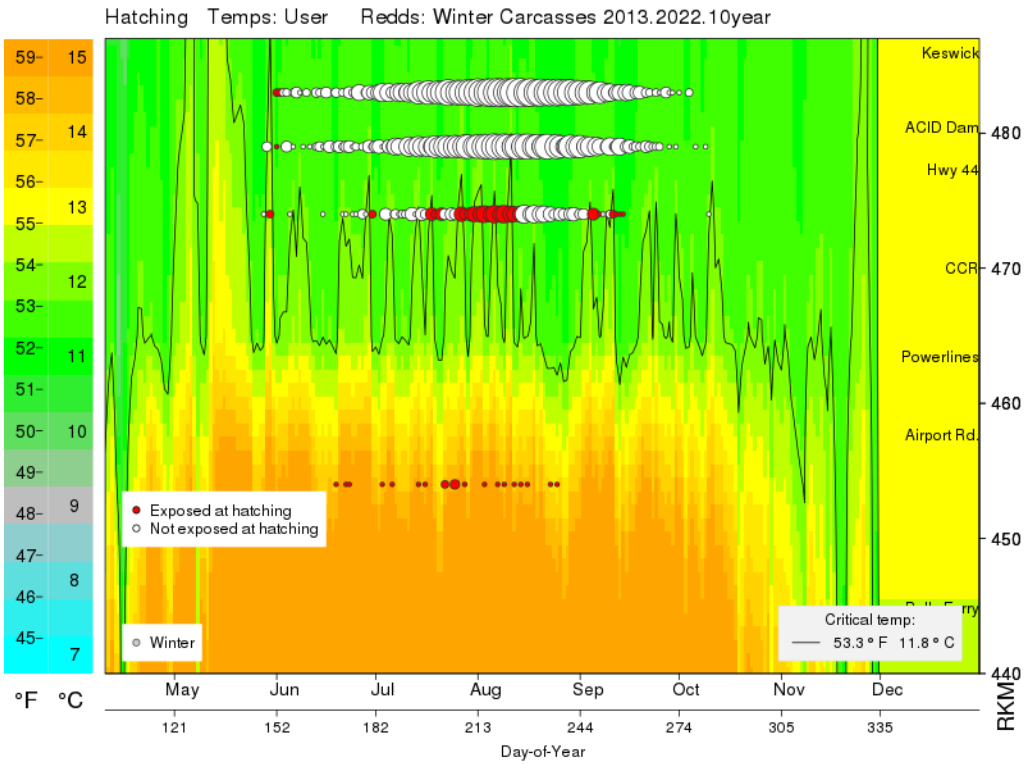

Figure 1. May 22, 90% forecast temperature landscape for no pulse operations with modeled temperatures starting May 21 for operations and using 2013-2022 redd locations and timing (Stage-independent mortality).

Figure 1 is a heatmap of the modeled temperature landscape for normal operations starting in May 2023 and ending in December 2024. It shows redds exposed at hatching and not exposed at hatching with red and white dots.

Notes

7397 Redds

Exposure to 11.82 degrees: 2.8% Pre Hatch, 8% Pre Emergence

Emergence Day: 272 Mean Day, 332 Last Day

99.6% Total Survival

Survival, mortality, and TDM summary

Surv. 0.996	Mort 0.004	TDM
1	0	Spawner Density
1	0	Background
1	0	Dewater

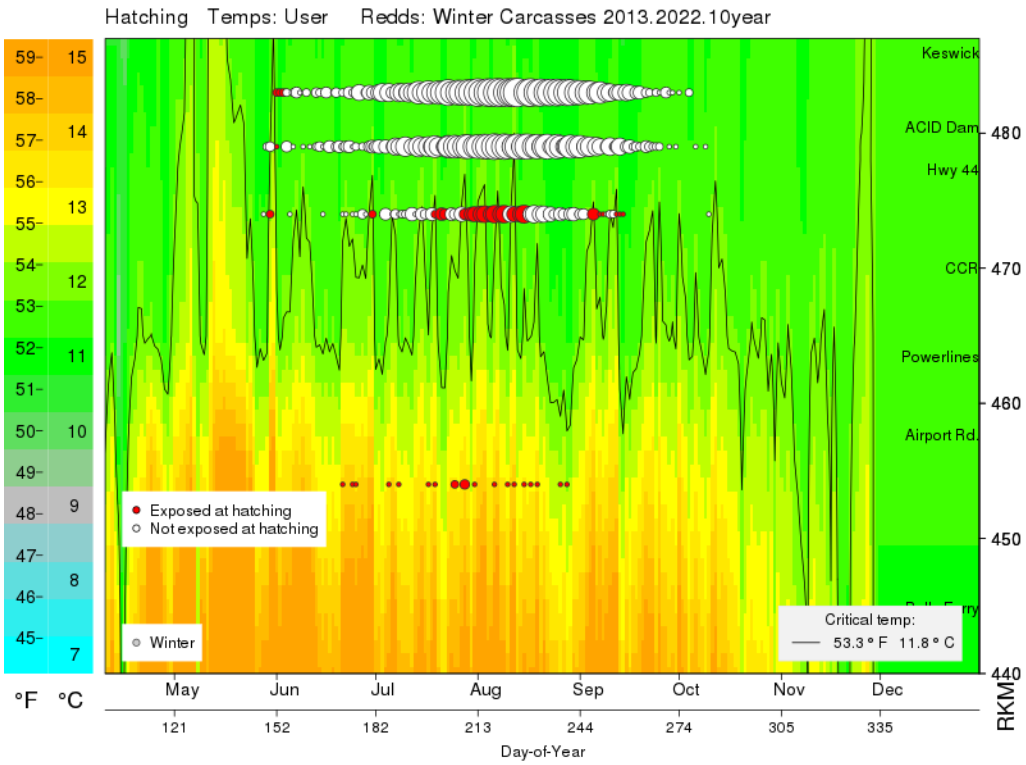

Figure 1. May 22, 90% forecast temperature landscape for Pulse Flow operations with modeled temperatures starting May 21 and using 2013-2022 redd locations and timing (Stage-independent mortality).

Figure 2 is a heatmap of the modeled temperature landscape for Pulse Flow operations starting in May 2023 and ending in December 2024. It shows redds exposed at hatching and not exposed at hatching with red and white dots.

Notes

7397 Redds

Exposure to 11.82 Degrees: 2.8% Pre Hatch, 8.2% Pre Emergence

Emergence Day: 272 Mean Day, 332 Last Day

99.6% Total Survival

Survival, mortality, and TDM summary

Surv. 0.996	Mort 0.004	TDM
1	0	Spawner Density
1	0	Background
1	0	Dewater

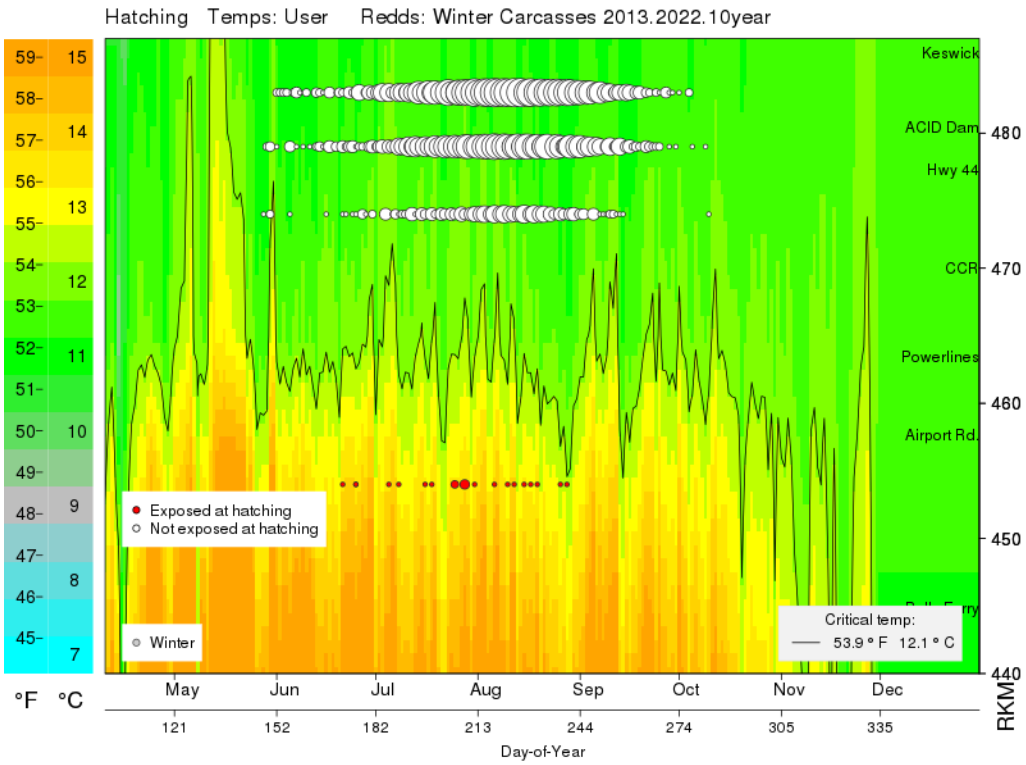

Figure 2. May 22, 90% forecast temperature landscape for Pulse Flow operations and targeting 56°F at Balls Ferry Bridge with modeled temperatures starting May 21 and using 2013-2022 redd locations and timing (Stage-independent mortality).

Figure 3 is a heatmap of the temperature landscape for Pulse Flow operations starting in May 2023 and ending in December 2024 It shows redds exposed at hatching and not exposed at hatching with red and white dots.

