BUREAU OF RECLAMATION

2021 Seasonal Report for Shasta Lake Storage Rebuilding and Spring Pulse

Central Valley Project, California
California-Great Basin Region

Shasta Dam in Winter 2020 (Reclamation)

U.S. Department of the Interior **June 2021**

Mission Statements

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The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

2021 Seasonal Report for Shasta Lake Storage Rebuilding and Spring Pulse

Central Valley Project, California
California-Great Basin Region

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Contents

Appendices

Appendix A - Sacramento River Fall and Winter Flow Refill and Redd Maintenance and Rice Decomposition Smoothing Guidance Document

Appendix B - Upper Sacramento River Spring Pulse Flow & Upper Sacramento River Scheduling Team Guidance Document

Appendix C – 2020 Fall Keswick Flow Reduction Alternatives

Appendix D – Upper Sacramento River Spring Pulse Flow Study Plan

Appendix E – Sacramento River 2021 Spring Pulse Operations Plan, March and April

Appendix F – Upper Sacramento Scheduling Team Fish Monitoring Plan

Purpose

This 2021 Seasonal Report for Shasta Lake Storage Rebuilding and Spring Pulse describes Shasta Lake operations and management in water year (WY) 2021 to support improvements, if necessary, to guidance documents for WY 2022, and fulfills commitments under the Record of Decision (ROD) for the Coordinated Long-Term Operation of the Central Valley Project (CVP) and State Water Project (SWP). By the end of June of each year, Reclamation provides information on the prior year's management of Shasta Lake storage rebuilding and spring pulse in order to inform the upcoming storage rebuilding and spring pulse season. Information provided in this report may also be considered or evaluated by the four-year independent review panels.

Background

Shasta Dam and Lake represent about 40 percent of the total reservoir storage capacity of the CVP and are located in northern California near Redding (Figure 1). Reclamation operates Shasta Dam in coordination with state and federal regulatory agencies (National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USFWS), California Department of Fish and Wildlife (CDFW), the State Water Resources Control Board (Water Board), and U.S. Army Corps of Engineers); tribal entities; Western Area Power Administration; water contractors and other stakeholders; and in conjunction with other CVP facilities. CVP operations provide for multiple purposes, including: the management of floodwater; storage of winter runoff for irrigation in the Sacramento and San Joaquin valleys; Municipal and Industrial (M&I) water supply; fish and wildlife mitigation, protection, and restoration; fish and wildlife enhancement in the Sacramento River and Delta; and hydropower generation.

