



United States Department of the Interior



BUREAU OF RECLAMATION

Central Valley Operations
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Sacramento, California 95821

IN REPLY REFER TO:

CVO-400
2.2.4.21

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: Transmittal of 2021 Sacramento River Temperature Management Plan - Order 90-5

Dear Mr. Ekdahl:

This letter transmits the Bureau of Reclamation's Sacramento River Temperature Management Plan (Plan) for Water Year 2021 (Enclosure A) pursuant to Order 90-5. Factors beyond the reasonable control of Reclamation prevent Reclamation from meeting 56°F at the Red Bluff Diversion Dam. The Plan will best protect the fishery by conserving cold water for later release and is necessary to implement measures to conserve winter-run Chinook salmon.

While Reclamation ended the 2020 water year with a Shasta storage of 2.2 million acre-feet, the 2nd highest storage for Dry hydrologic year types since the implementation of D-1641, CVPIA, and ESA requirements, water Year 2021 is currently the driest on record since 1977. The snowpack on the Sacramento River Basin at the start of April was 69 percent of average, but with very little rainfall. Conditions also significantly changed at the end of April when forecasted reservoir inflow from snowmelt did not materialize. This year, allocations to agricultural water service and repayment contracts are 0% and allocations to municipal and industrial contractors are only 25%. Storage in Trinity, Oroville, and Folsom reservoirs are low, and Reclamation is operating to water rights, Delta standards, and health and safety deliveries while seeking to facilitate water transfers to provide supplies to areas of the state in dire need.

Reclamation has been coordinating weekly with the State and Federal agencies through the Water Operations Management Team (WOMT) called for in the 2020 Record of Decision for the Long-Term Operation (LTO) of the Central Valley Project (CVP) and State Water Project (SWP). Starting in January, Reclamation provided and discussed 12-month operation outlooks in topic specific meetings with State Water Resources Control Board (Water Board) staff. The March forecasts identified the potential for a Tier 3 or a Tier 4 year under the LTO. Accordingly, Meet and Confer provisions with the Sacramento River Settlement Contractors (SRSC) were initiated. In the course of these discussions, a warm water bypass of power generation at Shasta Reservoir was discussed, coordinated through the SRTTG, and implemented, preserving over 300 TAF of cold water for later in the year. In March, Reclamation convened the Sacramento River Temperature Task Group (SRTTG) to consult with the California Department of Fish and Wildlife (CDFW), the U.S. Fish and

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Wildlife Service, the National Marine Fisheries Service (NMFS), and the U.S. Western Area Power Administration. These meetings also included the SRSC, Water Board, and Tribes. Reclamation also participated in the Water Board's April 21 workshop on 2021 Sacramento River Temperature Management and provided the Water Board a Draft Sacramento River Temperature Management Plan (Draft Plan) on May 4.

We received written comments on the Draft Plan from the Water Board on May 21st and respond to the input as follows:

- End-of-September carryover storage target of 1.25 MAF: Given the unique circumstances this year, the Governor's Drought Proclamation, and anticipated actions by the Water Board to curtail non-project diversions, the enclosed Plan shows an end-of-September storage in Shasta Reservoir of 1.25 MAF.
- Provisions for weekly coordination, reporting of anticipated changes and modeling and monitoring to inform decisions: Reclamation agrees with these provisions and has incorporated these commitments in the Temperature Management Plan.

We received written comments on the Draft Plan from NMFS on May 14, and respond to the input as follows:

- Continue to consider life history diversity for shaping the temperature season: Targeted lower temperatures (approximately 54.5°F) for the critical egg incubation period with 57°F shoulder temperatures. The recommended criteria of 53.7F for egg incubation was considered in earlier scenario development but would likely expend cold water pool prior to the end of August.
- Continue to preserve redds downstream to the Highway 44 Bridge: Reclamation will target the SAC gage located at the Highway 44 Bridge.
- Continue to use real-time management to respond to actual meteorological conditions: Reclamation will continue to anticipate warm meteorological conditions and take actions in advance to reduce the likelihood of exceed target temperatures.
- Represent the effect of power bypass operations: Reclamation incorporated the reservoir profile as of May 19 that includes cold water remaining following the majority of the power bypass. The power bypass concluded on May 24.
- Model an additional scenario with the driest hydrology and hottest meteorology on record to reflect a conservative forecast of conditions: Reclamation has requested this scenario be developed by the NMFS Southwest Fisheries Science Center and provided to SRTTG.
- Include a section committed to uncertainty and assumptions including those related to hydrology, meteorology, snowpack, accretions, and depletions: Reclamation has included this suggestion under the section titled "Key Areas of Uncertainty."

We received written comments on the Draft Plan from the SRSC on May 19 and respond to the input as follows:

- Balanced Release Schedule from Keswick: Reclamation has developed a release schedule less than suggested in June, July, and August in an effort to address comments from the Water Board suggesting an end of September carryover storage target of 1.25 MAF. This schedule is only feasible given the voluntary actions taken by the SRSC to reduce demands from the Sacramento River. If Delta water quality objectives require additional releases, and

additional releases from other reservoirs would place other objectives at risk, Reclamation would need to discuss at WOMET and revisit the carryover target with the Water Board.

Storage in Shasta Reservoir is the result of inflows less releases. Shasta Reservoir supports downstream diversions and Delta requirements in coordination with other CVP and SWP facilities and in response to non-project diverters. Reclamation coordinated with the SRSC on the voluntary actions for the lowest possible releases from Shasta Reservoir while meeting other system requirements. Actions include voluntary demand reductions, groundwater substitution, water transfers, and intense coordination to match releases to demand. These releases also account for system-wide drought actions such as modifying delta outflow and water quality requirements described in the Temporary Urgency Change Petition filed by Reclamation and the California Department of Water Resources (DWR), watershed-wide curtailments, increased releases from New Melones reservoir to meet delta objectives, reduced CVP and SWP allocations and other water management actions that decrease reliance on stored water throughout the summer. If requirements administered by the State of California, including those overseen by the Water Board, call for more water than anticipated, and other CVP and SWP reservoirs cannot be impacted, Reclamation will protect Health and Safety and storage in Shasta Reservoir may be less than estimated. Reclamation commits to weekly discussions on operational conditions for major CVP and SWP facilities, including Shasta Reservoir, during WOMET and commits to notifying the Water Board in writing in the event that the 1.25 MAF end-of-September storage is no longer feasible.

DWR is coordinating with Reclamation to update the Drought Contingency Plan required in the 2020 Incidental Take Permit for the State Water Project. The Drought Contingency Plan describes the system-wide operational conditions, approach, monitoring, and coordination that fall beyond the scope of Order 90-5. The Drought Contingency Plan supplements sections of this Temperature Management Plan and will be available by June 1, 2021.

While approval is not required under Order 90-5, if the Water Board objects to the enclosed Plan, the Water Board's objection must include identification of an alternative location for managing water temperatures to 56°F. In the absence of the Water Board providing an alternative location, Reclamation will implement this Plan until such time as alternative location can be provided or agreed upon.

For additional information, please contact me or Ms. Elizabeth Kiteck, Chief, Water Operations at (916) 979-2684 or ekiteck@usbr.gov.

Sincerely,

**KRISTIN
WHITE**

Kristin White
Operations Manager

Digitally signed
by KRISTIN

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SACRAMENTO RIVER TEMPERATURE MANAGEMENT PLAN FOR WATER YEAR 2021

INTRODUCTION

Conditions in the Central Valley are critically dry, and consequently, Shasta temperature management is limited by these dry conditions. Although temperature management in Water Year 2020 (a dry year) resulted in low temperature dependent mortality (3-7%) for brood year (BY) 2019 Sacramento River winter-run Chinook salmon, the overall survival was low. Although Water Year 2021 started with higher storage than previous critical years in recent history, hydrologic conditions supporting Shasta temperature management are critically low. The Northern Sierra Precipitation 8-Station Index indicates that this year's hydrologic conditions are the driest since 1977. In early April, Shasta Reservoir's cold water pool used to protect winter-run Chinook salmon was projected to be the smallest since 1977.

Unfortunately, conditions have deteriorated significantly from the April 1st forecast and expected inflow to the Sacramento River system (including the Yuba, Feather and American River watersheds) has decreased by approximately 685 TAF. On May 10, 2021, the Governor issued an Emergency Proclamation on drought conditions for the Sacramento –San Joaquin Bay-Delta (Delta) and other watersheds because of the continuing extreme dry conditions in the Delta watersheds. As such, numerous drought actions were rapidly planned and/or finalized to lessen the impact of the drought on fish and wildlife, water supply, public health and safety and carryover storage for next year. A report outlining these actions and the expected response from the Sacramento-San Joaquin system as a whole will be available by June 1, 2021. This temperature management plan includes many assumptions of drought actions in order to reach the forecasted Shasta and Keswick monthly releases; however, these actions are not fully explained in this report as they are system-wide actions rather than specific temperature management actions.