Notes

7397 Redds

Exposure to 12.14 degrees: 0.3% Pre Hatch, 1.5% Pre Emergence

Emergence Day: 271.7 Mean Day, 332 Last Day

99.7% Total Survival

Survival, mortality, and TDM summary

Surv. 0.997	Mort 0.003	TDM
1	0	Spawner Density
1	0	Background
1	0	Dewater

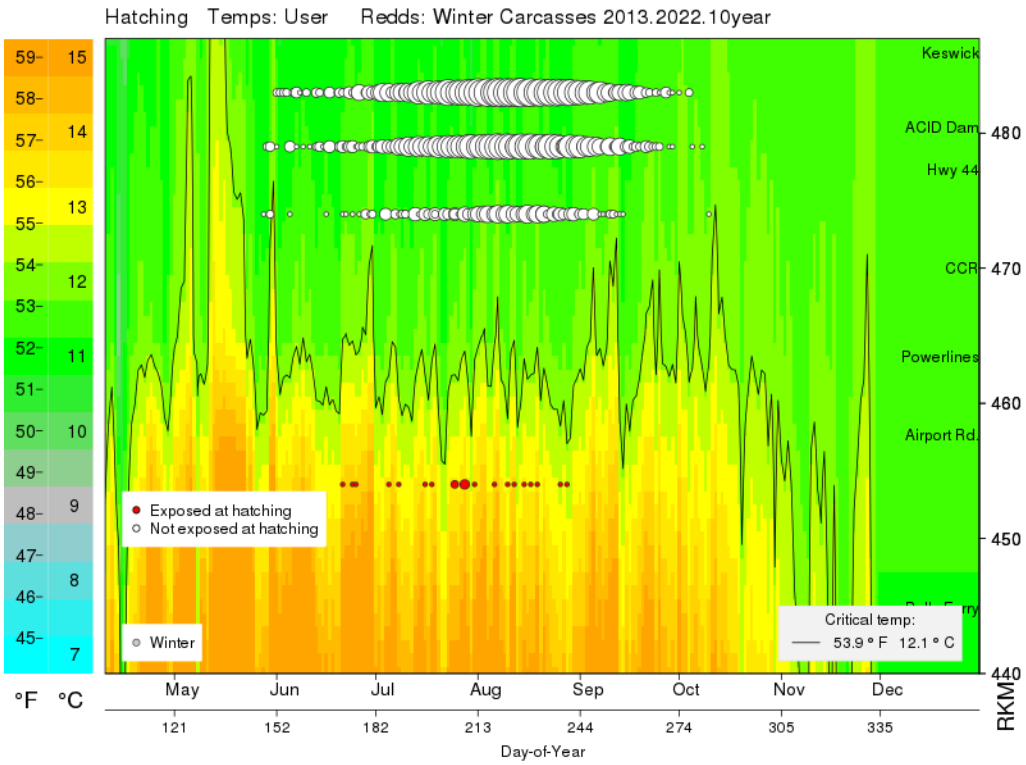

Figure 3. May 22, 50% forecast temperature landscape for Pulse Flow operations with modeled temperatures starting May 21 and using 2013-2022 redd locations and timing (Stage-independent mortality).

Figure 4 is a heatmap of the temperature landscape for Pulse Flow operations starting in May 2023 and ending in December 2024. It shows redds exposed at hatching and not exposed at hatching with red and white dots.

Notes

7397 Redds

Exposure to 12.14 degrees: 0.3% Pre Hatch, 2.3% Pre Emergence

Emergence Day: 272.4 Mean Day, 332 Last Day

99.7% Total Survival

Survival, mortality, and TDM summary

Surv. 0.997	Mort 0.003	TDM
1	0	Spawner Density
1	0	Background
1	0	Dewater

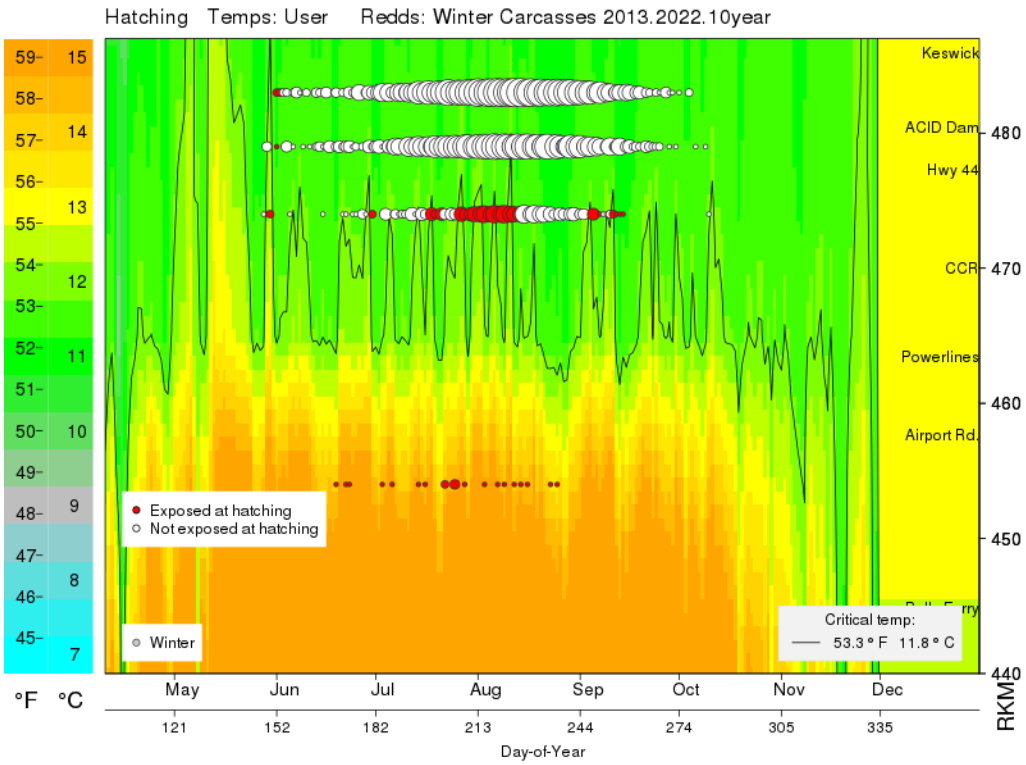

Figure 4. May 22, 90% forecast temperature landscape for no pulse operations with modeled temperatures starting May 21 and using 2013-2022 redd locations and timing (Stage-dependent mortality).

Figure 5 is a heatmap of the temperature landscape for normal operations starting in May 2023 and ending in December 2024. It shows redds exposed at hatching and not exposed at hatching with red and white dots.

Notes

7397 Redds

Exposure to 11.82 degrees: 2.9% Pre Hatch, 8% Pre Emergence

Emergence Day: 272 Mean Day, 332 Last Day

99.6% Total Survival

Survival, mortality, and TDM summary

Surv. 0.996	Mort 0.004	TDM
1	0	Spawner Density
1	0	Background
1	0	Dewater

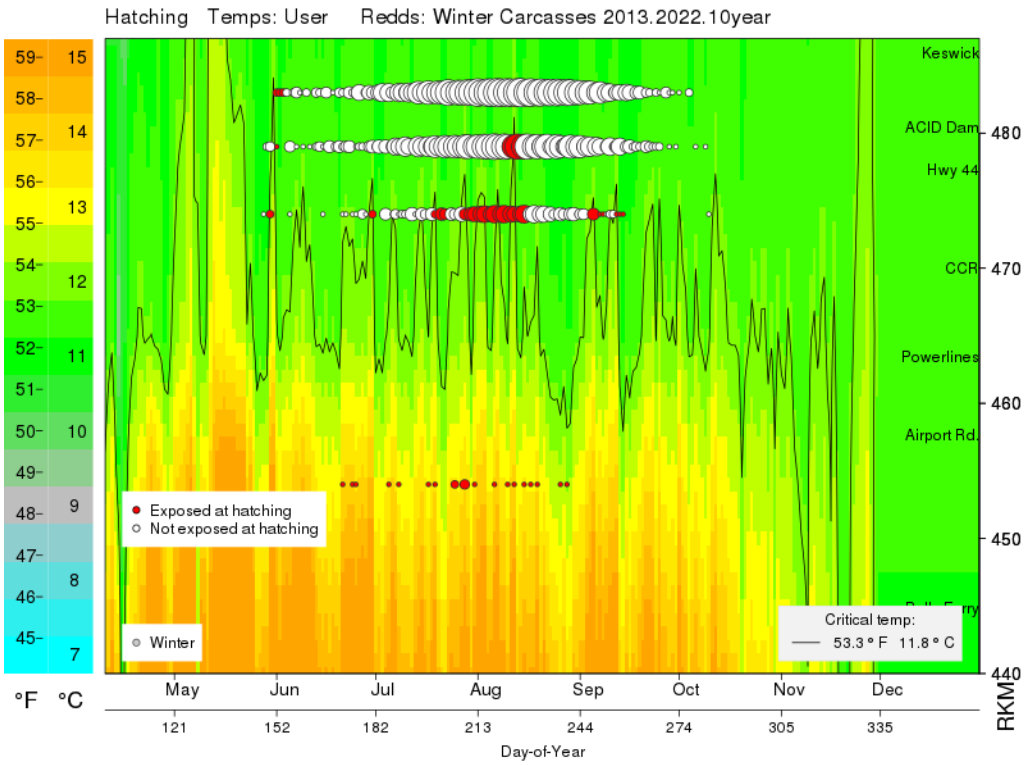

Figure 6. May 22, 90% forecast temperature landscape with Pulse Flow operations with modeled temperatures starting May 21 and using 2013-2022 redd locations and timing (Stage-dependent mortality).

Figure 6 is a heatmap of the temperature landscape for Pulse Flow operations starting in May 2023 and ending in December 2024. It shows redds exposed at hatching and not exposed at hatching with red and white dots.

Notes

7397 Redds

Exposure to 11.82 degrees: 6.6% Pre Hatch, 40.8% Pre Emergence

Emergence Day: 272 Mean Day, 332 Last Day

99.5% Total Survival

Survival, mortality, and TDM summary

Surv. 0.995	Mort 0.005	TDM
1	0	Spawner Density
1	0	Background
1	0	Dewater

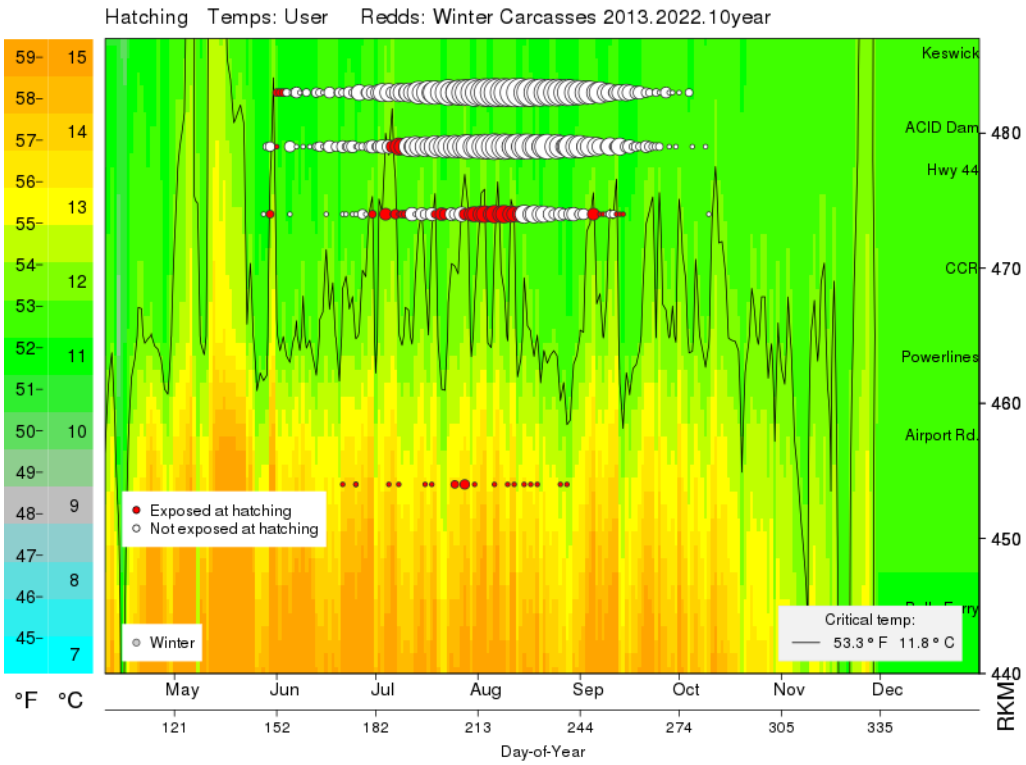

Figure 7. May 22, 90% forecast temperature landscape with Pulse Flow operations and targeting 56°F at Balls Ferry Bridge with modeled temperatures starting May 21 and using 2013-2022 redd locations and timing (Stage-dependent mortality).