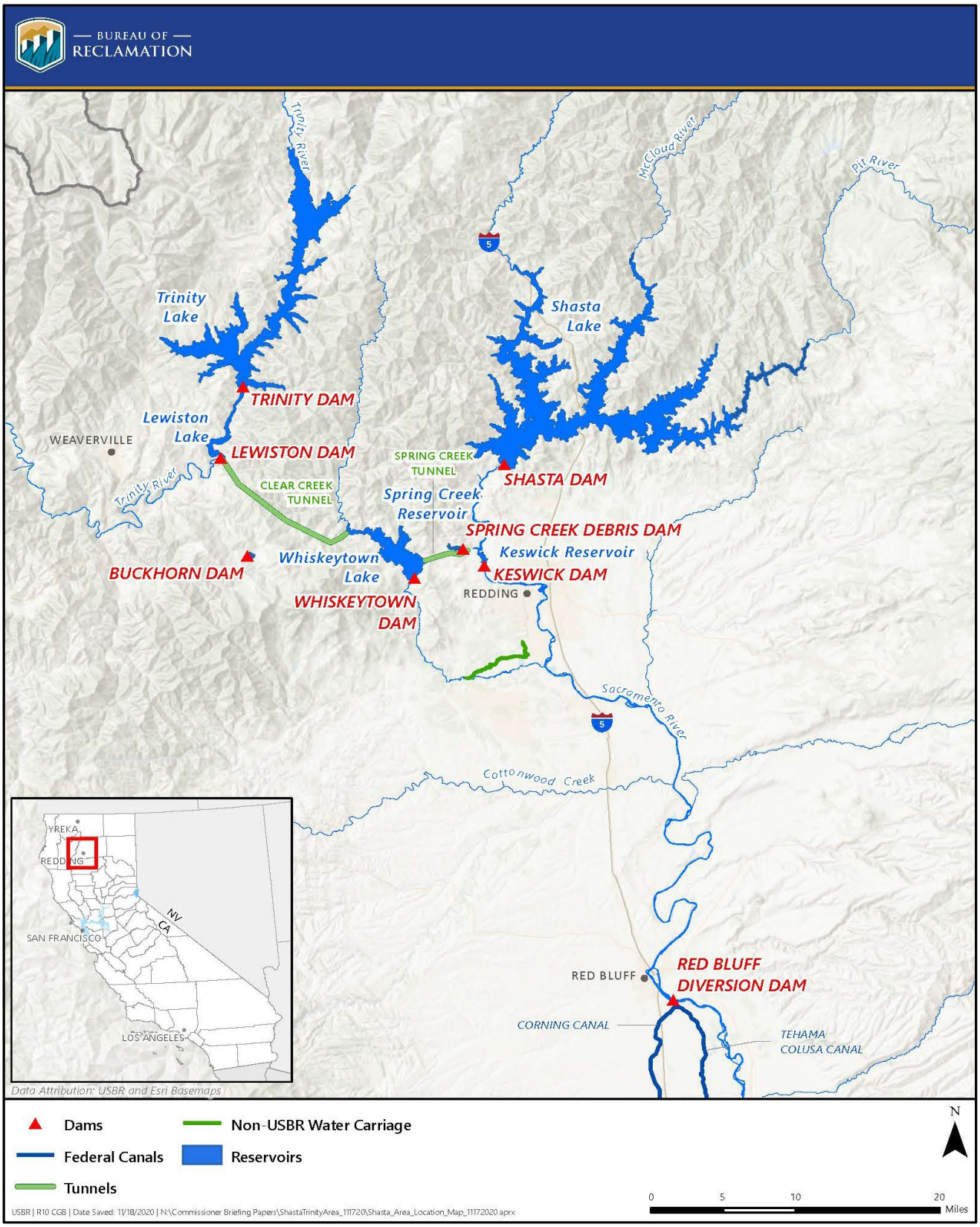

Figure 1. Shasta-Trinity System located in Northern California.

Reclamation consulted under the Endangered Species Act (ESA) with the USFWS and NMFS on potential effects of the Proposed Action on threatened and endangered species and their designated critical habitats. Reclamation provided the final Biological Assessment on October 17, 2019. In turn, the USFWS and NMFS issued their Biological Opinions of the Proposed Action on October 21, 2019. Fall and Winter Refill and Redd Maintenance, Rice Decomposition Smoothing, and Spring Pulse Flows are a part of the Upper Sacramento Operations described in the Proposed Action. Reclamation signed the ROD, which included the 2019 Biological Opinions from USFWS and NMFS, and began implementing the Proposed Action on February 18, 2020.

The ROD identifies the following operational components to increase spring Shasta Lake storage levels: (1) Fall and Winter Refill and Redd Maintenance, which sets minimum late fall and winter flows, including coordination on rice decomposition operations; (2) modified fall outflow requirements; (3) flexibility in late winter and spring export operations (especially in April and May); and (4) December 2018 changes to the Coordinated Operation Agreement for the CVP/ SWP. These operations, as well as real-time operations, are expected to result in increased storage at the end of September, which Reclamation anticipates will benefit the following May 1 storage in years without flood control releases. The ROD includes consideration of releasing spring pulse flows of up to 150 thousand acre-feet (TAF) from Keswick Dam to support the emigration of Chinook salmon. Implementation of a spring pulse flow depends on whether the projected total May 1 Shasta Lake 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 demands on the reservoir.

Two guidance documents provide implementation guidance on Shasta Lake's winter storage rebuilding and spring pulse flows pursuant to the ROD: (1) Sacramento River Fall and Winter Flow Refill and Redd Maintenance and Rice Decomposition Smoothing Guidance Document (Fall and Winter Guidance Document, Appendix A); and (2) Upper Sacramento River Spring Pulse Flow & Upper Sacramento River Scheduling Team Guidance Document (Spring Guidance Document, Appendix B). The scope of guidance includes the deliverables, schedule, and processes to implement operations during the fall, winter, and spring. The primary deliverables of the Fall and Winter Guidance document are: (1) flow schedules related to the fall and winter refill in Shasta Lake; and (2) redd maintenance and rice decomposition smoothing activities. The Spring Guidance Document primary deliverables are related to the spring pulse flow action: (1) preliminary spring-run Chinook salmon survival estimates; (2) the Pulse Flow Study Plan; and (3) the Pulse Flow Operation Plan. Reclamation must also comply with the Water Board Water Rights Order 90-5.

Seasonal Operations

WY 2021 was the first year where fall and early winter operations were guided by the 2020 ROD. In the fall of 2020, a coordinated effort to reduce Keswick Dam releases was evaluated by the Upper Sacramento Scheduling Team (USST) in order to minimize winter-run and fall-run Chinook salmon redd dewatering impacts. Very dry hydrology in WY 2021 afforded few opportunities for Shasta Lake refill and storage remained low throughout the fall, winter, and spring. In WY 2021, there were no flood control releases and a spring pulse flow action was not taken. May 1 storage in Shasta Lake was 2.28 MAF.

Operational Background Information

This section describes the 2020 ROD commitments, including guidance on how Reclamation manages flows below Keswick Dam in the fall, winter, and spring while building storage in Shasta Lake during this time period. Additionally, a historical overview of climatic conditions is summarized.

Commitments of the 2020 ROD

Fall operations at Shasta Dam are dominated by water temperature control and provision of fish spawning habitat. By late fall, the remaining cold water pool in Shasta Lake is usually limited. This can be a delicate balancing act. If the early fall flows are too high then fall-run Chinook salmon may construct their redds at higher elevations (i.e. in shallow areas) of the river and become vulnerable to dewatering when the flows are reduced later in the fall. If early fall flows are reduced too soon, then winter-run Chinook salmon redds from which juveniles have not yet emerged may be dewatered. In addition to dewatering of Chinook salmon spawning and rearing habitat, Sacramento River releases cannot be too low early in the fall because there are still significant instream diversion demands on the mainstem of the Sacramento River between Keswick Dam and Wilkins Slough. Depending on conditions, upstream reservoir releases may be needed in order to meet the Water Board Delta requirements.

Reclamation operates Shasta Dam in the winter for flood control, including both the channel capacity within the Sacramento River and Shasta Lake flood conservation space. When not operating for flood control, Shasta Dam is operated primarily to conserve storage while meeting minimum flows both down the Sacramento River and in the Delta. These minimum flows are held until irrigation demands or Delta requirements require increased releases, typically beginning in the spring.