This Water Year 2021 Sacramento River Temperature Management Plan (Plan) reflects coordination starting in February 2021 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) (2020 ROD) 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 (Water Board), 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 Plan was developed in coordination with and with input from the SRTTG. It includes temperature

locations and targets through October 31, modeled winter-run Chinook salmon egg mortality, estimated dates for operation of the side gates on the TCD, and the estimated end-of-September cold water pool. Throughout Plan implementation, Reclamation will monitor the cold water pool, compare measured conditions to actual performance, and provide regular updates through the SRTTG. In the event measured cold water pool conditions vary from what is projected and temperature performance appears at risk, Reclamation will reconvene the SRTTG in preparation for an adjustment of this Plan. If the adjustment impacts the temperature Tier and/or other warranted indicators as discussed by the SRTTG, then a modified summer temperature release strategy will be evaluated to remain within the Tier's anticipated performance level. Reclamation will work with NMFS and the other members of the SRTTG during fall operations to conserve storage and address the potential for redd dewatering.

Based on the February 90% exceedance forecast, Reclamation identified that Water Year 2021 was likely to be a Tier 4 year and initiated interagency coordination activities regarding Shasta reservoir seasonal management. In a Tier 4 year, there is less than 2.5 MAF of total storage in Shasta Reservoir at the beginning of May, and/or Reclamation cannot meet 56°F at CCR. Conditions on May 1 along with modeling based on measured reservoir profiles confirm that Water Year 2021 is a Tier 4 temperature management season.

BACKGROUND

The 2020 ROD requires use of conservative forecasts through the seasonal planning process for reservoir releases (including developing initial and updated allocations) and temperature management planning, such that monthly release forecasts and associated allocations are typically based on a 90 % exceedance inflow forecast through September. The Plan manages the cold water pool at Shasta Reservoir using a tiered strategy to better manage the limited cold water resource for winter-run Chinook salmon egg survival. The tiered approach recognizes the substantial influence of hydrology on available cold water and targets a temperature of 53.5°F in the upper Sacramento River above Clear Creek from May 15 to October 31. The 2020 ROD incorporates a number of measures to improve Shasta storage and the related cold water pool for the upcoming temperature management season. Reclamation will manage water temperatures based on the following tiers, depending on the actual size of the cold water pool in a given year:

- Tier 1 – Sufficient volume of cold water to target 53.5°F or lower starting May 15 through October 31
- Tier 2 – Sufficient volume of cold water to target 53.5°F during critical egg incubation period
- Tier 3 – A volume of cold water that can target 53.5-56°F during critical egg incubation period; and consideration of intervention measures in lower Tier 3 years
- Tier 4 – Insufficient cold water to maintain 56°F or lower; and consideration of intervention measures

Reclamation's Plan uses modeling and professional expertise to identify the most protective tier that can be achieved given the available cold water. Before the reservoir stratifies and the volume of cold water is known, Reclamation estimates temperature capabilities based on projections of storage.

PRE-SEASON ACTIONS

As Water Year 2021 began to shape out, Reclamation worked with water users, the State and Federal fishery agencies and other stakeholders to implement several actions prior to the start of the temperature management season. These actions are listed below with a brief description:

May 28, 2021

Winter-run Chinook Salmon Conservation Hatchery Production: In February 2021, a multi-agency team discussed increasing Livingston Stone National Fish Hatchery (LSNFH) winter-run Chinook salmon production targets for Water Year 2021. Typically, the USFWS would collect 60 females and 100 males out of the Keswick fish trap; however, due to poor conditions and anticipated low survival of BY 2021 natural winter-run Chinook salmon, they anticipate collecting 120 females and 180 males.

Reclamation is also preparing chillers for use later in the season in the event that deliveries to the hatchery become too warm.

Shasta Critical Year Determination: In February, Reclamation notified senior water right holders on the Sacramento River of a Shasta Critical Year and a reduction to 75% of contract totals under the Sacramento River Settlement Contract.

Water Transfers and Reduced Diversions: Sacramento River Settlement Contractors' (SRSC) scheduled diversions and transfers to other Sacramento Valley Water Users for 2021 are 1,117,000 AF, an amount that is less than the volumes diverted and transferred in Water Year 2015. Diversions and transfers are approximately 65% of Settlement Contract totals, an additional 10% reduction from the 75% shortage provisions. SRSC have made available 170,000 AF of water available for transfer to other areas of the State in critical need. This transfer water will be held in Shasta Reservoir over the summer to assist with managing cold water pool. SRSC are also considering alternatives to rice decomposition water that will provide additional water savings. The SRSC propose to establish, in cooperation with Reclamation, an emergency groundwater pumping program to further reduce diversions and address the migratory needs of the Pacific Flyway. Weekly coordination with Reclamation and contractors on diversions maximizes efficiencies to retain as much water in Shasta as possible while meeting demands.

Shasta Warm Water Power Bypass: On April 18, 2021 Reclamation adjusted operations to bypass Shasta Dam's powerplant and temperature control device (TCD) due to the low water elevation in Shasta Reservoir. Reclamation released water from the warmer, upper layers of Shasta Reservoir directly through the dam's river outlets into the Sacramento River. The purpose of this warm water release was to maintain Sacramento River flows through the spring while preserving the limited supply of colder water for use later in the summer when most critical for endangered winter-run Chinook salmon. Fishery agencies provided preliminary guidance on the maximum temperatures (60 deg F at Clear Creek - CCR) and Reclamation has been coordinating with the Agencies weekly on the need for potential revisions. Monitoring for unanticipated effects includes monitoring temperatures and their impacts to hatchery winter-run Chinook salmon at LSNFH and monitoring winter-run Chinook salmon in the Sacramento River (e.g., observations of pre-spawning mortality in adults). When fisheries conditions showed possible adverse effects from the warmer release, Reclamation received updated guidance from the Fishery agencies and began to manage the river temperatures to 57 deg F at the SAC gage (Sacramento River upstream from Highway 44 bridge) beginning on May 15 by adjusting the release blend from the bypass with the powerplant and TCD. The bypass was further reduced as water temperatures in Shasta Lake increased in order to maintain downstream river temperatures at 57 deg F at SAC. The warm water bypass ended on May 24th due to warming temperatures and is estimated to have conserved over 300 TAF of cold water (<53 deg F) for use later in the summer and fall and resulted in a reduction in power generation worth approximately \$5 million.

SYSTEM-WIDE DROUGHT OPERATIONS

As mentioned previously, a series of drought actions are being implemented or planned for implementation for Water Year 2021 that will support reduced releases from Shasta Reservoir in order to support temperature management through the summer. These actions will be described in more detail in

the Drought Contingency Plan (to be released by June 1, 2021) and are briefly listed below for reference:

- Temporary Urgency Change Petition to modify Delta requirements
- Emergency drought barrier to minimize Delta salinity intrusion
- Minimum exports to limit releases needed to support Delta needs
- Limited use of New Melones to meet delta outflow and salinity requirements
- Urban water conservation to limit releases needed to support system needs
- Curtailments from the SWRCB to reduce demands throughout the system
- Low or zero allocations to CVP and SWP contractors

The combination of these actions may allow for the reduced releases from Shasta Reservoir without causing devastating impacts to other CVP or SWP reservoirs. A description of the system wide operation is included in the Drought Contingency Plan.

MODELING ASSUMPTIONS AND LIMITATIONS

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's draft Plan submitted in early May did not specifically model the anticipated power bypass for May and only captured the effects of the power bypass through the end of April. This was due to a model limitation where releases from elevations other than that of the TCD were not an option in Reclamation's version of HEC-5Q model. As stated above, the power bypass ended May 24 due to warming conditions in the river. This model includes the effects of the power bypass through May 19, the date of the profile used for the modeling. Between May 19 and May 24, the power bypass was significantly less than it has been in late April and early May. Although Reclamation expects to see minor benefits with the remainder of the power bypass action, its reduced volume is unlikely to have a significant impact on the temperature management plan included in this report. Profile and modeling updates will be provided to SRTTG regularly to include any benefit of the power bypass not captured by this Plan. Moving forward, Reclamation is working with other agencies through a collaborative effort to build a more flexible model that can simulate power bypass and other operations for analyzing unique operations in the future.

Water transfers between the SRSC and South of Delta contractors were not finalized at the time of the Draft Plan released in early May and were therefore not included in the modeling for the Draft Plan. The anticipated effect of both reducing demands to make this water available and delivering this water to the purchasers have been incorporated into the release schedule and temperature modeling for this Final Plan.

This release schedule assumes approximately 170 TAF being made available for transfer to CVP contractors south of the delta through crop idling and groundwater substitution. This analysis assumes this water is delivered only across the month of October. Reclamation will continue to evaluate conditions and work with both SRTTG members and the south of delta purchasers on the best timing for delivery of this water given the temperature management plan.

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. However, when Reclamation approached this process similarly this year, the combination of historical data and the 25% exceedance L3MTO forecast created data quality issues and the data was not usable. The 50% exceedance L3MTO forecasted temperatures were used in the April temperature modeling and development of the draft temperature management plan. This is a less conservative approach than was historically used. Reclamation was able to correct the data quality error from the previous draft to use the 25% exceedance L3MTO forecast for the Final Plan. In addition, NMFS’ comment letter requested more conservative meteorology and hydrology be considered in a sensitivity study. This study will be completed by the NMFS Southwest Fisheries Science Center and shared with the SRTTG.