Figure 7 is a heatmap of the temperature landscape for Pulse Flow operations and targeting 56 degrees Fahrenheit at Balls Fery Bridge starting in May 2023 and ending in December 2024. It shows redds exposed at hatching and not exposed at hatching with red and white dots.

Notes

7397 Redds

Exposure to 11.82 degrees: 3.4% Pre Hatch, 24.8% Pre Emergence

Emergence Day: 271.7 Mean Day, 332 Last Day

99.6% Total Survival

Survival, mortality, and TDM summary

Surv. 0.996	Mort 0.004	TDM
1	0	Spawner Density
1	0	Background
1	0	Dewater

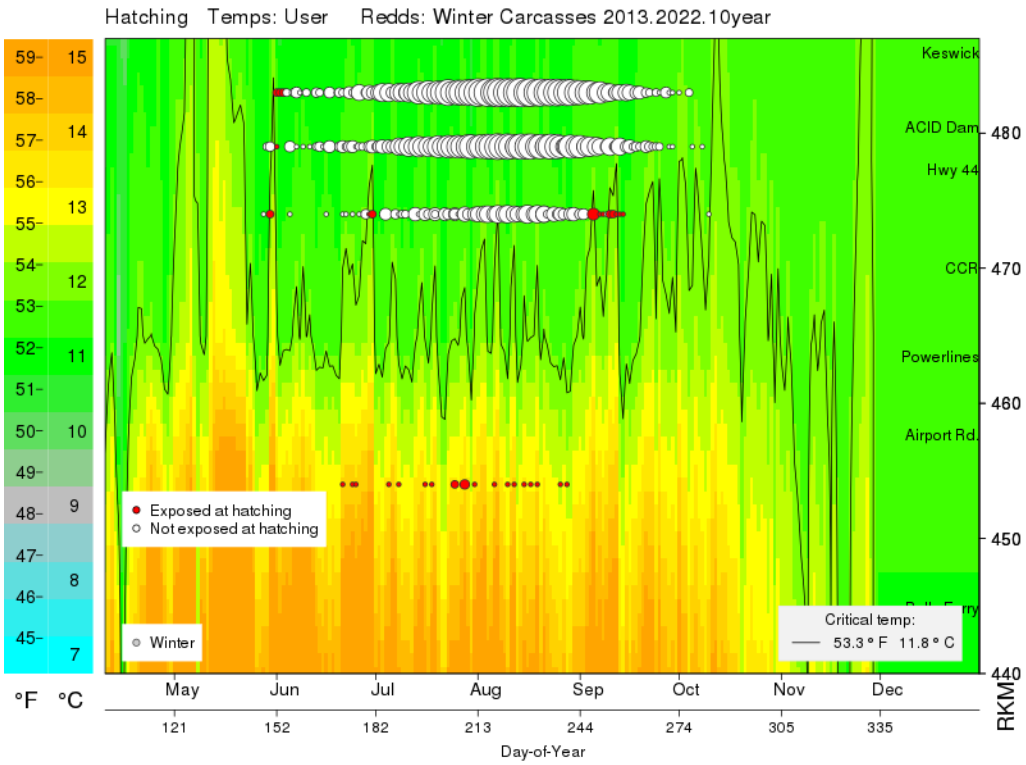

Figure 8. May 22, 50% forecast temperature landscape with modeled temperatures starting May 21 and using 2013-2022 redd locations and timing (Stage-dependent mortality).

Figure 8 is a heatmap of the temperature landscape with modeled temperatures starting in May 2023 and ending in December 2024. It shows redds exposed at hatching and not exposed at hatching with red and white dots.

Notes

7397 Redds

Exposure to 11.82 degrees: 0.6% Pre Hatch, 31.5% Pre Emergence

Emergence Day: 272.4 Mean Day, 332 Last Day

99.7% Total Survival

Survival, mortality, and TDM summary

Surv. 0.997	Mort 0.003	TDM
1	0	Spawner Density
1	0	Background
1	0	Dewater

Table 1. Biological modeling parameter information.

Parameter	**May 22, 2024 Scenario**
Meteorology source	L3MTO Meteorology 25%
Time period	1/1/24-4/22/24: Observed temperature 4/23/24-11/29/24: Simulated
Reservoir Model used	HEC-5Q
River Model used	HEC-5Q
Shasta Profile date	5/15/2024
TCD Gate operations	HEC-5Q
Sacramento water temperatures used	HEC-5Q output at Keswick, Highway 44, Clear Creek, and Balls Ferry.
Biological Model used	SacPAS Fish model (Temperature effect only)
Temperature Mortality Models	Stage-independent mortality Stage-dependent mortality
Egg emergence timing model	Linear. 958 ATUs (degrees C), as indicated for Zeug et al. on SacPAS under Egg to emergence timing model.
TDM redd time distribution	Aerial Surveys 2013-2022 (7,397 redds)
TDM redd space distribution	Aerial Surveys 2013-2022 (7,397 redds)
TDM Tcrit (50th percentile)	Stage-independent mortality: 12.14°C Stage-dependent mortality: 11.82°C
TDM bT (50th percentile)	Stage-independent mortality: 0.026°C-1d-1 Stage-dependent mortality: 0.436°C-1d-1
Critical Days	Stage-independent mortality: All Stage-dependent mortality: 4 days
TDM estimate	See Figures

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Attachment 10: Description of SWFSC Temperature-dependent Mortality Modeling Scenarios – May 28, 2024

Total number of scenarios simulated: 4 Model Start Date: May 8, 2024

Modeling framework used: "Full" models:

Shasta: CE-QUAL-W2
Keswick: CE-QUAL-W2
Upper Sacramento River: RAFT

Temperature-dependent mortality: Stage independent (Martin et al, 2017)

Keswick Release Scenario Assumptions:

Label	Description	Jun	Jul	Aug	Sept	Oct	Nov
Run 1	No pulse	10500	13900	10500	8000	5500	4000
Run 2	Pulse 53.5F at CCR	10500	13900	10500	8000	5500	4000
Run 3	Pulse 56F at BSF	10500	13900	10500	8000	5500	4000
Run 4	Pulse 50% exceedance	9500	12000	10000	8000	6000	4500

Hydrology:
All simulations are run with forecasted inflows from the California Nevada River Forecast Center at a 90% (Runs 1—3) or 50% (Run 4) exceedance hydrology.

Meteorology:
All simulations are run with the meteorological time series taken from the historical record for year 2016.

Inflow temperature:
All simulations are run with the inflow tributary temperatures to Shasta Reservoir from the historical record for year 2016.

Initial Shasta conditions:

Variable	Value/Description
Temperature profile date	5/8/2024
Initial storage (TAF)	4388
Initial storage date	5/8/2024
Initial elevation (ft)	1061
Initial elevation date	7/20/2022

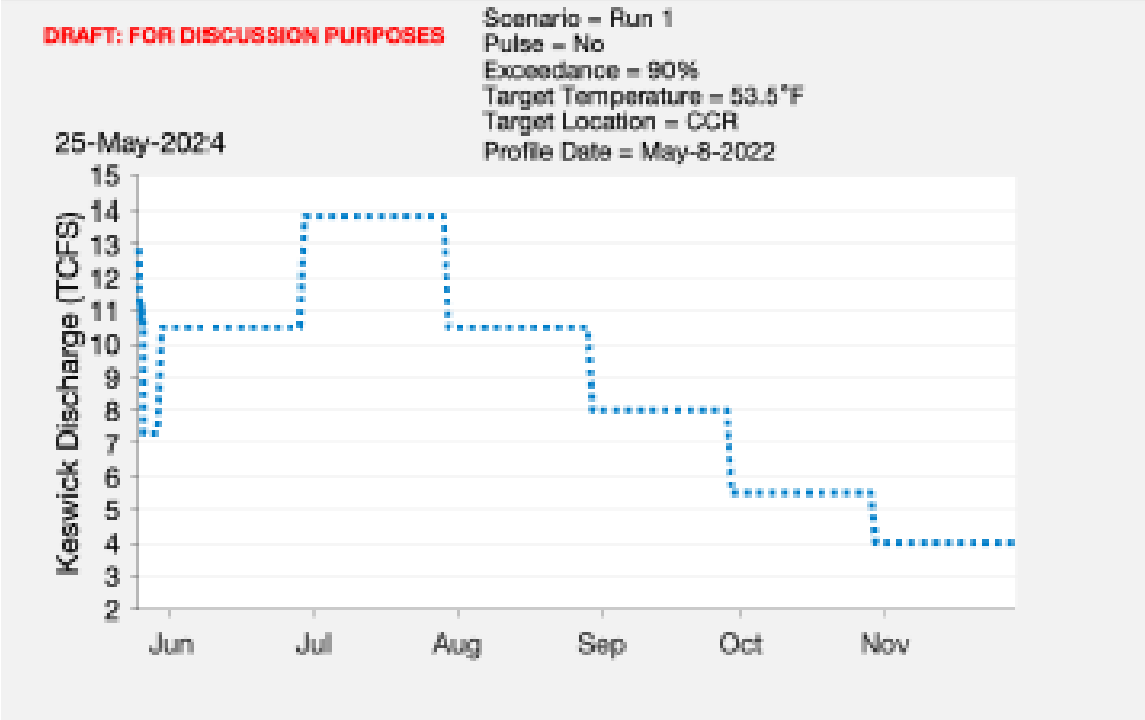
Temperature Target (Pattern/shaping) Parameters:

Model runs use all combinations of values given in the table below, along with the 4 release scenarios described in Section 2.