Under the Fall and Winter Refill and Redd Maintenance action, Reclamation rebuilds storage and cold water pool for the subsequent year during the fall and winter, while also trying to maintain releases to keep winter-run Chinook salmon redds underwater. Releases may drawdown storage necessary for water temperature management in a subsequent year. Reclamation, in coordination with the Sacramento River Temperature Task Group (SRTTG) and the USST, will conduct a risk analysis of the remaining winter-run Chinook salmon redds, the probability of sufficient cold water in a subsequent year, and a conservative distribution and timing of subsequent winter-run Chinook salmon redds. If combined productivity of the remaining redds plus a conservative scenario for the following year is less than the productivity of maintaining, Reclamation will reduce releases to rebuild storage. Following the emergence of winter-run Chinook salmon and prior to the majority of fall-run Chinook salmon spawning, upstream Sacramento Valley CVP contractors and the Sacramento River Settlement Contractors (SRSC) propose to work to synchronize their diversions to lower peak rice decomposition demand, pursuant to Reclamation's conservation measure Rice Decomposition Smoothing. With lower late October and early November flows, fall-run Chinook salmon are less likely to spawn in shallow areas that would be subject to dewatering during winter base flows. Early reductions (late October–early November) would balance the potential for dewatering winter-run Chinook salmon redds and early fall-run Chinook salmon redds. Real-time fish monitoring data, operational conditions, and modeling is shared through the SRTTG and the USST.

If Reclamation determines based on the above analysis that reduced releases are needed to rebuild storage, targets for winter base flows (December 1 through the end of February) from Keswick Dam would be set in October based on Shasta Lake end-of-September storage. Table 1 shows the initial schedule for Keswick Dam releases based on the Shasta Lake storage condition. This schedule would be refined through future modeling efforts as part of the seasonal operations planning.

Table 1. Keswick Dam Release Schedule for End-of-September (EOS) Storage

Keswick Release (cfs)	Shasta EOS Storage
3,250	≤2.2 MAF
4,000	≤2.8 MAF
4,500	≤3.2 MAF
5,000	≤3.2 MAF

In addition to the requirements under the Water Board Water Rights Order 90-5, ramping rates for Keswick Dam releases between July 1 – March 31 would be reduced between sunset and sunrise and include:

- Keswick releases > 6,000 cfs, reductions in releases may not exceed 15 percent per night, and no more than 2.5 percent per hour.
- Keswick releases 4,000 cfs to 5,999 cfs reductions in releases may not exceed 200 cfs per night, or 100 cfs per hour.
- Keswick releases between 3,250 cfs and 3,999 cfs; reductions in releases may not exceed100 cfs per night. Ramping rates do not apply during flood control or if needed for facility operational concerns. The SRTTG and USST may also determine a need for a variance.

Reclamation will release spring pulse flows of up to 150 TAF in coordination with the USST 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 USST determines the timing, duration, and frequency of the spring pulse within the 150 TAF volume. Wet hydrology downstream of Keswick Dam may meet the need for pulse flows without increased releases. Based on current science, which may be updated through the USST, the spring pulse could be 0 to 2 pulses of 10,000 cfs at Wilkins Slough for three days each, at a time when Wilkins Slough flows are less than 9,000 cfs. The ramping rates described above apply during a spring pulse flow action as well.

Historical Overview

The historic daily average Shasta Lake storage volumes (MAF) from WY 1995 – 2021 are shown in Figure 2. In WY 2020, the end of September daily average Shasta Lake storage volume was lower than the historic average (WY 1996 – 2020 average: 2.6 MAF; WY 2020 value: 2.2 MAF), but were the second highest for a dry year since the implementation of the Water Board Decision 1641, the Central Valley Project Improvement Act (CVPIA), and ESA requirements. In WY 2021, the May 1

daily average Shasta Lake storage volume was 58 percent of the historic average (WY 1995 – 2021 average: 3.8 MAF; WY 2021 value: 2.3 MAF).

The northern Sierra 8-Station Index is shown in Figure 3. As of June 2021, precipitation in WY 2021 is equal to approximately 44 percent of the average from WY 1967 – 2021 (WY 1967 – 2021 average: 51.8 inches; WY 2021 value as of June 15: 23.1 inches). Mean monthly air temperatures at Shasta Dam (SHS) for October, December, April, and May in WY 2021 were higher than average for the period of record WY 2013 – WY 2021. Further, a comparison of mean monthly air temperatures in California for WY 2021 compared to a period of record from 1895 – 2010 is shown in Figure 4 (data from 2011 through present was not readily available). From October – April in WY 2021, a majority of Shasta County experienced air temperatures above normal (top 10% of years analyzed) (Abatzoglou et al. 2021).