RELEASE OUTLOOK

The Shasta Reservoir release strategy included in this plan and temperature modeling relies on numerous drought actions throughout the Sacramento and San Joaquin watersheds to reduce reliance on stored water from CVP and SWP reservoirs this summer. These drought actions have added a degree of flexibility to help manage storage at Shasta, Oroville and Folsom reservoirs for meeting public health and safety needs, repelling salinity in the delta, producing hydropower and providing additional cold water for fishery protection throughout the summer. In their May 17 comment letter (revised on May 24), NMFS provided feedback to reduce releases from the “base” run submitted in the draft plan and to set an end of September carryover target. Similarly, the SRSC also suggested reduced releases from the “base” run. The Water Board also provided feedback in their May 21st comment letter to support an end-of-September carryover target of 1.25 MAF. In response to these comments, Reclamation has crafted this release schedule to be less than the “base” scenario and to meet 1.25 MAF by the end of September. 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.

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. As requested in the May 21 Water Board comment letter, Reclamation commits to reporting out on the status of this release outlook, temperature management and overall system operations at the weekly WOMT meeting. Table 1 describes the monthly forecasted operations for releases and storage targets.

Table 1. Monthly forecasted operations for Shasta and Keswick Reservoir releases and estimated storage.

Operations Information/Month	June	July	August	September
Shasta Releases (TAF)	332	351	346	255
Keswick Releases (cfs)	7,100	7,500	7,100	5,800

Operations Information/Month	June	July	August	September
Keswick Releases (TAF)	422	461	436	345
Spring Creek Power Plant (TAF)	90	110	90	90
Shasta End-of-Month Storage (TAF)	1,822	1,598	1,379	1,250

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, 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 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 assumption areas along with their areas of uncertainty is listed below:

Inflow hydrology: This forecast is based off the 90% exceedance inflow hydrology for both Shasta reservoir and the remainder of the watershed. By May, the difference between the 90% and the 99% exceedance forecast is fairly low. For Water Year 2021, this difference is only 45 TAF for June through September. Inflows below the 90% may cause challenges in meeting the 1.25 MAF storage target at the end of September; however lower inflows do not necessarily confirm this number cannot be met as it will depend on the flexibility in the remainder of the system in the late summer. As stated above, Reclamation commits to reporting out on the status of this release outlook, temperature management and overall system operations at the weekly WOMT meeting.

Meteorology: California's climate is sensitive to large-scale ocean-atmosphere oscillations and is highly variable from year to year. California has the greatest variation in precipitation compared to all other U.S. States. Significantly higher ambient air temperatures than assumed in this forecast may result in the need to adjust the temperature management plan and increase target temperatures. Conversely, some events such as wildfires can have a large influence on reducing water temperatures as was observed during Water Year 2020. Smoke and haze may dampen the effects of unusually warm air temperature conditions on reservoir heating and downstream in-river warming.

Lake temperature profile and modeling updates will be provided to SRTTG regularly to communicate uncertainties in modeling throughout the temperature management season. A comparison between modeled profiles and actual profiles will be presented to SRTTG to help track the accuracy of forecasts and how uncertainties with the meteorology impacted Shasta Lake temperature model results.

May 28, 2021

Accretions and Depletions: Accretions/depletions are the net gain or loss between the main upstream reservoirs (Shasta, Oroville, and Folsom) and the Delta, as measured at Freeport along the Sacramento River. They include the net of inflow from smaller tributaries and creeks, diversions from various water users north of the Delta and natural losses due to infiltration and evaporation. The forecasted releases used in this modeling were developed to both meet the end of September storage target of 1.25 MAF and avoid causing devastating impacts to other parts of the system. The system response to the planned Shasta releases is partly determined using the assumptions for the monthly accretion/depletions. The methodology for forecasting these accretions and depletions in Water Year 2021 is unique to previous years due to the significant drought actions being taken to reduce depletions throughout the system. This methodology, explained in more detail in the Drought Action Plan, comes with significant uncertainty. While minor changes in accretions/depletions may cause adjustments in other parts of the system, major increases in system-depletions may lead to an increase in Shasta releases in order to maintain salinity control in the Delta. As stated above, Reclamation commits to reporting out on the status of this release outlook, temperature management and overall system operations at the weekly WOMT meeting.

Delta Water Quality: Similar to the accretion/depletion description above, the forecasted releases made assumptions regarding necessary flows from the system to meet delta outflow and water quality objectives. These assumptions, explained in more detail in the Drought Contingency Plan, include anticipated approval of the TUCP to relax both outflow and water quality standards in June and July and actions by the Water Board to curtail other diversions. While minor changes in flows required to meet delta water quality may cause adjustments in other parts of the system, major increases may lead to an increase in Shasta releases in order to maintain salinity control in the Delta. As stated above, Reclamation commits to reporting out on the status of this release outlook, temperature management and overall system operations at the weekly WOMT meeting.

TEMPERATURE STRATEGY

Preliminary temperature analyses, presented to the SRTTG in February and March 2021, included model runs with CCR target temperature at 56°F. These preliminary simulation results showed that the temperature target of 56°F could not be maintained for the entire temperature management season. These runs are characterized by end-of-September cold water pool volumes less than 400 TAF, early side gate use, and rising temperatures above target thresholds at the end of the simulation.

In March 2021, Reclamation estimated stage-dependent and stage-independent temperature-dependent mortalities (TDMs), End-of-September Cold Water Pool (EOS CWP), and side gate operations for all 358 scenarios using the Temperature Tier Selection Protocol (TTSP). However, because the TTSP tool was developed for Tier 2 and Tier 3 Year types, it did not perform well for Water Year 2021 considering this year is a Tier 4 Water Year. This assessment of scenarios suggested no temperature management scenario could meet Tier 1-3 biological objectives and facility configuration criteria to avoid loss of temperature control (exceed 56°F) throughout the duration of the temperature control period. The 358 examined TTSP scenarios achieved temperature dependent mortality ranging from 90% to 99%. Reclamation commits to updating this TTSP to address future Tier 4 years through SRTTG prior to the Water Year 2022 temperature management season.

Since the TTSP approach was unable to inform target temperature criteria or duration for a Tier 4 year, Reclamation gathered input from the Water Board, NOAA Fisheries, the USFWS, CDFW, Tribes, and other stakeholders on these elements of the TMP. The agencies and stakeholders provided advice on temperature criteria for the protection of salmonids.

Reclamation crafted a Plan to minimize modelled temperature dependent mortality with available cold water

within the following criteria and approaches:

- **Fall Certainty:** Approach seeks to avoid use of the side gates until September or later, if possible. Reclamation was able to develop a Draft Plan with scenarios that would rely on the side gates (i.e., full side gate use) by August 29 (Table 2).
- **Life History Timing Diversity:** Approach seeks to develop a temperature window to target 2 standard deviations of historical spawning, starting May 15. Reclamation was able to develop a Plan that starts June 15 and extends through August.
- **Critical Egg Incubation Timing and Shoulder Temperatures:** Approach seeks to develop a temperature plan with a colder window during the critical egg incubation period with potentially warmer shoulder temperatures, if necessary. Reclamation used the 53.7°F egg incubation criteria to guide the temperature management approach. Reclamation was able to develop a plan that targets temperatures of 54.5°F during the critical egg incubation time period and shoulder temperatures near 57°F for holding adult winter-run Chinook salmon (Table 1). The egg incubation criteria of 53.7°F was used as critical threshold input parameter for the temperature dependent mortality modelling efforts (see Attachment for more information on model assumptions).
- **Spatial Diversity:** Approach seeks to target temperatures are the most downstream point possible while balancing the approaches listed above. Reclamation was able to develop a plan that targets preserving redds down to the Highway 44 Bridge.
- **Cold water efficiency:** Reclamation would operate to temperatures at SAC (Highway 44 Bridge) and respond to actual meteorological conditions.

This plan approach, Scenario 13, includes an initial shaping of temperatures to best meet the above goals and that would be refined through further SRTTG input on tradeoffs. The TDM results for scenario 13 ranged from 64-78% (Table 3).

Reclamation has also included a separate reference alternative that starts June 15 and operates to 55°F at Highway 44 Bridge (Scenario 14; Table 1). The TDM results for scenario 14 ranged from 73-97% (Table 3).

Important performance metrics (TDM, side gate operations, end-of-September cold water pool volume) for each scenario are described in Table 3. Assumptions and more information for these scenarios are described in Attachments 1-2.

Table 2. Water temperature target in degrees Fahrenheit at Keswick and Highway 44 for proposed scenarios. HEC-5Q does not perform well after September 14. Water temperatures may be warmer than these targets and HEC-5Q results. Warmer water temperatures described in Attachment 2 describe the late season water temperatures that were used for the temperature dependent mortality modeling.

Month/ Scenario	Keswick S13	Hwy 44 S13	Keswick S14	Hwy 44 S14
May	56.2	56.1	56.2	56.1
June	55.1	55.1	55.7	55.6
July	54.5	54.6	55.0	55.1
August	54.3	54.4	55.2	55.2
September	54.9	54.9	54.9	54.8

Month/ Scenario	Keswick S13	Hwy 44 S13	Keswick S14	Hwy 44 S14
October	55.7	55.5	54.6	54.4
November	53.0	52.5	52.7	52.3

Table 3. TDM, Storage, and first side gate usage for different scenarios.