Variable	Value(s)
Target location	CCR and BSF
Target temperature (°C and °F)	(°C) 11.9 & 13.3 (°F) 53.5 & 56
Shoulder temperature (°C and °F)	(°C) NA (°F) 58
Window length (weeks)	NA
Center date	NA
Redd year distribution	aggregate 2016-2022

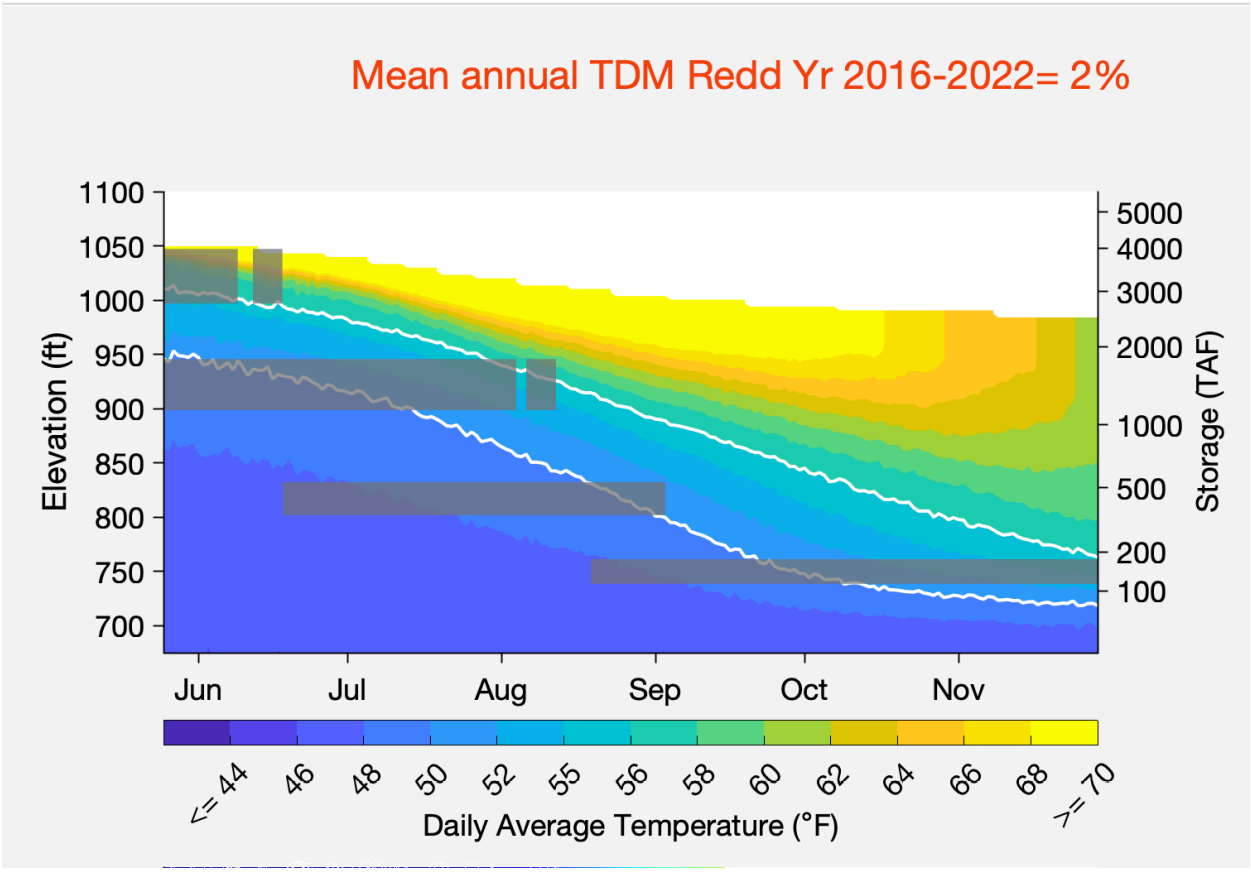
Figures:

Run 1: No Pulse



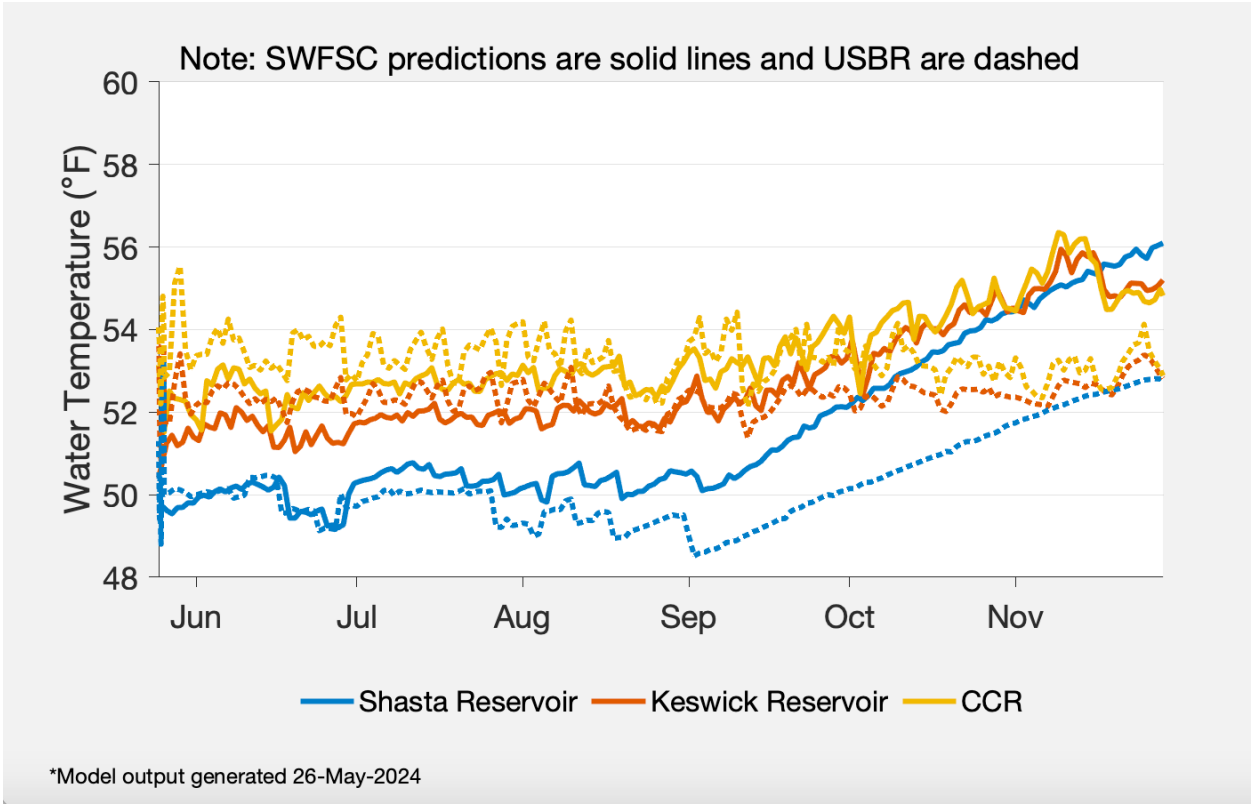
Simulated Timeseries of Keswick Discharge

The figure shows a line graph of simulated Keswick discharge measured in thousands of cfs between the months of June and November.



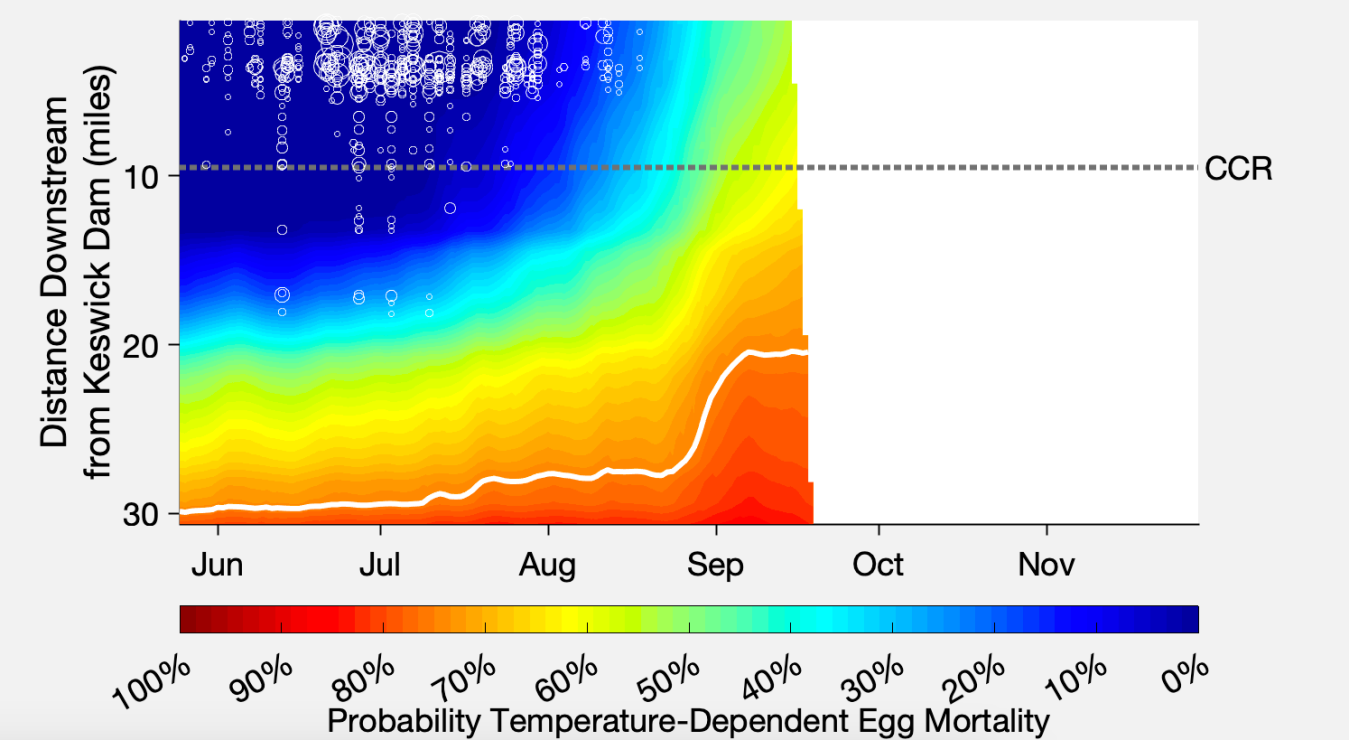
Simulated Shasta Reservoir Water Temperature Profile

This figure shows the simulated Shasta Reservoir water temperature profile and storage levels between June and November. Gray boxes indicate the opening of temperature control device gates. The mean annual Temperature-dependent mortality for redds 2016 – 2022 is 2%.