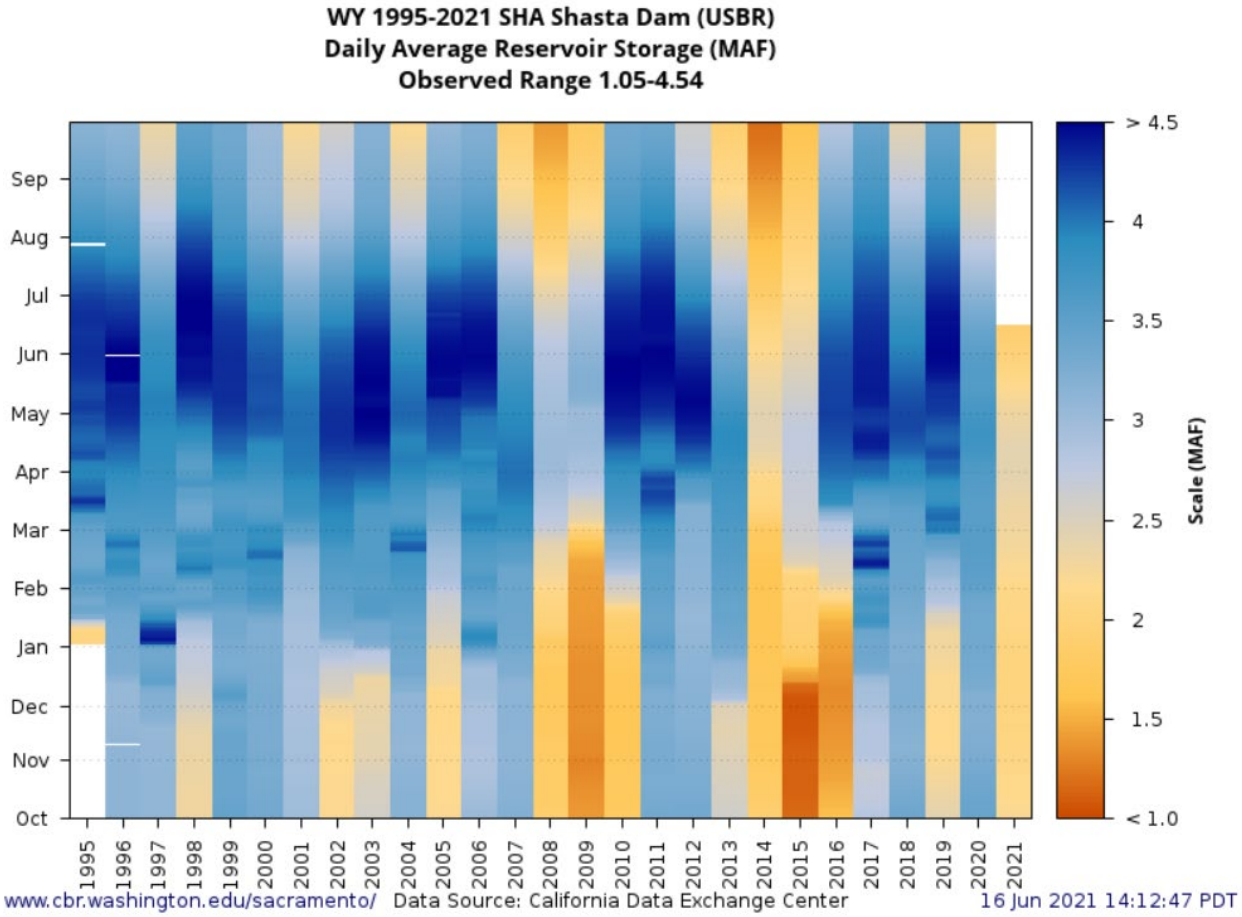

Figure 2. Shasta Lake Storage (MAF) from WY 1995-2021, as of June 2021. Source: http://www.cbr.washington.edu/sacramento/data/query_river_allyears.html