Metric/Scenario	S13	S14
HEC-5Q TDM - Anderson (%)	78.2 – 78.4	94.4 – 96.6
HEC-5Q TDM - Martin (%)	66.6 – 77.3	80.1 – 87.6
RAFT TDM – Mean / Median Martin (%)*	64 / 71	73 / 81
End of Sept CWP Storage (TAF)	173	230
First Side Gate Use	7/13/21	8/8/21
Full Side Gate	8/29/21	9/19/21
End of September Storage (MAF)	1.25	1.25

* Included in Attachment 3

The TDM results achieved with HEC-5Q modeling resulted in higher values than those from the CE-QUAL modeling as referenced in NMFS' comment letter on the Draft Plan. Although these models use different input assumptions, the difference in results was larger than expected. Reclamation hypothesizes this is related to the HEC-5Q and CE-QUAL predicted temperatures after September 15. River temperatures are adjusted post-September 15 from the HEC-5Q targets rather than the CE-QUAL's post-September 15 predictions to estimate temperature dependent mortality. In Table 3, TDM ranges that represent HEC-5Q temperature targets (e.g. lower estimate) and the adjusted post-September 15 temperatures. Reclamation will continue to coordinate through SRTTG to review these and other model results and may update these TDM estimates based on those discussions.

Two additional factors were considered to evaluate a feasible scenario that reduces the risk of losing control of temperature management in the fall period. The first factor is the end-of-September cold water pool estimate. Reclamation considers a minimum of 460 TAF as a conservative buffer to achieve a temperature performance of 56°F at CCR from September 15 through October 31. Neither of the scenarios reflect a range of end-of-September cold water volumes sufficient to manage unknown factors during September and October. Therefore, the two scenarios in the Plan may not be able to provide temperature management in late-September and October. The other factor is the timing of opening of the first TCD side gate. Reclamation modeling found improving temperature conditions would result in the first TCD side gate being used on July 13. Based on Reclamation's operational experience, the later the first side gate is deployed, the greater the likelihood to maintain temperature management control into the fall.

Reclamation anticipates working with SRTTG prior to June 15 to discuss the risks and tradeoffs between scenarios S13 and S14 along with any suggestion adjustments to determine the final approach. To implement the Plan, Reclamation will monitor the cold water pool projections and compare to actual performance during implementation to ensure sufficient cold water pool throughout the Plan's duration. The primary risk management criterion is defined as a cold water pool less than 49°F which is more than 10 percent less than the projected volume. In addition, ongoing modeling results will be completed for each monthly SRTTG meeting and more often as necessary. These results will be considered should they

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indicate increased or decreased risk to fall temperature performance, which is a concern to Reclamation based on the uncertainty in meteorology, hydrology, and real-time operation conditions unknown to Reclamation at the time of TMP selection. 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 adjustment of the TMP. As in past years, Reclamation will work with NMFS and the other members of the SRTTG during fall operations to both reduce releases to conserve storage and to address the potential for Chinook salmon redd dewatering.

TECHNICAL ASSISTANCE AND CONSULTATION

Year-around

Agencies meet weekly in the WOMT to discuss operations at all major CVP and SWP facilities. In addition, technical teams meet regularly to review observed data and make adjustments to the Plan as needed. The combination of WOMT and technical team meetings will allow for discussion and feedback on real-time management on at least a weekly basis with staff from the fisheries agencies, the Water Board, and other appropriate entities.

December to January – Conservation of Cold Water Pool and Inactive Temperature Management Period

Reclamation provided monthly updates via e-mail to the SRTTG, outlining current river and reservoir conditions, operations, hydrology, meteorology, and long-range precipitation forecast information. No significant issues concerning temperature management arose during this period and the SRTTG was not convened.

February through April – Temperature Management Preparation

Reclamation convened SRTTG meetings, starting in February 2021, on a monthly basis to ensure communication and coordination among the parties in preparation for the temperature management season.

In mid-February 2021, Reclamation prepared initial projections of anticipated temperature management capability and considerations based on the 90% February hydrologic and runoff forecasts from DWR and National Weather Service River Forecast Center. Reclamation's February projections showed that a Tier 4 year was likely. Reclamation initiated interagency coordination through the Drought and Dry Year activities and stakeholder coordination through the Meet and Confer activities described in the 2020 ROD.

In February 2021, a multi-agency team discussed increasing LSNFH winter-run Chinook salmon production targets for Water Year 2021. Typically, the USFWS would collect 60 females and 100 males out of the Keswick fish trap; however, due to poor conditions and anticipated low survival of BY 2021 natural winter-run Chinook salmon, they anticipate collecting 120 females and 180 males.

In mid-March 2021, the Sacramento River Settlement contractors initiated the meet and confer commitments under the 2020 Record of Decision and began discussions on voluntary measures for Shasta Cold Water Pool Management Dry Years, Drought Years, and Successive Dry Years. Reclamation's Proposed Action 4.12.5 describes that in Tier 3 and 4 years, Reclamation shall meet and confer with USFWS, NMFS, DWR, CDFW, and Sacramento River Settlement Contractors on voluntary measures to be considered if drought conditions continue into the following year, including measures that may be beyond Reclamation and DWR's discretion. If dry conditions continue, Reclamation will regularly meet with this group (and potentially other agencies and organizations) to evaluate current hydrologic conditions and the potential for continued dry conditions that may necessitate the need for development of a drought contingency plan (that

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may include actions from the toolkit) for the water year.

In mid-March 2021, Reclamation prepared updated projections of anticipated temperature management capability based on 90% March hydrologic and runoff forecasts and historical performance. These projections were provided to the SRTTG in advance of the March SRTTG meeting. In March, the projected total Shasta storage on May 1 was less than 2.5 MAF, so Reclamation continued discussions regarding Tier 4 operations.

In mid-April, Reclamation prepared updated projections of anticipated temperature management capability including considerations from updated 90% hydrologic and runoff forecasts. These updated projections were also shared with the SRTTG in advance of scheduled SRTTG meetings and served as the first assessment of candidate scenarios for the WY2021 temperature management plan.

On April 13, 2021, Reclamation sent a letter to the Water Board seeking support for early temperature management actions. On April 15, 2021, the Water Board responded to Reclamation's letter that they were supportive of early actions that improve temperature management.

On May 5, 2021, Reclamation distributed and requested input on the draft Temperature Management Plan to the Water Board and SRTTG.

On May 17, 2021, Reclamation submitted a Temporary Urgency Change Petition to request the Water Board to consider modifying requirements of Reclamation and DWR water right permits to enable changes in operations of the CVP and SWP that would allow for delivery of water with conservation for later instream uses and water quality requirements. As announced by the Governor in his May 10, 2021 Emergency Proclamation on drought conditions for the Bay-Delta and other watersheds, the continuation of extremely dry conditions in the Delta watershed has resulted in an inadequate water supply that is not able to meet both water right permit obligations for instream flows and water quality under Water Rights Decision 1641 (D-1641). For more information:

https://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/tucp/index.html

In mid-late May, Reclamation received letters from the Water Board, NMFS, and SRSC commenting on the draft Temperature management Plan. Reclamation reviewed these comments and took them into consideration when developing the final Plan. These letters are posted to the [SWRCB's web page](#).

October to May – Spring Pulse Flow

On October 20, 2020, a multiagency team began meeting to plan for spring pulse flow actions. During WY 2021, the Spring Pulse Flow sub-team of the Upper Sacramento River Scheduling Team developed a Spring Pulse Flow Study Plan and a WY 2021 Spring Pulse Operations Plan. The Spring Pulse Operations Plan was shared with the Upper Sacramento Scheduling Team and the Sacramento Temperature Task Group in March and April. Projected Shasta Reservoir storage for May did not meet the initial criteria for implementation of a spring pulse flow action. Therefore, a spring pulse flow will not occur on the Upper Sacramento River during Water Year 2021 and is not included in this plan.

MONITORING AND REPORTING

CDFW, PSMFC, and USFWS started weekly carcass and redd surveys for winter-run Chinook salmon in April. Monitoring efforts by these agencies increased to twice weekly surveys in spawning reaches on May 3. This monitoring allows for observations of pre-spawn mortality or potential effects associated with spring TMP operations. These data are being shared in real-time so Reclamation and others are notified regarding pre-spawn mortality and the initiation of spawning during May. From June through

October, Reclamation plans to convene SRTTG meetings each month, or more often as warranted by any changing conditions, to ensure tracking and monitoring of the temperature strategy. Temporary exceedances of the daily average temperature criteria of more than 3 consecutive days will be reported to the SRTTG. Should changes to the strategy be necessary, those changes will be developed through communication and coordination with the SRTTG, and other interested parties as warranted.

In October 2021, data collection by CDFW and communication to Reclamation operations will be coordinated to determine the ending date of the temperature management period: October 31, or when the SRTTG determines, based on real-time monitoring that an estimated 95 percent of Winter-run Chinook Salmon eggs have hatched, and alevin have emerged, whichever is earlier.

In November 2021, Reclamation will operate the TCD to minimize in-river thermal impacts with remaining cold water pool resources after the end of the temperature management season, if available, until seasonal changes and ambient conditions dominate river cooling downstream.

For Water Year 2021, Reclamation will complete, in coordination with SRTTG as appropriate, the following monitoring and reporting practices:

- Monthly letters to the Water Board containing relevant data and information as identified in Order 90-5.
- Near-real-time reporting through Reclamation’s web interface of relevant information, located at the following website: <https://www.usbr.gov/mp/cvo/vungvari/sactemprrpt.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. The modeling and tracking information that support the Plan are attached (Attachments 1 and 2). Meeting information can be accessed at the following website: <https://www.usbr.gov/mp/bdo/sacramento-river-temperature-task-group.html> and <https://www.usbr.gov/mp/cvo/temperature.html>
- Monitoring and communication to determine on-set of winter-Run Chinook Salmon spawning.
- Monitoring and communication to determine when an estimated 95% of winter-Run Chinook Salmon eggs have hatched and alevin have emerged.