Simulated Water Temperatures at Shasta Reservoir, Keswick, and CCR

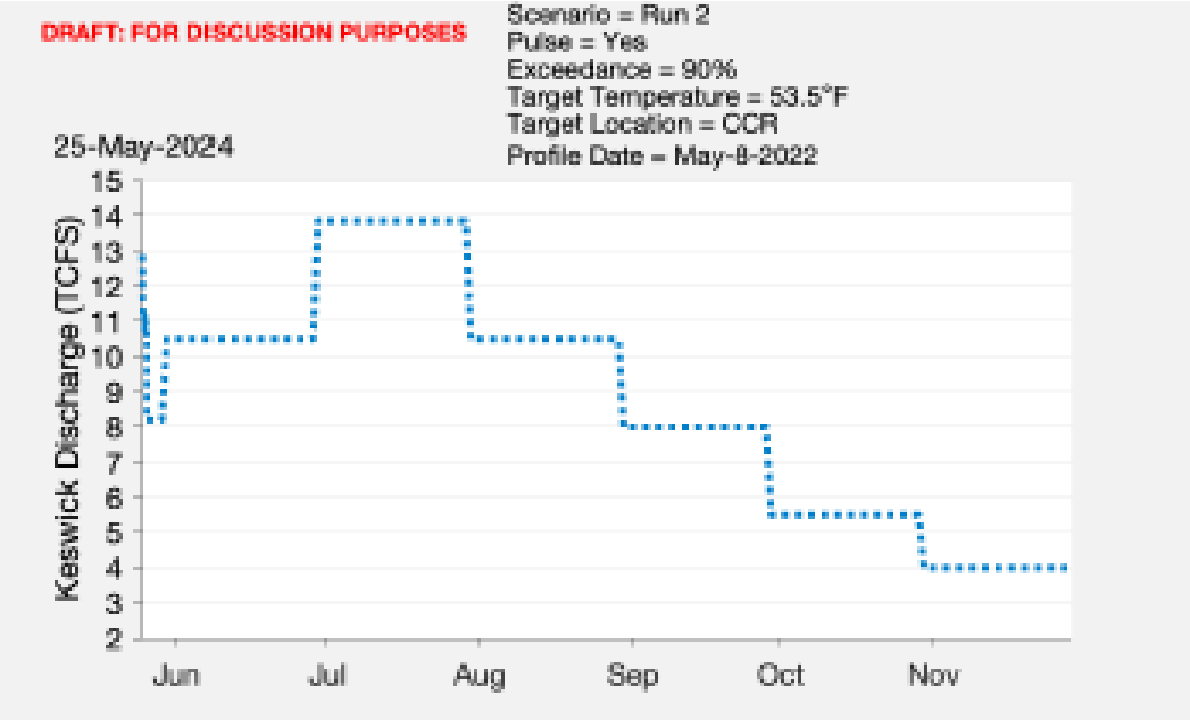
The figure shows simulated water temperatures at Shasta Reservoir, Keswick, and CCR from June to November. Solid lines depict Southwest Fisheries Science Center model predictions and dashed lines depict predictions made from Reclamation's HEC5Q models.



Estimated temperature-dependent egg mortality

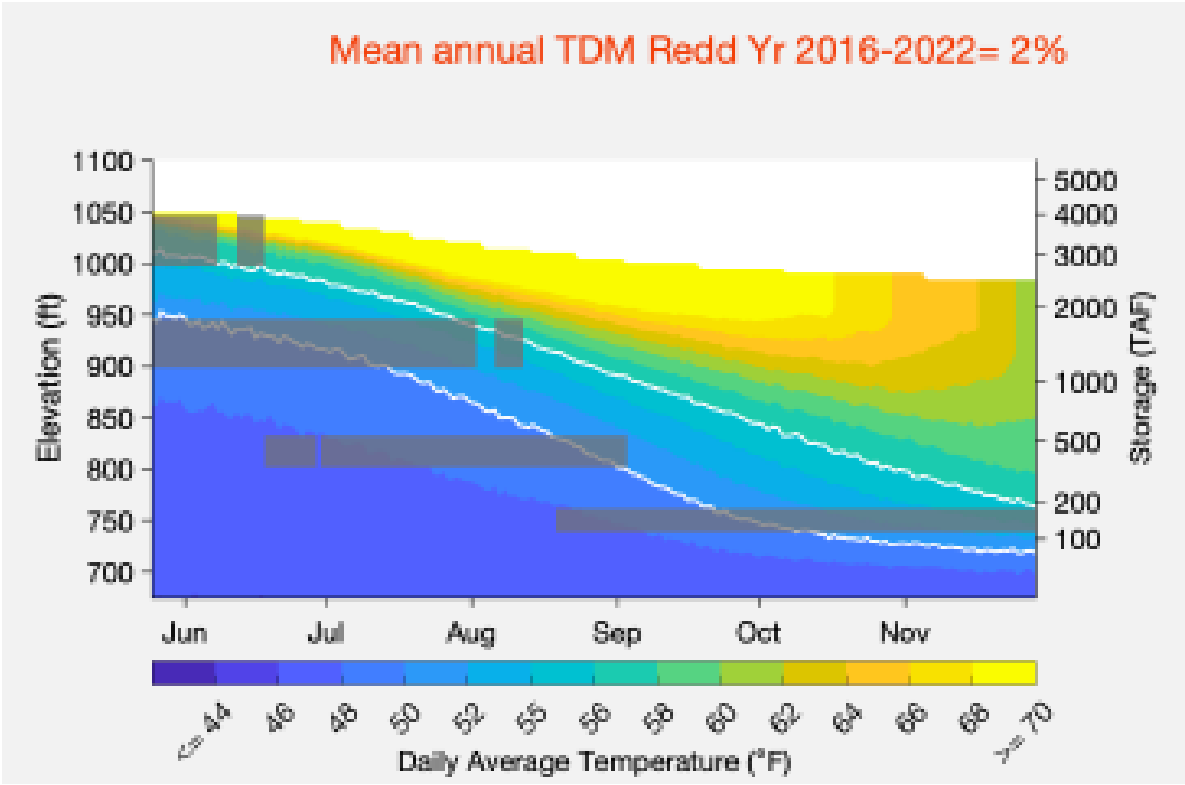
The figure shows probability of temperature-dependent egg mortality probability as it varies across downstream distance from Keswick Dam between 0 and 30 miles and through the months of June to September.

Run 2: Pulse 53.5F at CCR



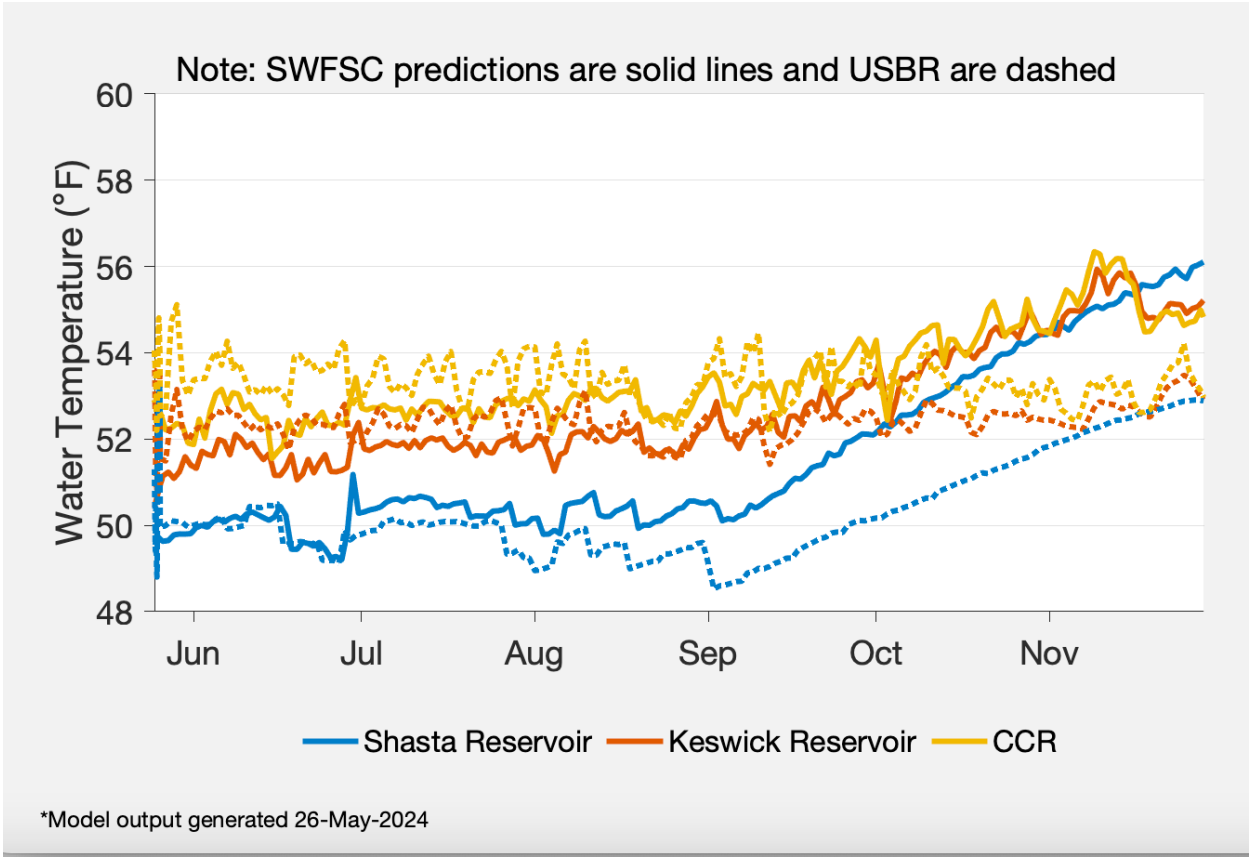
Simulated Timeseries of Keswick Discharge

The figure shows a line graph of simulated Keswick discharge measured in thousands of cfs between the months of June and November.