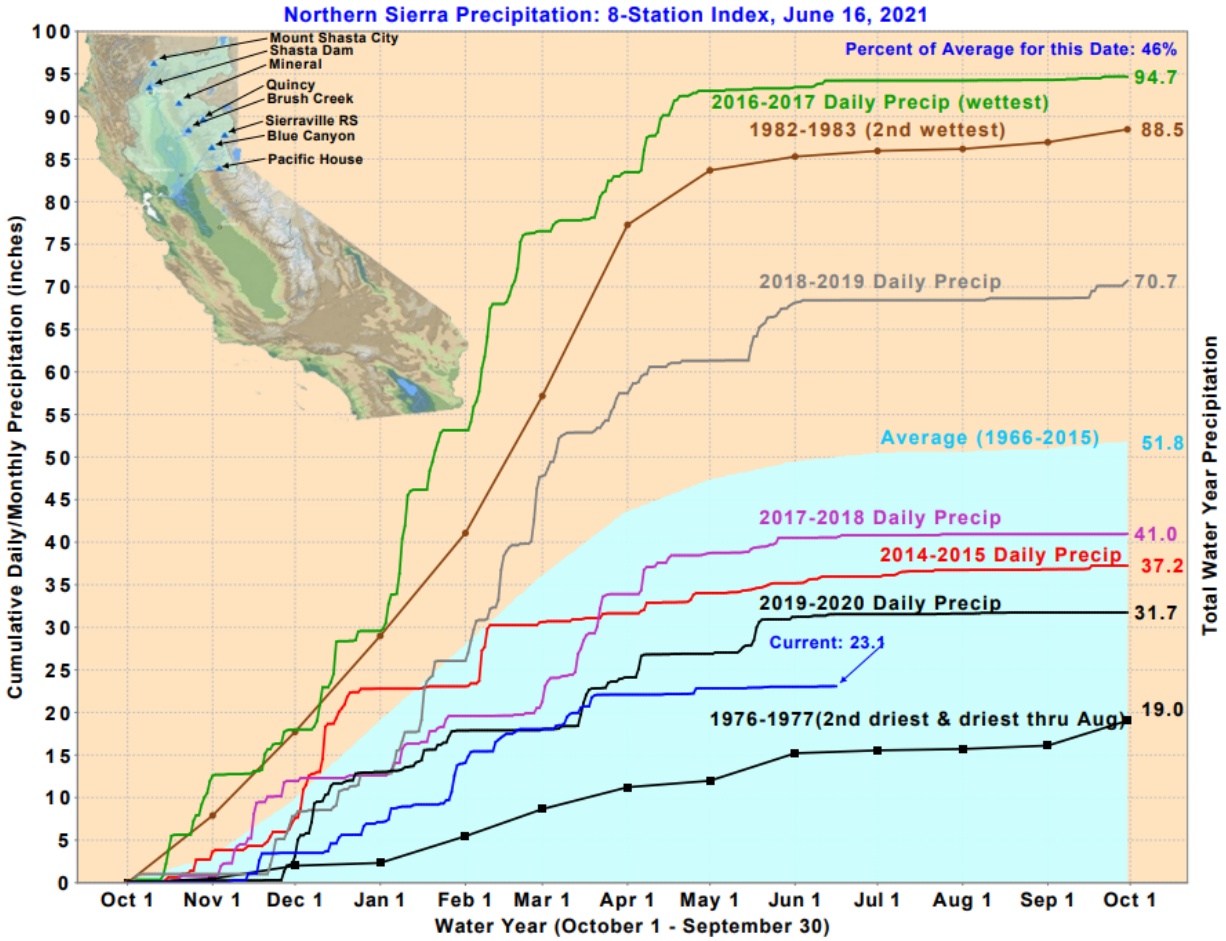

Figure 3. Northern Sierra Precipitation: 8-Station Index as of June 2021. Source: javareports (ca.gov)

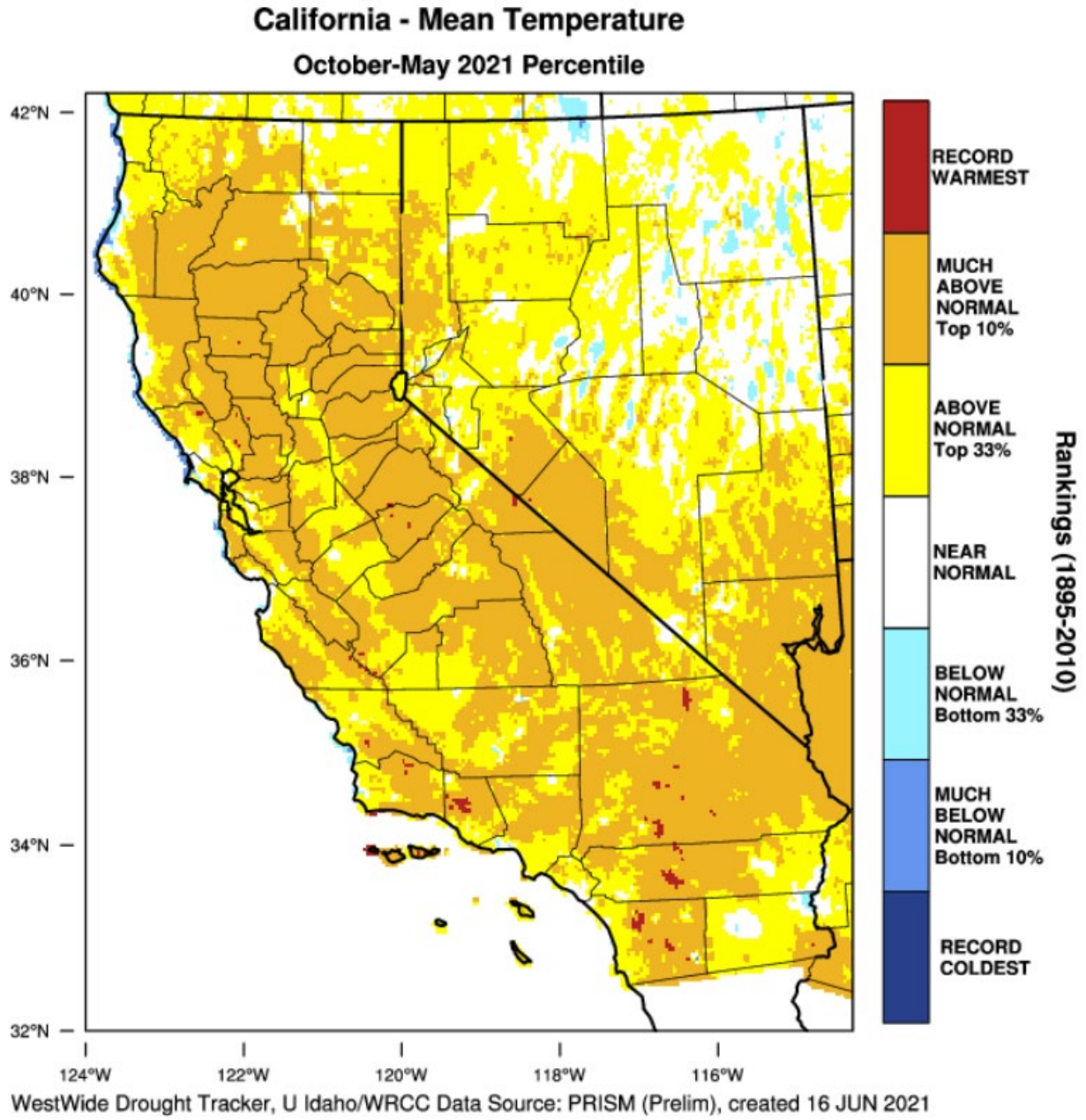

Figure 4. California temperature percentiles for WY2021 as of June 2021 compared to a period of record of 1895 – 2010. Source: https://wrcc.dri.edu/wwdt/index.php?region=ca

General Water Year Conditions and Operations

Shasta County yielded below normal or less precipitation in WY 2021 to date as compared to a period of record 1895-2010 (Abatzoglou et al. 2021) (data from 2011 through present was not readily available). In general, storage conditions in Shasta Lake were low in the fall of 2020 as a result of dry hydrologic conditions the previous year. In WY 2021, storage conditions in Shasta Lake did not exceed the elevations at which the U.S. Army Corps of Engineers would require flood management, and therefore Keswick Dam releases were not necessary for flood control purposes.