Reclamation intends to provide temperature profile measurements for Shasta, Whiskeytown, and Trinity Reservoirs in Water Year 2021 as shown in Table 3 below:

Table 3. Frequency and detail of Northern Central Valley Project temperature profile monitoring

Reservoir	Every Month	Every 2 Weeks	Every Week	Comment
Shasta	01/01–03/01 12/1–12/31	03/01–04/01 11/15–12/01	04/01–11/15	25 ft intervals for “Every Month,” otherwise 5 ft intervals
Whiskeytown	01/01–12/31			25 ft intervals
Trinity	01/01–12/31			25 ft intervals

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

The 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 its website identified above as soon as the information becomes available.

Reclamation has relied on CDFW's carcass and redd surveys to determine onset of winter-run Chinook salmon spawning and will rely on CDFW to calculate when an estimated 95% of eggs and alevin have hatched and emerged. As in past years, Reclamation intends to use the CDFW redd dewatering survey to provide information on potential redd dewatering and stranding for informing real-time operations of Shasta and Keswick Dams during the fall transition period.

Reclamation will continue to support and conduct monitoring, modeling, and other evaluations needed to ensure that temperature management actions are optimized and in order to inform future management actions. Reclamation will continue to coordinate with CDFW on river operations and flood control releases to ensure this program can be safely and effectively implemented. Evaluations of operational actions on the Upper Sacramento River will be documented in the Shasta Cold Water Pool and Winter-Refill seasonal reports.

Reclamation's website (<https://www.usbr.gov/mp/cvo/vungvari/sactemprrpt.pdf>) and letters provide the information to meet the needs of the SWRCB and fisheries agencies for the locations currently being monitored. Should the SWRCB or fisheries agencies require the data from any of the monitoring stations outlined above in other formats or need to obtain data from other monitoring sites that Reclamation maintains or has access to, Reclamation can work with the SWRCB or fisheries agencies to provide that data.

Reclamation will report to the Executive Director in writing within 2 business days in the event that Reclamation's operations deviate from those outlined in the plan. The report would explain why actual operations deviated from the TMP, address whether the carryover storage requirements and other TMP objectives will be achieved and will include a plan to address any deficiencies within Reclamation's reasonable control.

WATER RIGHTS ORDER 90-5

Order 90-5 identified a 56°F temperature objective as "the temperature that will protect the fishery from adverse thermal effects during salmonid spawning and egg incubation." It further recognizes that Reclamation's ability to control temperatures is dependent on the amount of water in storage at Shasta Reservoir, ambient air temperatures, tributary inflow and other factors, and that the length of the reach to be protected must be flexible and requires careful planning. Order 90-5 provides that factors beyond Reclamation's reasonable control include conditions where protection of the fishery can best be achieved by allowing a higher temperature in order to conserve cool water for a later release, and conditions where allowing a higher temperature is necessary to implement measures to conserve winter run Chinook salmon.

For Water Year 2021, Reclamation has determined that it cannot reasonably maintain 56°F at Red Bluff Diversion Dam and that:

- Protection of the fishery can best be achieved by allowing a higher temperature in order to

- conserve cool water for later release,
- A higher temperature is necessary to implement measures to conserve winter-run Chinook salmon.

Reclamation's Plan to conserve cold water for the duration of the temperature management period and operate to a higher temperature at Red Bluff Diversion Dam will best protect the fishery from adverse thermal effects during salmonid spawning and egg incubation. More specifically, Reclamation will be operating to the temperatures and compliance locations included in the Plan which are upstream of Red Bluff Diversion Dam.

CONSTRAINTS

Reclamation operates the CVP to deliver water under existing agreements and contracts, including the Sacramento River Settlement (SRS) contracts, water service contracts (for irrigation and municipal and industrial purposes), refuge water supply contracts, other agreements, and other requirements such as D-1641.

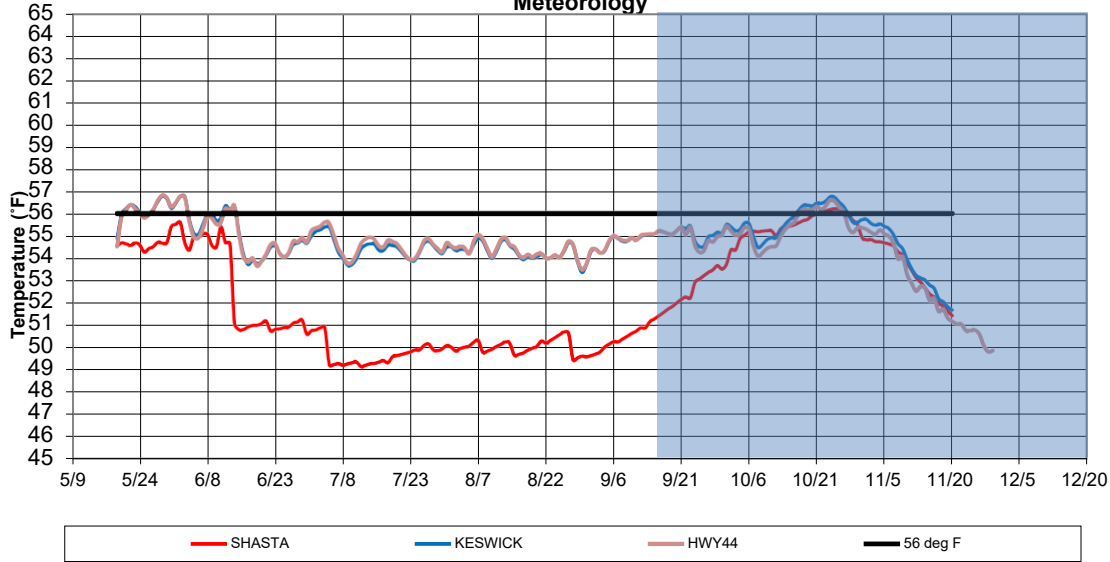
The SRS contracts are settlement contracts executed with senior water right holders along the Sacramento River below Shasta Dam to address senior water rights managed by the State of California. The SRS contracts provide for the delivery of approximately 2.1 (MAF) of water. Article 5(a) of the SRS contracts provides that the Contract Total will be reduced by 25% in a Shasta Critical Year. This remains a Critical Year, so the SRS Contract Totals were reduced by 25% for water year 2021.

Under the Coordinated Operation Agreement (COA) (as amended in 2018), the CVP is responsible for 60% of water released from storage to meet all in-basin uses in the Sacramento River watershed under balanced conditions in Critical years. In-basin uses include all accretions and depletions within the Sacramento River watershed, which include delivery of water to SWP settlement contractors along the Feather River, among other demands. These Feather River settlement agreements provide over 1 million acre-feet of water each year and Shasta Reservoir delivers 60% of that amount. DWR has reduced contract deliveries to the Feather River Contractors this water year, and Reclamation assumed a 50% allocation for them in the analysis. The State Water Board lifted Term 91 on December 24, 2020, and reestablished it with a curtailment notice on April 29, 2021. Reclamation anticipates the Water Board will pursue curtailment of other water users in the Central Valley and Delta.

CVP water service and repayment contracts are met after satisfying senior water rights and regulatory requirements. Water service contract allocations are a product of an integrated operation of the entire Central Valley Project in coordination with the State Water Project that considers available water supply, regulatory obligations including temperature management, conveyance ability and physical capacities. CVP water service contractors were initially allocated 5% for agricultural and 55% for municipal and industrial of their Contract Total; however, these allocations were updated to 0% and 25% by late May.

Attachment 1: HEC-5Q Output for Scenario 13

Sacramento River Modeled Temperature
2021 May 90%-Exceedance Water Outlook - L3MTO 25%
Meteorology



	Shasta deg F	Keswick deg F	Hwy44 deg F	Igo deg F	Trinity deg F	Lewiston deg F
May	54.7	56.2	56.1	51.3	46.0	49.4
Jun	52.7	55.1	55.1	53.5	46.2	49.5
Jul	49.8	54.5	54.6	56.7	46.8	50.9
Aug	50.1	54.3	54.4	58.7	47.8	50.9
Sep	51.5	54.9	54.9	58.1	50.2	52.1
Oct	55.4	55.7	55.5	55.3	52.0	53.1
Nov	52.6	53.0	52.5	52.9	51.6	51.8