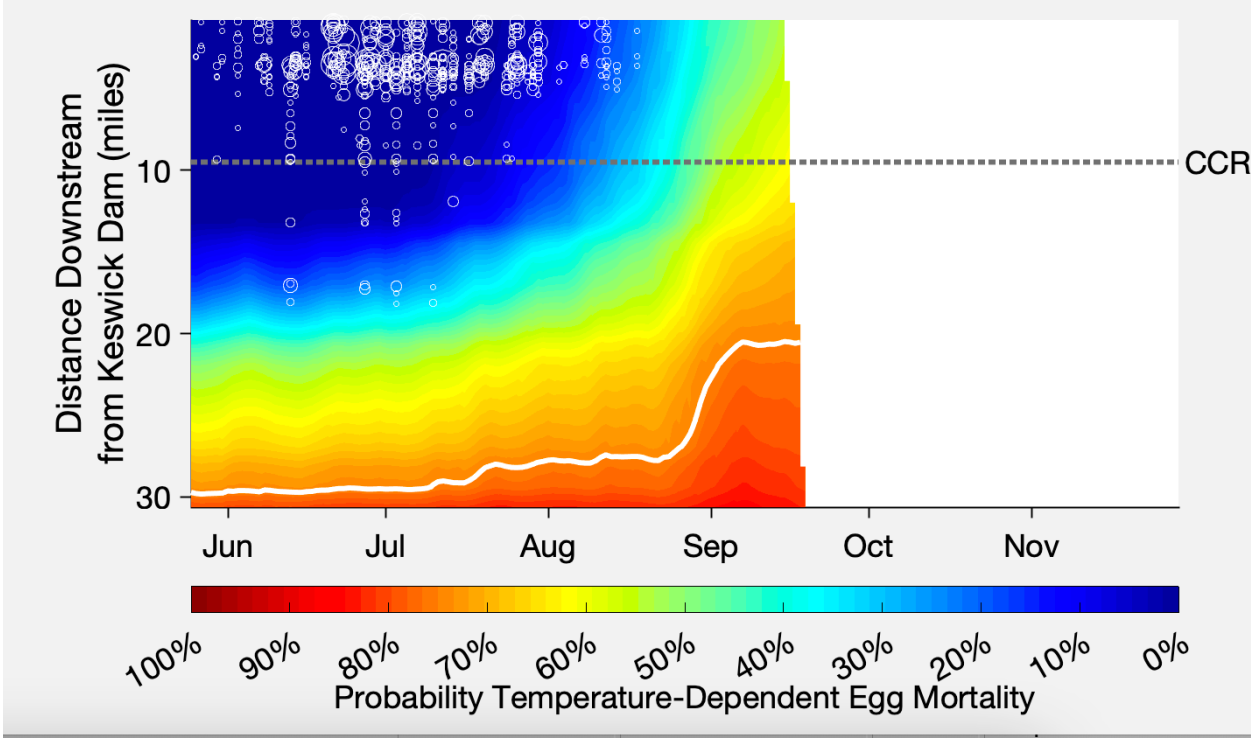
Simulated Shasta Reservoir Water Temperature Profile

This figure shows the simulated Shasta Reservoir water temperature profile and storage levels between June and November. Gray boxes indicate the opening of temperature control device gates. The mean annual Temperature-dependent mortality for redds 2016 – 2022 is 2%.



Simulated Water Temperatures at Shasta Reservoir, Keswick, and CCR

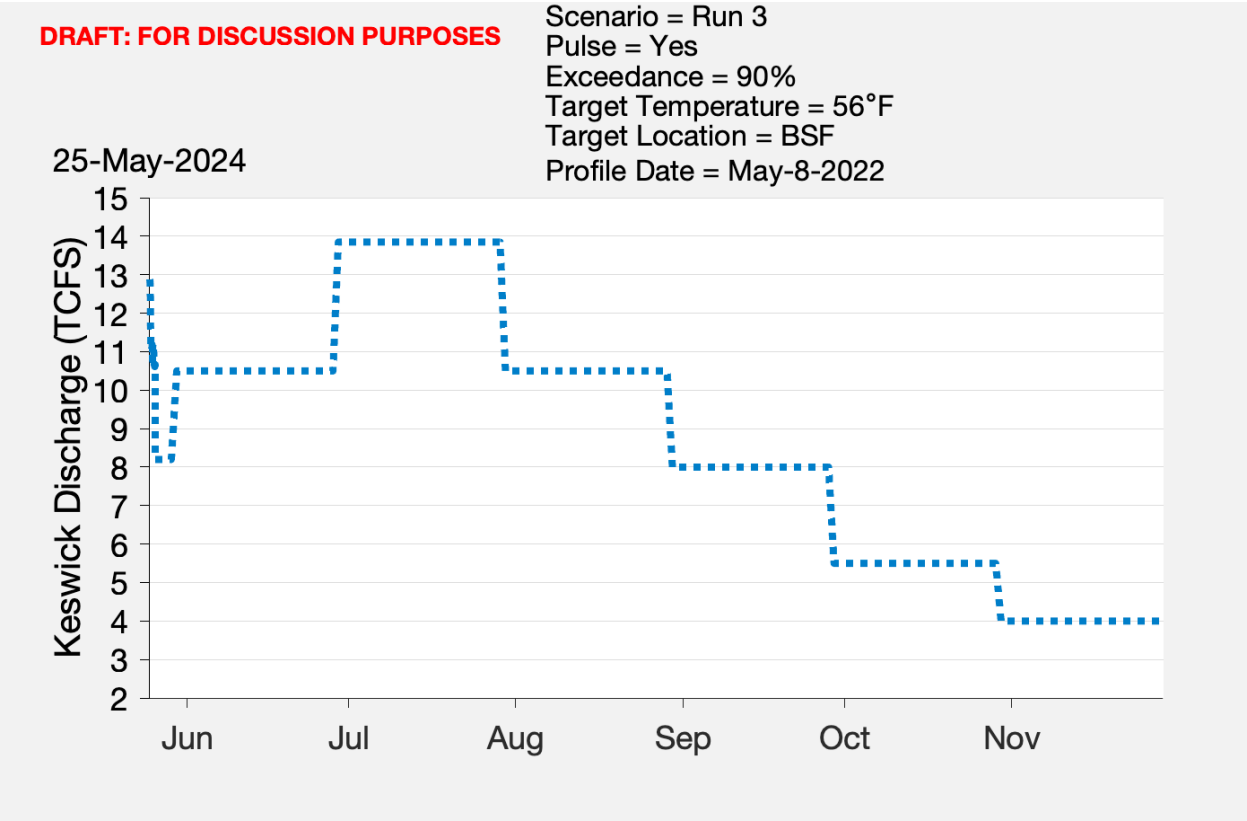
The figure shows a line graph of simulated water temperatures at Shasta Reservoir, Keswick, and CCR from June to November. Solid lines depict Southwest Fisheries Science Center model predictions and dashed lines depict predictions made from Reclamation's HEC5Q models.



Estimated temperature-dependent egg mortality

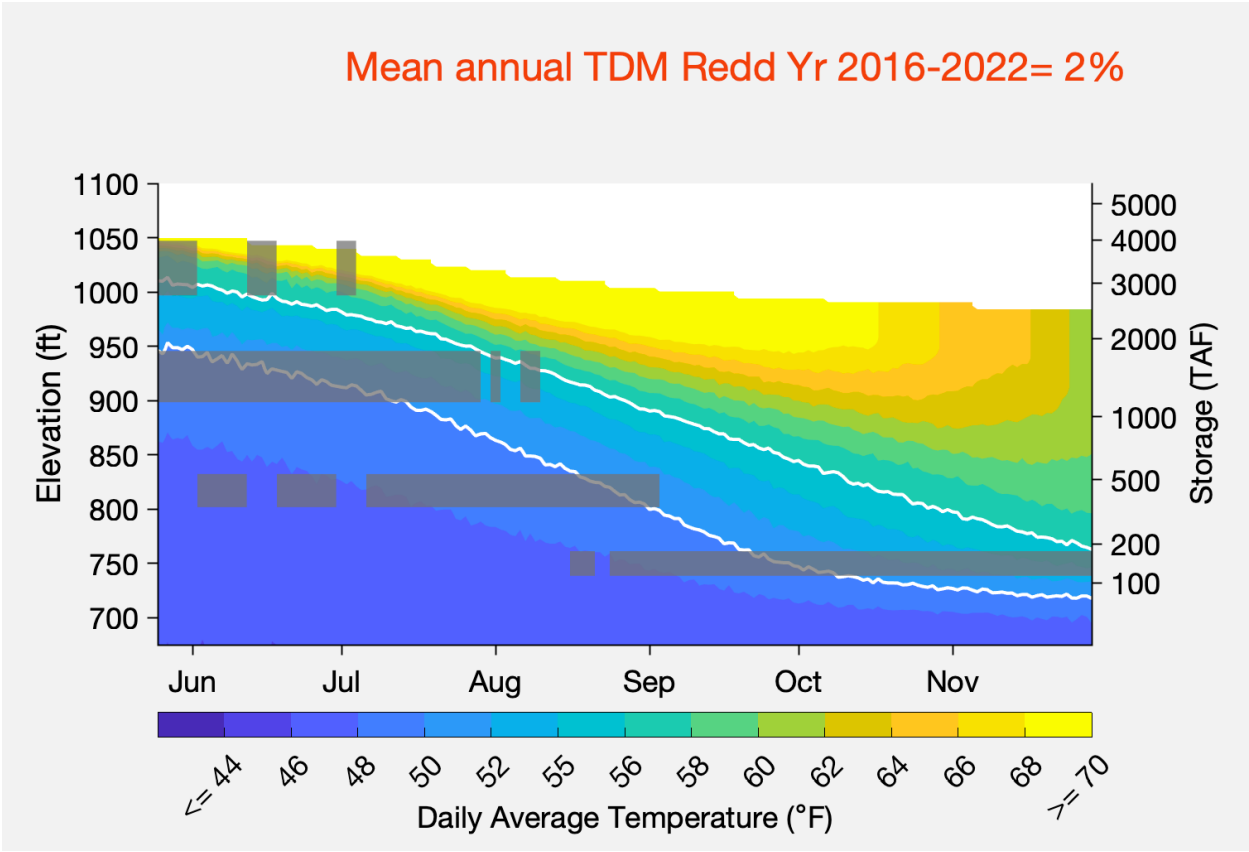
The figure shows probability of temperature-dependent egg mortality probability as it varies across downstream distance from Keswick Dam between 0 and 30 miles and through the months of June to September.