The rain gauge at Shasta Dam (SHA) received the greatest amount of precipitation in WY 2021 in January with 8.0 inches. February is typically one of the most productive runoff months into Shasta Lake. However, in WY 2021, gauges measured only 3.6 inches of precipitation and inflows to Shasta Lake declined thereafter. Precipitation in March recovered some moisture in the system but fell short to make up for the lack of prior storm events; 0.5 inches of precipitation fell in April. The rain gauge at Shasta Dam reported a total of 23.7 inches for WY 2021 (as of May 2021), which is less precipitation than other recent critically dry years (WY 2014: 33.8 inches; WY 2015: 51.9 inches). Precipitation for the Northern Sierra Eight Station Index for WY 2021 compared to the average is shown in Figure 5.

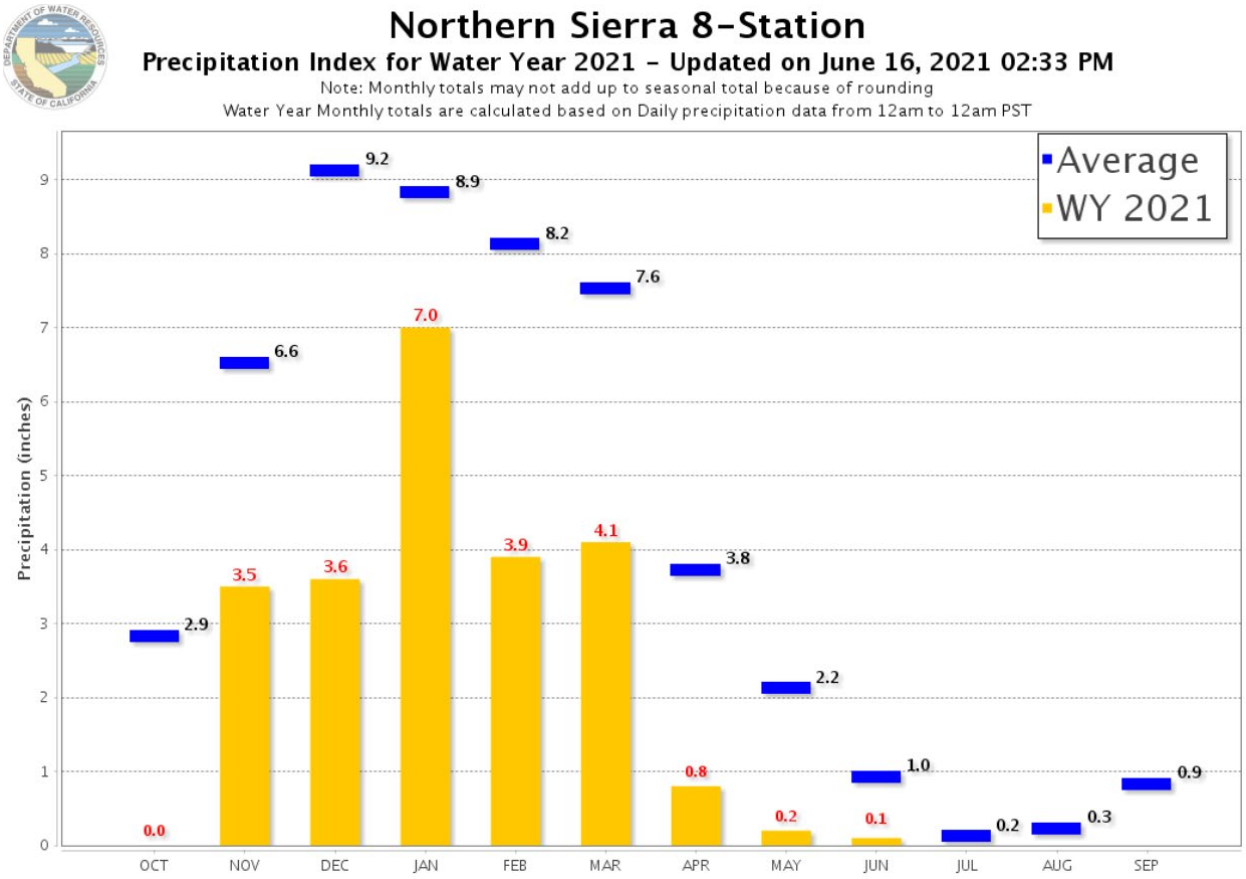

Figure 5. Precipitation for WY 2021 compared to the average for the Northern Sierra Eight Station Index as of June 2021.

Snowpack for the Sacramento River region was poor, and reflected in an area wide snow water equivalent of 21.5 inches, based on the April DWR B-120. The Sacramento Eight Station Index for WY 2021 reported 22.9 inches of precipitation for the region (as of May 2021). As of May 2021, WY 2021 is the driest on record since 1977. Although WY 2021 received well below average rainfall, the snowpack in March 2021 indicated significantly higher expected runoff; conditions significantly changed at the end of April 2021 when it became clear that expected reservoir inflow from snowmelt did not materialize. The May 90 percent exceedance forecast for WY 2021 Sacramento Valley Four River Index identified a reduction of expected runoff of 685 TAF from those generated only a month earlier in April. The total expected inflow into Shasta Lake reduced by 290 TAF between April and May. Water supply indices reported the Sacramento River Unimpaired Runoff was a "Critical" year for the Sacramento Valley Index (DWR 2021a).