Run date: 5/25/21 S13

EOM Sept storage: 1.25 MAF

Trinity profile date: 5/13/21

Whiskeytown profile date: 5/18/21

Shasta profile date: 5/19/21

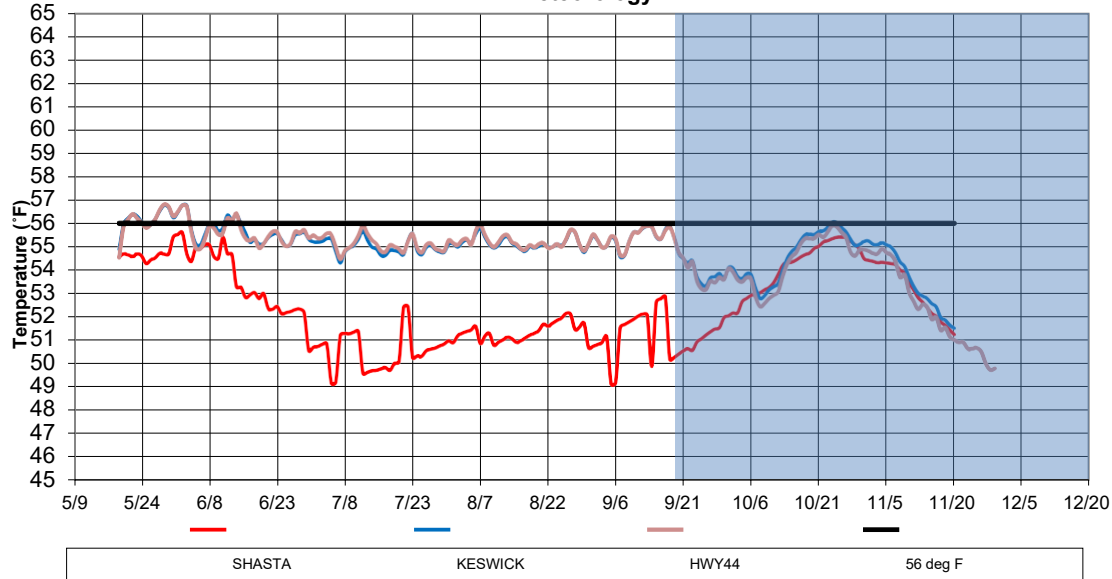
Projected Side gates: First Jul 13 Full Aug 29

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

End of September Cold-Water-Pool less than 56 deg F: 173 TAF

Attachment 1: HEC-5Q Output for Scenario 14

**Sacramento River Modeled Temperature
2021 May 90%-Exceedance Water Outlook - L3MTO 25%
Meteorology**



	Shasta deg F	Keswick deg F	Hwy44 deg F	Igo deg F	Trinity deg F	Lewiston deg F
May	54.7	56.2	56.1	51.3	46.0	49.4
Jun	53.5	55.7	55.6	53.5	46.2	49.5
Jul	50.5	55.0	55.1	56.7	46.8	50.9
Aug	51.3	55.2	55.2	58.7	47.8	50.9
Sep	51.2	54.9	54.8	58.1	50.2	52.1
Oct	54.1	54.6	54.4	55.3	52.0	53.1
Nov	52.3	52.7	52.3	52.9	51.6	51.8

Run date: 5/25/21 S14

EOM Sept storage: 1.25 MAF

Trinity profile date: 5/13/21

Whiskeytown profile date: 5/18/21

Shasta profile date: 5/19/21

Projected Side gates: First Aug 8 Full Sep 19

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

End of September Cold-Water-Pool less than 56 deg F: 230 TAF

Attachment 2

HEC5Q Temperature and Temperature Dependent Modeling Methods and Assumptions

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, historical temperatures on the Sacramento River at Shasta Dam, Keswick Dam, above Clear Creek, Balls Ferry, Jelly's Ferry, and Bend Bridge are interpolated to estimate temperatures at river miles where simulated redds were located. Actual water temperatures at KWK and CCR were used from 1/1/21 to 5/24/21. HEC-5Q output estimates water temperatures at Keswick Dam; however, there is no temperature gauge at the Keswick Dam, and therefore, the KWK gauge was used for TDM temperature input for the time period 1/1/21 to 5/24/21.

Between September 15 and November 29, daily temperatures at the simulated redds' river miles are typically estimated based on a relationship between cold water pool volume less than 56 degrees F at the end of September in Shasta Lake and water temperatures above Clear Creek derived by Central Valley Operations. Reclamation thinks this relationship is more reliable in that time period than outputs from the HEC-5Q model. The 90% confidence interval value from this analysis was used as a conservative estimate. The average difference between the simulated temperatures above Clear Creek and the simulated temperatures at the redds' river miles during this period are used to adjust above Clear Creek estimated temperatures for each river mile. Forecasted water temperatures in degrees Fahrenheit temperatures shown below were used for TDM modeling, instead of HEC-5Q modeled temperatures for 9/15/2021-11/29/21.

Scenario 13 Forecasted Water Temperatures at Keswick:
 $-0.0067 * (\text{Cold Water Pool Storage}) + 58.9900 + 1.7$
 $-0.0067 * 173 + 58.9900 + 1.7 = \mathbf{59.53 \text{ degrees Fahrenheit}}$

Scenario 13 Forecasted Water Temperatures at Clear Creek:
 $-0.0062 * (\text{Cold Water Pool Storage}) + 59.2742 + 2.5 = 60.286$
 $-0.0062 * 173 + 59.2742 + 2.5 = \mathbf{60.70 \text{ degrees Fahrenheit}}$

Scenario 14 Forecasted Water Temperatures at Keswick:
 $-0.0067 * (\text{Cold Water Pool Storage}) + 58.9900 + 1.7$
 $-0.0067 * 230 + 58.9900 + 1.7 = \mathbf{59.15 \text{ degrees Fahrenheit}}$

Scenario 14 Forecasted Water Temperatures at Clear Creek:
 $-0.0062 * (\text{Cold Water Pool Storage}) + 59.2742 + 2.5 = 60.286$
 $-0.0062 * 230 + 59.2742 + 2.5 = \mathbf{60.35 \text{ degrees Fahrenheit}}$

We provide TDM estimates using both the water temperature time series adjusted using the regression relationship described above (Table 1), as well as TDM estimates using water temperature time series that used HEC-5Q forecasted water temperatures later in the season (Table 2).

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. Two models were used: 1. Martin et al (2017) for stage independent modeling whereby a single temperature threshold is used from spawning and

¹ Martin B.T. et al. (2017). Phenomenological vs. biophysical models of thermal stress in aquatic eggs. Ecology Letters 10:50-59.

incubation through emergence; and 2. Anderson et al. (2018)² for stage dependent modeling for targeting different temperatures before, during, and after the most sensitive stages during egg incubation. The methods are applied to a set of simulated redds representative of redd construction timing and location from 2012-2020 and the results summarized on a seasonal level for comparison. Further information about the model's assumptions are documented in Table 1 below.

² Anderson, J. (2018). Using river temperature to optimize fish incubation metabolism and survival: a case for mechanistic models. ResearchGate Preprint. 10.1101/257154.

Table 1. Water temperature and winter-run Chinook salmon temperature-dependent mortality assumptions with adjusted end of season water temperatures.

Parameter	Scenarios 13 and 14 Run Date 05/25/21	Scenarios 13 and 14 05/25/21
Meteorology source	Forecasted Meteorology 25% L3MTO	Forecasted Meteorology 25% L3MTO
Operations Forecast	May forecast (based on May 1 90% hydrology)	May forecast (based on May 1 90% hydrology)
Time period	HEC5Q forecast: 5/19/21-11/29/21 TDM Input: 1/1/2021-11/29/2021	HEC5Q forecast: 5/19/21-11/29/21 TDM Input: 1/1/2021-11/29/2021
Reservoir Model used	HEC-5Q	HEC-5Q
River Model used	HEC-5Q until 9/14 then historic relationship to end of September storage below 56 degrees F	HEC-5Q until 9/14 then historic relationship to end of September storage below 56 degrees F
Shasta Profile date	5/19/21	5/19/21
TCD Gate operations	HEC-5Q	HEC-5Q
Sacramento water temperatures used for TDM	<ul style="list-style-type: none"> 1/1/2021-5/24/21: Actual KWK and CCR water temperatures. 5/25/21-9/14/21: HEC-5Q output at Keswick Dam and Clear Creek 9/15/21-12/31/21: Regression relationship at KWK (59.53 F for S13 and 59.15 F for S14) and CCR (60.70 F for S13 and 60.35 F for S14) 	<ul style="list-style-type: none"> 1/1/2021-5/24/21: Actual KWK and CCR water temperatures. 5/25/21-9/14/21: HEC-5Q output at Keswick Dam and Clear Creek 9/15/21-12/31/21: Regression relationship at KWK (59.53 F for S13 and 59.15 F for S14) and CCR (60.70 F for S13 and 60.35 F for S14)
Biological Model used	SacPAS Fish model	SacPAS Fish model
Temperature Mortality Model	Stage-independent mortality (Martin)	Stage-dependent mortality (Anderson)
Egg emergence timing model	Linear. 958 ATUs (degrees C), as indicated for Zeug et al. on SacPAS under Egg to emergence timing model.	487 (degree C days)
TDM redd time distribution	Observed 2012-2020	Observed 2012-2020
TDM redd space distribution	Observed 2012-2020	Observed 2012-2020
TDM Terit (50th percentile)	53.7°F (12.056°C)	53.7°F (12.056°C)
TDM bT (50th percentile)	0.026°C ⁻¹ d ⁻¹ (0.0144°F ⁻¹ d ⁻¹)	1.17°C ⁻¹ d ⁻¹ (0.65°F ⁻¹ d ⁻¹)
Critical Days	All	3
TDM Output (%)	Scenario 13: 77 Scenario 14: 88	Scenario 13: 78 Scenario 14: 95

Table 2. Water temperature and winter-run Chinook temperature-dependent mortality assumptions with HEC-5Q end of season water temperatures.