Run 3: Pulse 56F at BSF



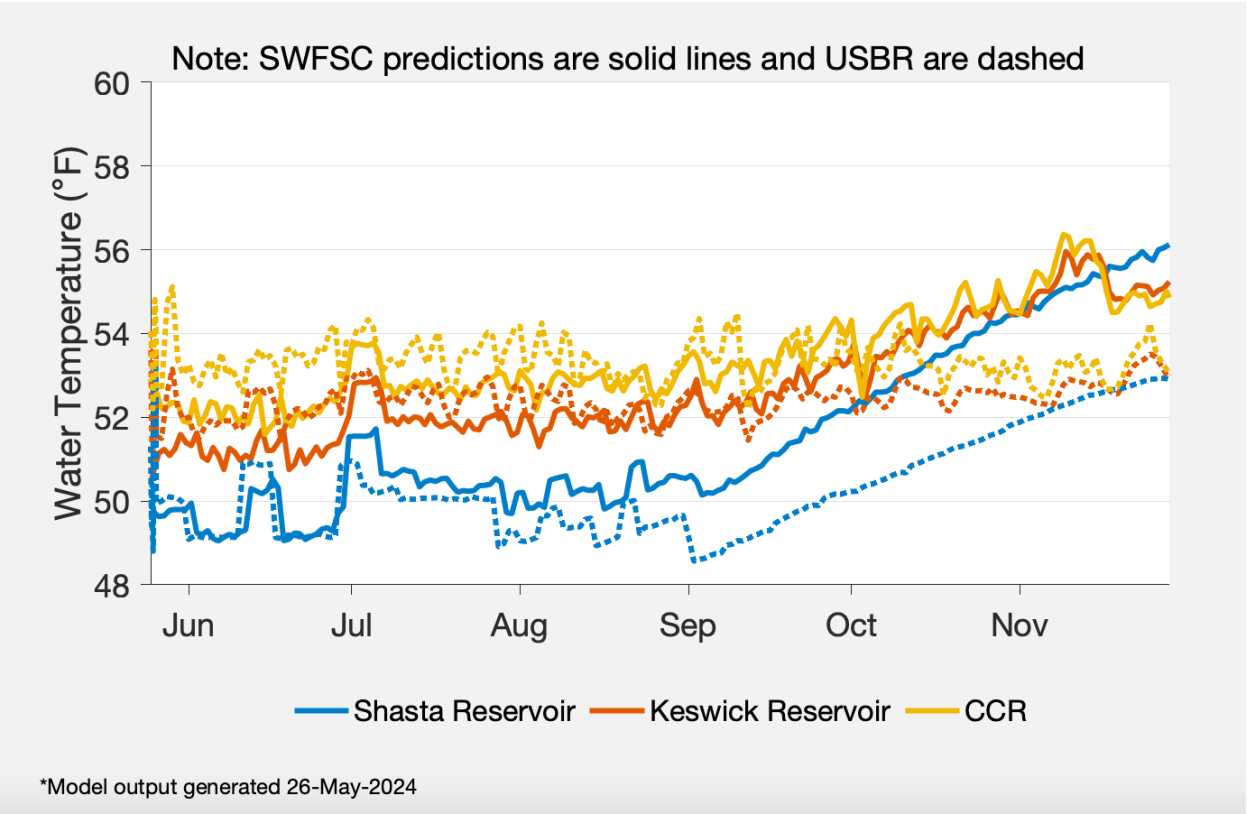
Simulated Timeseries of Keswick Discharge

The figure shows a line graph of simulated Keswick discharge measured in thousands of cfs between the months of June and November.



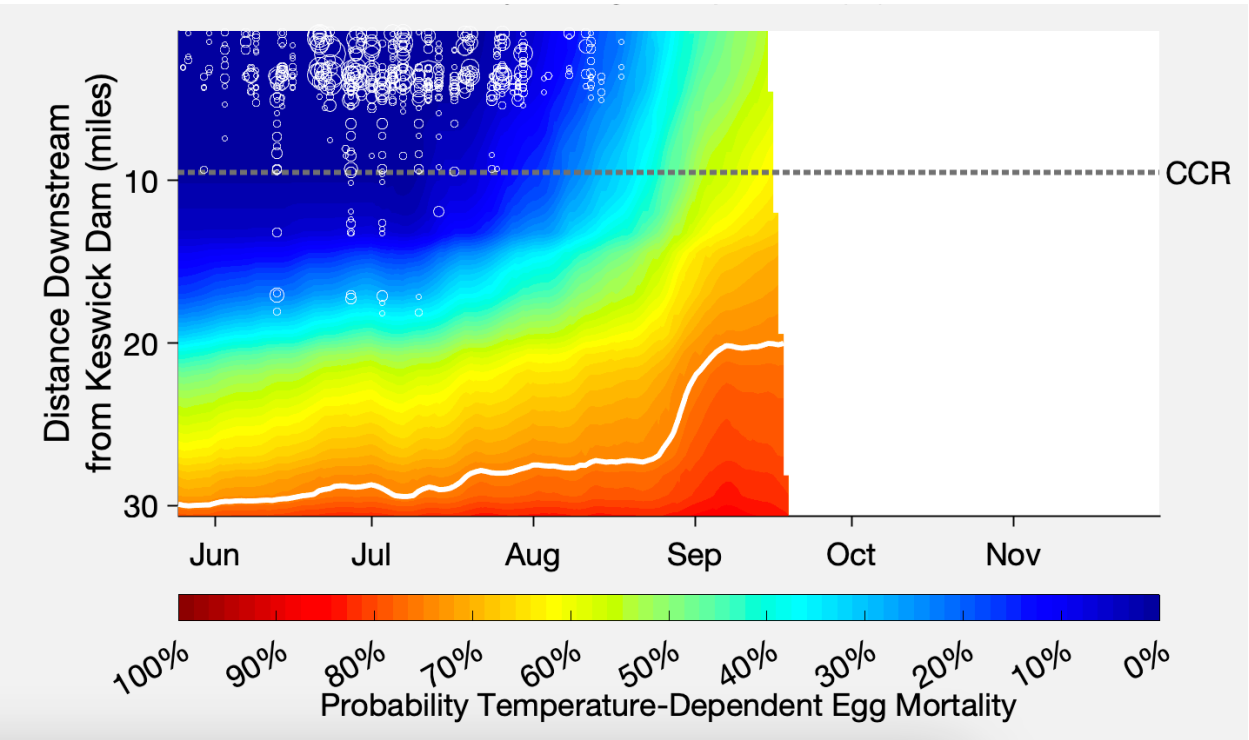
Simulated Shasta Reservoir Water Temperature Profile

This figure shows the simulated Shasta Reservoir water temperature profile and storage levels between June and November. Gray boxes indicate the opening of temperature control device gates. The mean annual Temperature-dependent mortality for redds 2016 – 2022 is 2%.



Simulated Water Temperatures at Shasta Reservoir, Keswick, and CCR

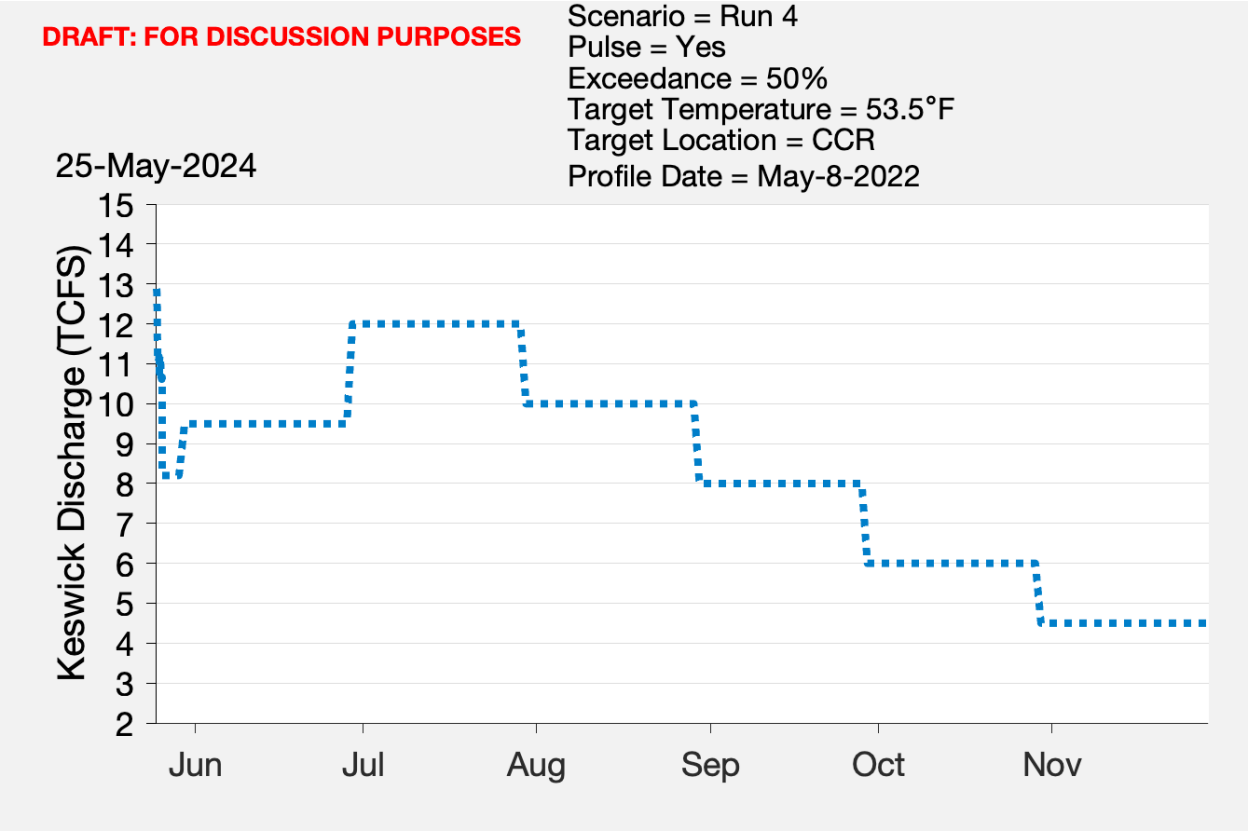
The figure shows a line graph of simulated water temperatures at Shasta Reservoir, Keswick, and CCR from June to November. Solid lines depict Southwest Fisheries Science Center model predictions and dashed lines depict predictions made from Reclamation's HEC5Q models.