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, 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, water temperature management capabilities, and others. In addition, uncertain or unplanned events can also influence real-time operation decisions (e.g., wildfire events, or reservoir release reductions for USACE downstream flood protection). Planned operational targets are regularly updated on Reclamation's website (https://www.usbr.gov/mp/cvo/) late winter through early summer, depending on hydrologic conditions.

Hydrologic Conditions

Watershed runoff in the upper Sacramento River basin is typically dominated by winter precipitation that refills and replenishes both Shasta Lake's total storage and the cold water pool. The runoff is quantified as late spring through summer (April through July) inflow volume. The Sacramento River watershed basin runoff forecasted inflow volume and its quality (i.e., water temperature) are fundamental to operational planning. The inflow volume projection is updated routinely by DWR and the National Weather Service-California Nevada River Forecast Center (CNRFC), where uncertainty is represented by percent runoff exceedances (Figure 6). By May 1, water supply forecasts for Shasta Lake inflow runoff ranged between 40 percent and 41 percent of the average for the 90 percent and 50 percent runoff exceedances, respectively (DWR 2021b).

Table 2 provides insight to the hydrologic characteristics of WY 2021. Because operational planning is significantly influenced by future forecasts, these uncertainties and modified decisions are translated into the performance and efficiency of the system-wide operation.

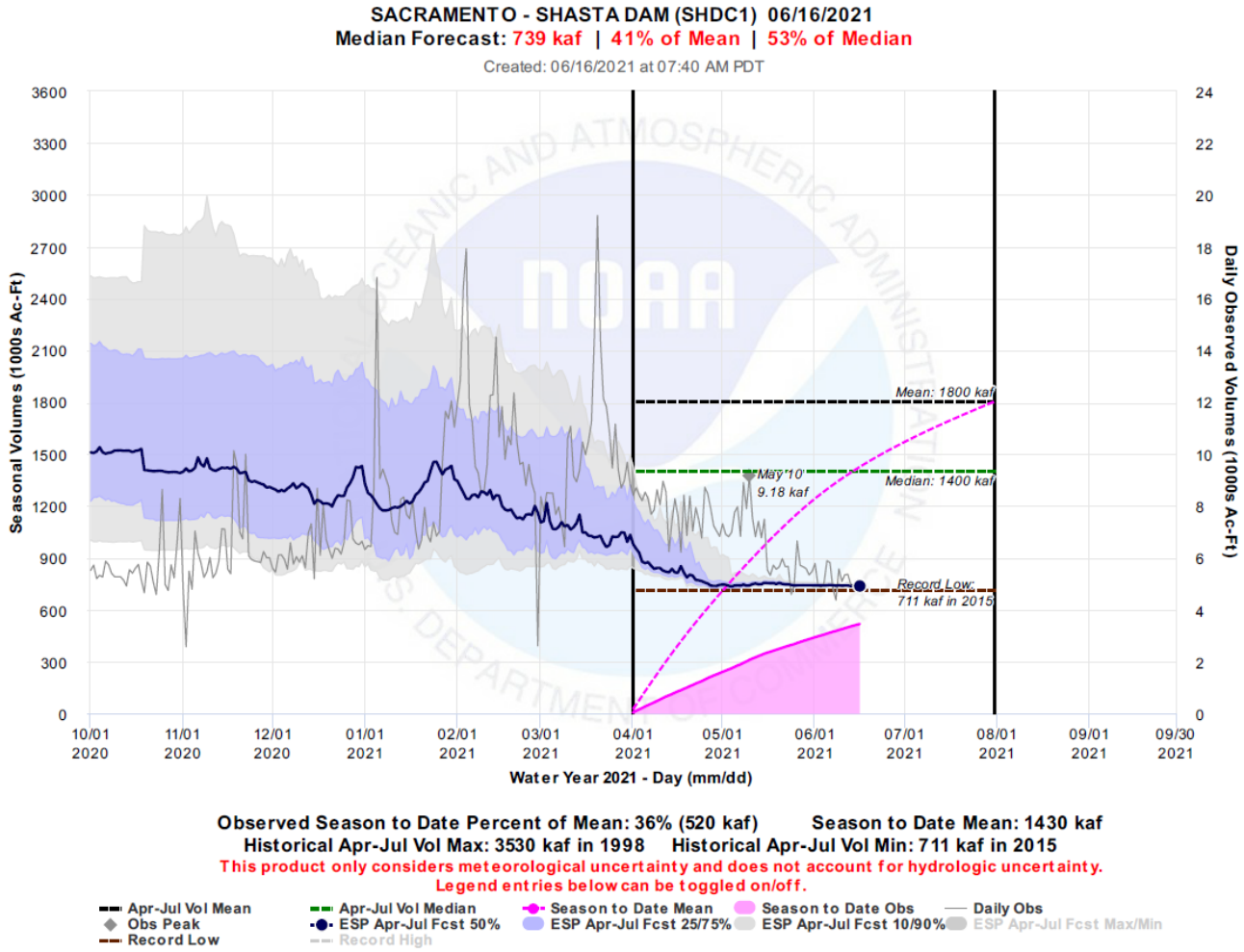

Figure 6. WY 2021 forecasted (10 percent, 50 percent, 90 percent exceedance) and actual daily and cumulative inflow volume at Shasta Lake. Source: https://www.cnrfc.noaa.gov/water_resources_update.php

Table 2. WY 2021 Northern Sierra precipitation, Sacramento Basin snowpack, and Sacramento Valley Index statistics by month.