Parameter	Scenarios 13 and 14 Run Date 05/28/21	Scenarios 13 and 14 05/28/21
Meteorology source	Forecasted Meteorology 25% L3MTO	Forecasted Meteorology 25% L3MTO
Operations Forecast	May forecast (based on May 1 90% hydrology)	May forecast (based on May 1 90% hydrology)
Time period	HEC5Q forecast: 5/19/21-11/29/21 TDM Input: 1/1/2021-11/29/2021	HEC5Q forecast: 5/19/21-11/29/21 TDM Input: 1/1/2021-11/29/2021
Reservoir Model used	HEC-5Q	HEC-5Q
River Model used	HEC-5Q until 9/14 then historic relationship to end of September storage below 56 degrees F	HEC-5Q until 9/14 then historic relationship to end of September storage below 56 degrees F
Shasta Profile date	5/19/21	5/19/21
TCD Gate operations	HEC-5Q	HEC-5Q
Sacramento water temperatures used for TDM	<ul style="list-style-type: none"> • 1/1/2021-5/24/21: Actual KWK and CCR water temperatures. • 5/25/21-12/31/21: HEC-5Q output at Keswick Dam and Clear Creek 	<ul style="list-style-type: none"> • 1/1/2021-5/24/21: Actual KWK and CCR water temperatures. • 5/25/21-12/31/21: HEC-5Q output at Keswick Dam and Clear Creek
Biological Model used	SacPAS Fish model	SacPAS Fish model
Temperature Mortality Model	Stage-independent mortality (Martin)	Stage-dependent mortality (Anderson)
Egg emergence timing model	Linear. 958 ATUs (degrees C), as indicated for Zeug et al. on SacPAS under Egg to emergence timing model.	487 (degree C days)
TDM redd time distribution	Observed 2012-2020	Observed 2012-2020
TDM redd space distribution	Observed 2012-2020	Observed 2012-2020
TDM Tcrit (50th percentile)	53.7°F (12.056°C)	53.7°F (12.056°C)
TDM bT (50th percentile)	0.026°C ⁻¹ d ⁻¹ (0.0144°F ⁻¹ d ⁻¹)	1.17°C ⁻¹ d ⁻¹ (0.65°F ⁻¹ d ⁻¹)
Critical Days	All	3
TDM Output (%)	Scenario 13: 67 Scenario 14: 80	Scenario 13: 78 Scenario 14: 94

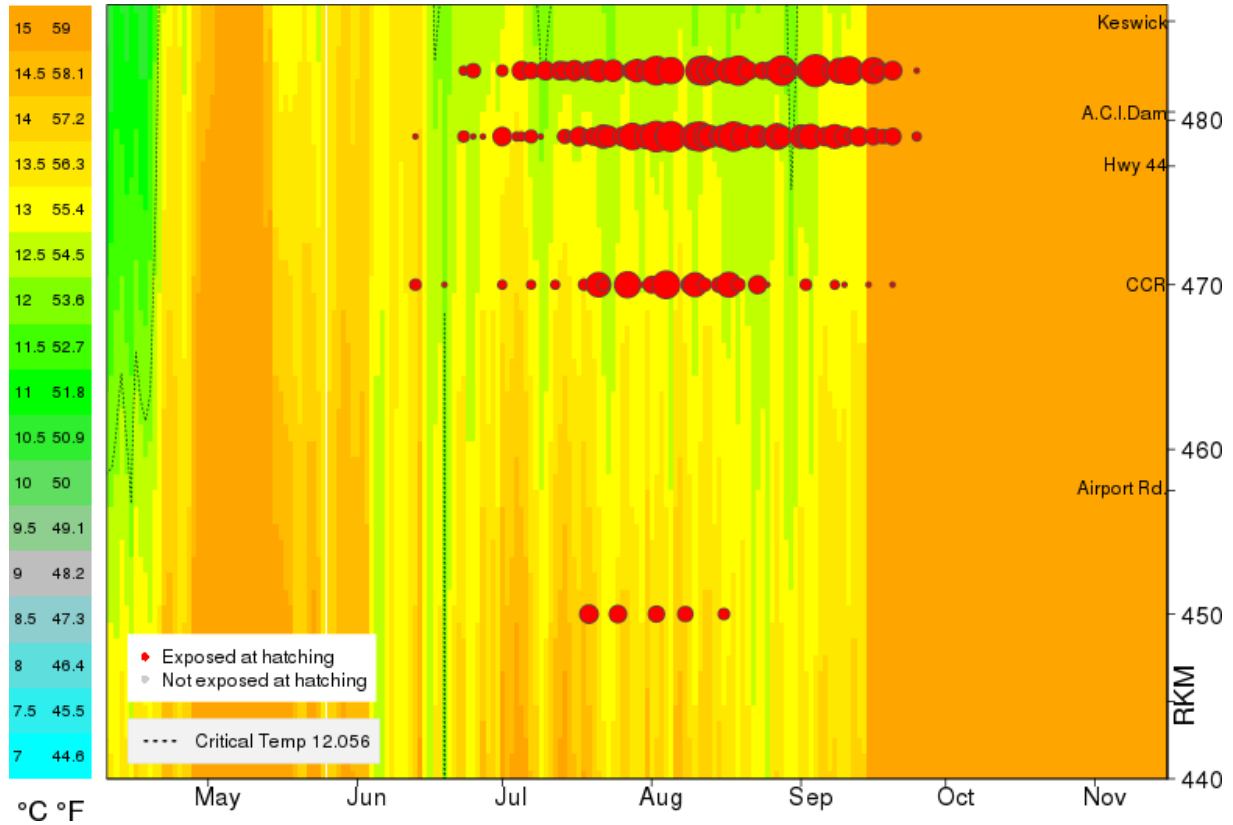


Figure 1. Forecasted Sacramento River winter-run Chinook salmon redd exposure at hatching to forecasted water temperatures described in Scenario 13 using temperatures adjusted end-of-season regression approach.

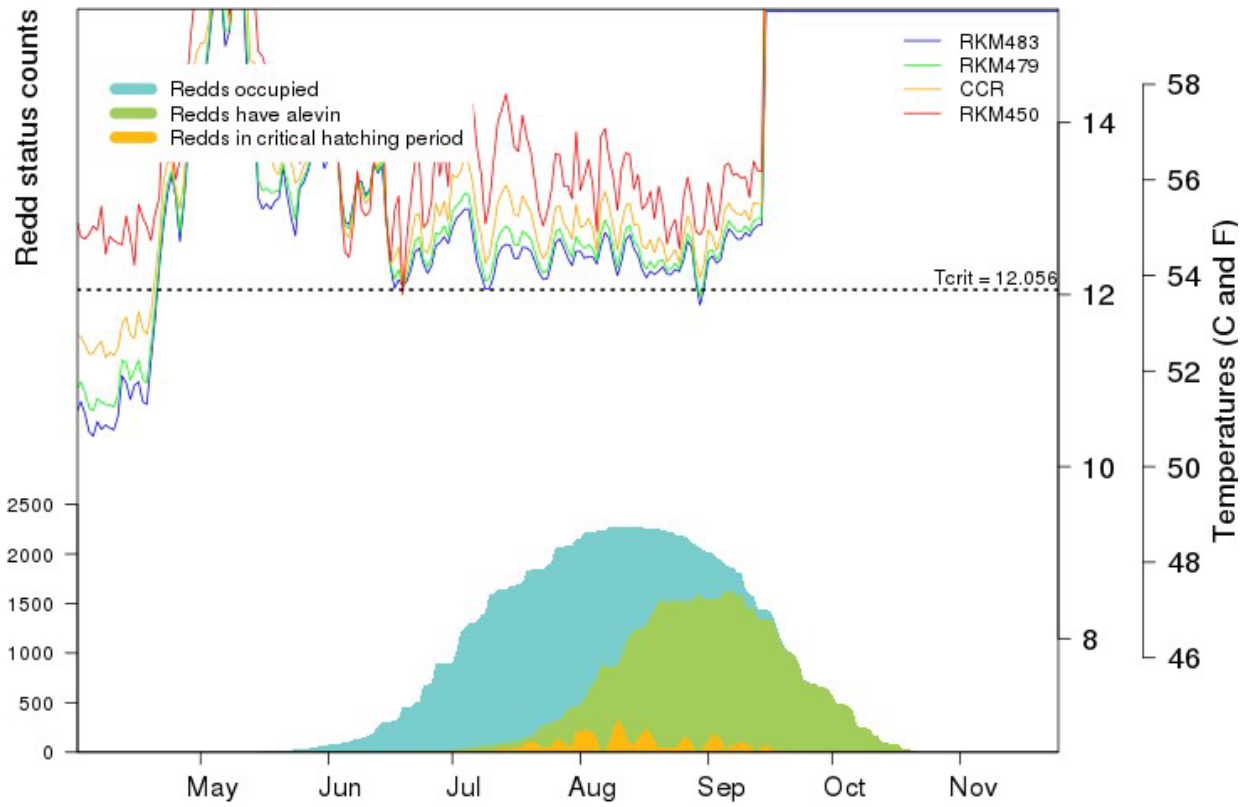


Figure 2. Winter-run Chinook salmon redd and egg incubation timing with forecasted water temperatures from Scenario 13 using temperatures adjusted end-of-season regression approach.