Estimated temperature-dependent egg mortality

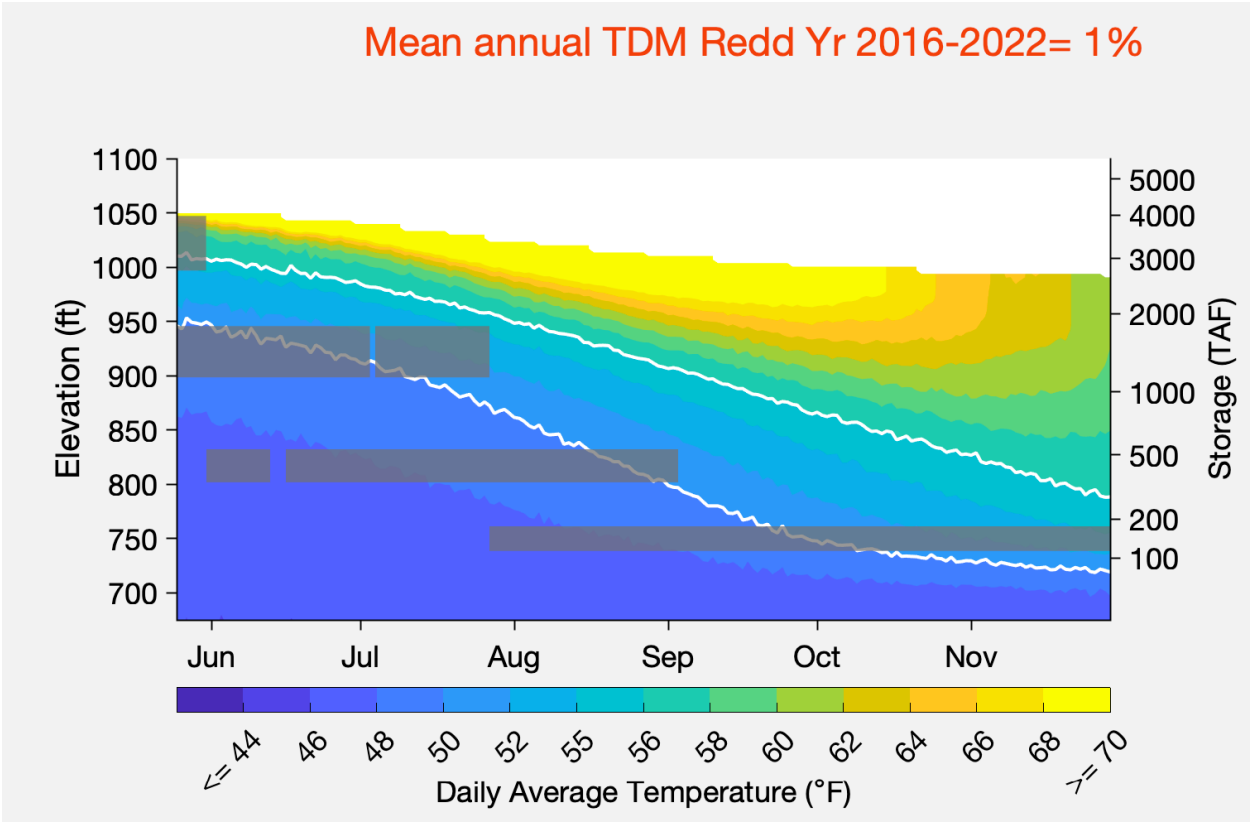
The figure shows probability of temperature-dependent egg mortality probability as it varies across downstream distance from Keswick Dam between 0 and 30 miles and through the months of June to September.

Run 4: Pulse 50% exceedance



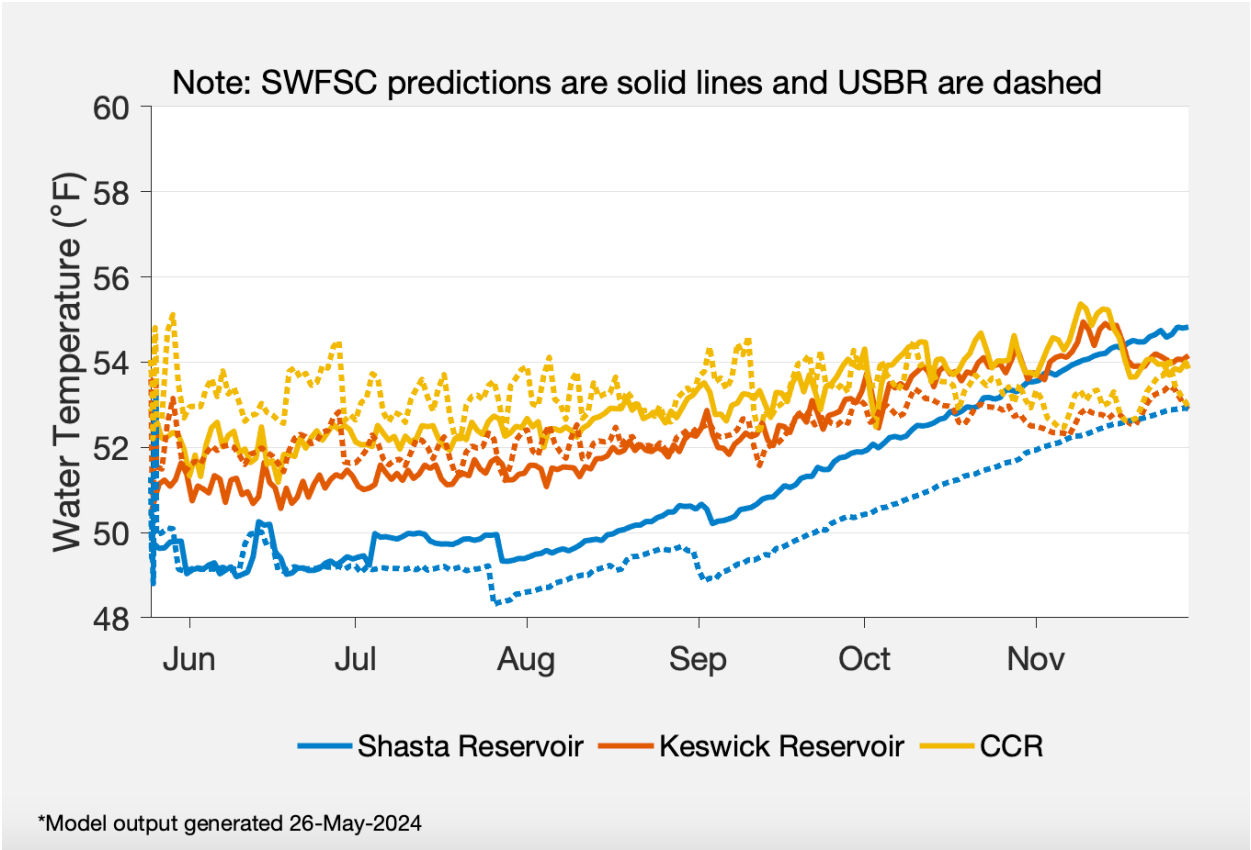
Simulated Timeseries of Keswick Discharge

The figure shows a line graph of simulated Keswick discharge measured in thousands of cfs between the months of June and November.



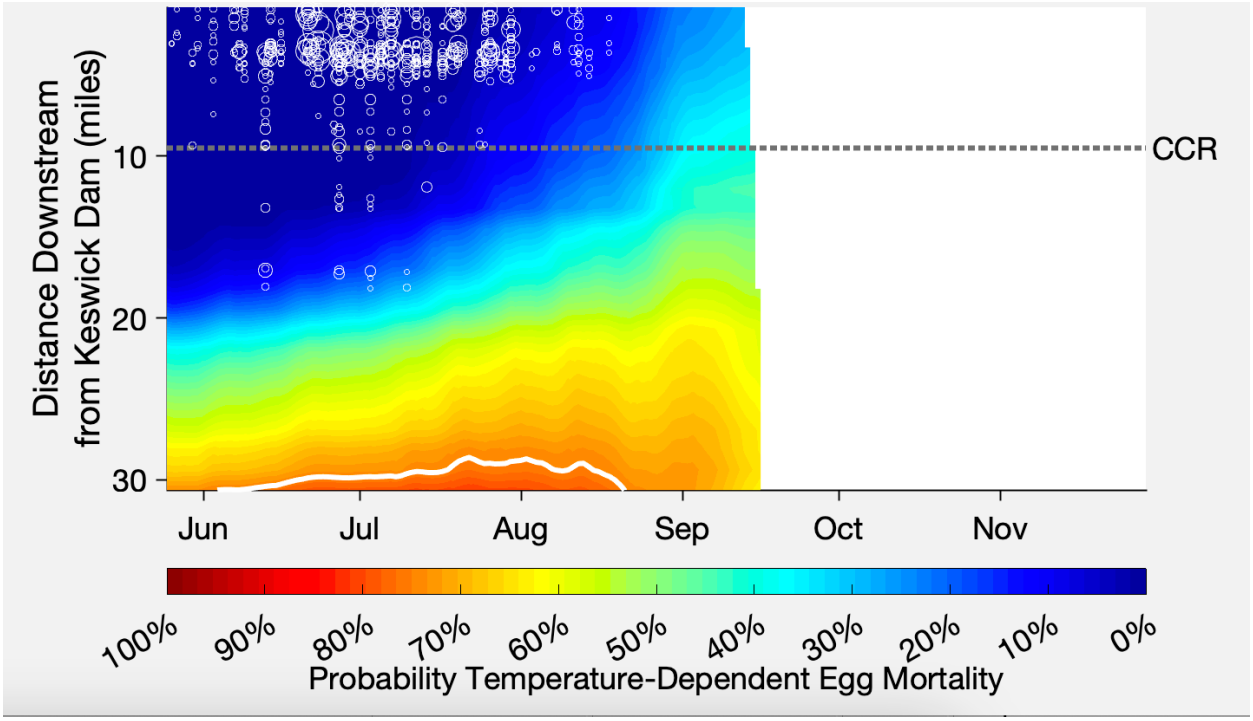
Simulated Shasta Reservoir Water Temperature Profile

This figure shows the simulated Shasta Reservoir water temperature profile and storage levels between June and November. Gray boxes indicate the opening of temperature control device gates. The mean annual Temperature-dependent mortality for redds 2016 – 2022 is 2%.



Simulated Water Temperatures at Shasta Reservoir, Keswick, and CCR

The figure shows a line graph of simulated water temperatures at Shasta Reservoir, Keswick, and CCR from June to November. Solid lines depict Southwest Fisheries Science Center model predictions and dashed lines depict predictions made from Reclamation's HEC5Q models.



Simulated Shasta Reservoir Water Temperature Profile

This figure shows the simulated Shasta Reservoir water temperature profile and storage levels between June and November. Gray boxes indicate the opening of temperature control device gates.