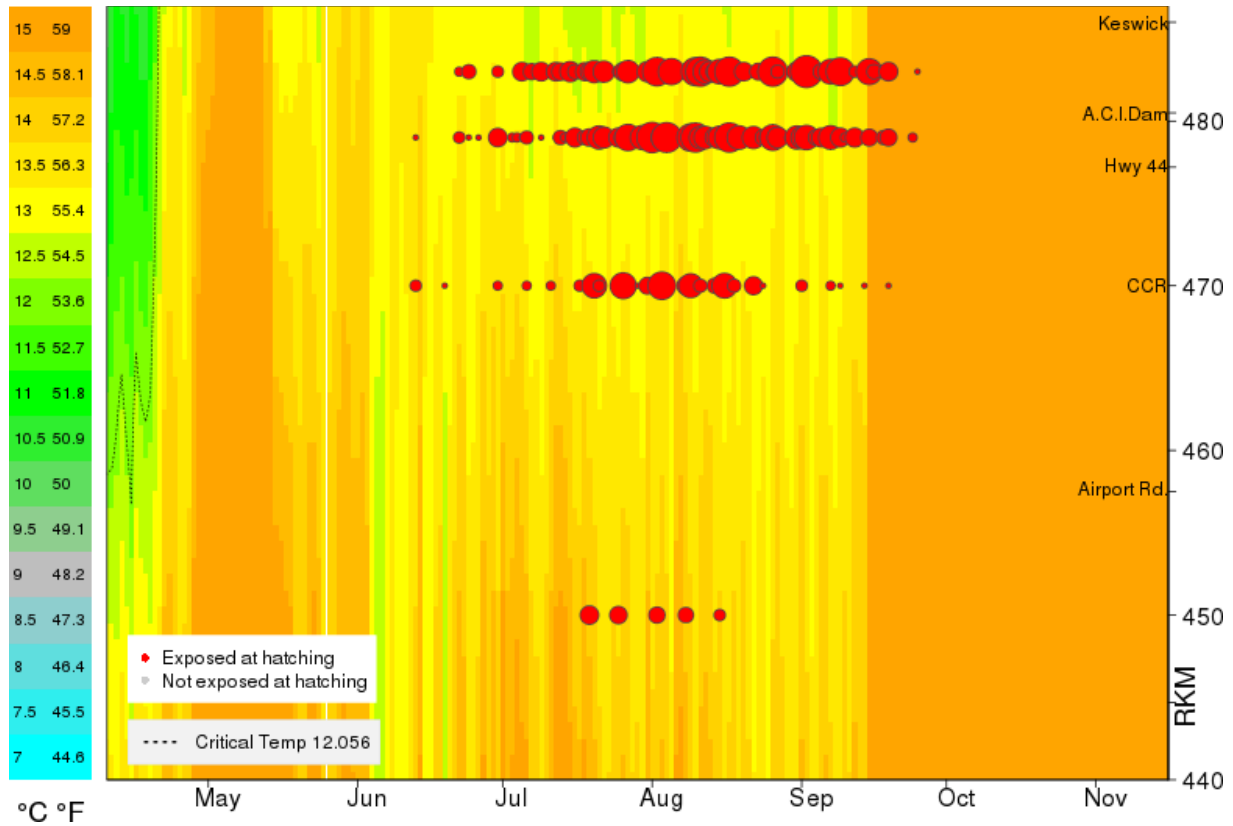


Figure 3. Forecasted Sacramento River winter-run Chinook salmon redd exposure at hatching to forecasted water temperatures described in Scenario 14 using temperatures adjusted end-of-season regression approach.

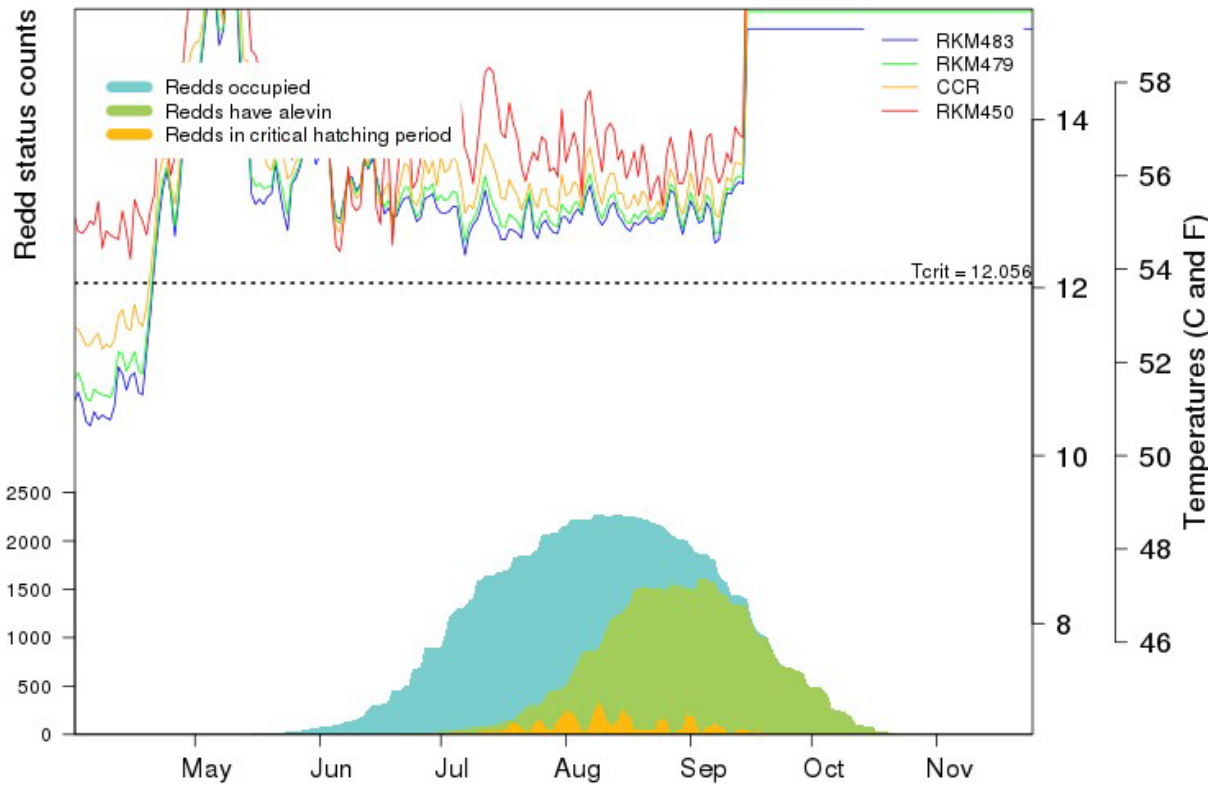


Figure 4. Winter-run Chinook salmon redd and egg incubation timing with forecasted water temperatures from Scenario 14 using temperatures adjusted end-of-season regression approach.

Attachment 3: Summary Document for Shasta/Keswick Operational Scenarios
 Prepared by the Southwest Fisheries Science Center on May 27th, 2021

Below are results for two USBR scenarios ran May 26th 2021. The scenarios have hydrology (Input 90% exceedance) and air temperature (25% exceedance of L3MTO) as inputs. Outputs from the 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 stage-independent temperature mortality model (Martin et al. 2017) for the 2021 temperature management season.

Further details of modeling methods are at: <https://oceanview.pfeg.noaa.gov/CVTEMP/>

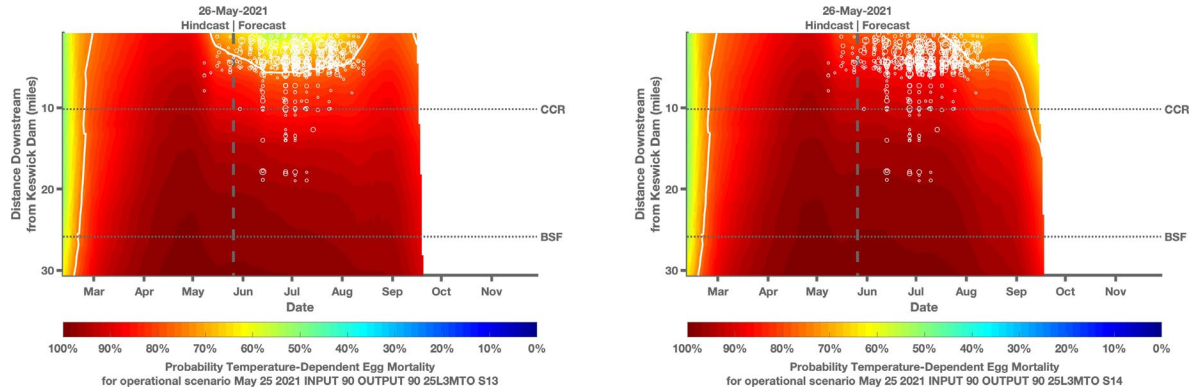


Figure1: Estimated temperature-dependent egg mortality produced by the NMFS stage-independent temperature mortality model under the two May 25th 2021 scenarios. 2012-2019 redd distributions are used for all plots with meteorology from 2009-2018. The plot is assuming the mean from the 10-year meteorological ensemble (2009-2018).

Table 1: Estimated temperature-dependent egg mortality under different scenarios assuming a 2012-2019 spatial and temporal redd distribution using output from the RAFT water temperature model.

Scenario	RIVER MODEL	Mean (%)	Median (%)
MAY_25_2021_INPUT_90_OUTPUT_90_25L3MTO S13	RAFT	64	71
MAY_25_2021_INPUT_90_OUTPUT_90_25L3MTO S14	RAFT	73	81