Water Year 2021 Month[1]	Northern Sierra 8-Station Precipitation (Cumulative water year in inches through month)	Northern Sierra 8-Station percentage of historic monthly average precipitation (for month)	Sacramento River Basin Snowpack (percent of April 1st average)	Sacramento Valley Index (40-30-30 Index 50 percent Exceedance)
November	3.5	53	N/A	N/A
December	7.1	39	N/A	5.9
January	14.1	78	31	5.3
February	18.0	47	45	5.0
March	22.1	53	70	4.6
April	22.9	21	75	4.4
May	23.1	9	20	4.0

[1] Monthly totals may not add up to seasonal total because of rounding

Key Events/Decisions

The key events and decisions that influenced the WY 2021 Fall and Winter Refill and Redd Maintenance action and the Spring Pulse Flow action include:

- Fall Keswick Dam Release – Rice Decomposition Smoothing: USST members and SRSC coordinated fall Keswick Dam releases to manage downstream delivery demand and fishery protection. By coordinating delivery of water required for rice decomposition in the fall, managers discouraged fall-run Chinook salmon from spawning at higher flow rates, thus reducing the potential to dewater redds once the water demand for rice decomposition has been met. This coordinated effort was an attempt to meet multi-objective purposes in the system while continuing to minimize fishery impacts. Objectives and decision points from the USST are shown in Table 3; minimum flow requirements at Wilkins Slough are shown in Table 4. The majority of the rice decomposition efforts occurred in October 2020; a timeseries graphic of average weekly SRSC scheduled depletions under normal contract deliveries compared with scheduled depletions under modified contract deliveries are shown in Figure 12.
- Flood Risk and USACE Flood Control Space Operations: Winter flood risk was not elevated due to low Shasta Lake storage conditions during WY2021.

- Storms: While there was refill potential in Shasta Lake afforded by the USACE flood control curve, January through May 2021 yielded few storm events offering little chance for Shasta Lake refill.
- Shasta Storage: By late March 2021, prior to agricultural demands/diversions, total Shasta Lake storage volume did not recover and refill as a result of very dry hydrology and low inflow volumes. In addition, May 1 storage in Shasta Lake was 2.28 MAF, approximately 58 percent of the average.
- Water Transfer: In response to the critically dry conditions in California's Central Valley, and as done in 2014 and 2015, the SRSC propose to enter into forbearance agreements to make available a portion of their Base Supply to purchasers in other areas of the CVP. This action would reduce the required releases from Shasta Lake in the summer to satisfy senior water rights and would instead provide for releases for delivery in the late summer and early fall of 2021. The additional spring and summer reservoir storage would support colder water temperatures downstream for winter-run Chinook salmon egg incubation. These transfers require approval from Reclamation which includes verifying the water made available, agreeing to temporarily store this water in Shasta Lake, and then increasing releases from Shasta for delivery later in the summer and early fall.
- Shasta Power Bypass and Shasta Temperature Control Device: The Temperature Control Device (TCD) on Shasta Dam draws water from different elevations in the lake, allowing Reclamation to use warmer surface water earlier in the season and preserve cold water for the temperature management season later in the year, while maintaining hydropower generation. The dry conditions and low reservoir storage this year prevented pulling water into the TCD from the highest elevations in the reservoir and therefore only the middle gates were available to use in the spring. Using these lower-elevation middle gates would have pulled the limited cold water earlier, leaving less cold water for the summer and fall releases. Beginning April 18, 2021, Reclamation began partially bypassing power generation at Shasta Dam to draw water through river outlets higher on the face of the dam than the elevation of the middle gates of the TCD. This action ended on May 25, 2021. This action preserved approximately 300 TAF of cold water for later in the year. The power bypass action resulted in a reduction in power value by approximately $5 million. Preliminary modeling showed the Water Transfer action and the Shasta Power Bypass action would extend the window of lower temperatures by an additional ~2-4 weeks and lower temperature dependent egg mortality of winter-run Chinook salmon by approximately 5-10 percent depending on the final Temperature Management Plan. Additional information regarding survival estimates will be reported in the 2021 Shasta Cold Water Pool Seasonal Report.
- Spring Pulse Flow Determination: As of early April 2021, per the Spring Pulse Flow criteria adopted in the ROD, since the projected and actual May 1 storage of Shasta Lake was less than 4 MAF (indicating insufficient cold water pool for Tier 1), a Spring Pulse flow was not pursued in order to protect the cold water pool and water temperature management performance for the 2021 season.

Table 3. Objectives and Decision Points for Fall Flow Reduction from the USST in WY 2021.

Week (2020-2021)	Decision Points	Temperature Management (control at end of season)	Fisheries Objectives/ Interests & Timing	Water Users, Bird, Refuge Diversion Interest & Timing	Agricultural & Regulatory
8/1–8/23	N/A	N/A	N/A	N/A	N/A
8/24–8/31	N/A	N/A	9 dewatered redds	N/A	N/A
9/1–9/7	N/A	N/A	Winter-run redds protection: flows to cover shallow water redds	Flows for refuge habitat, bird habitat	N/A
9/8–9/15	N/A	N/A	Winter-run redds protection: flows to cover shallow water redds	Flows for refuge habitat, bird habitat	SRSC starts panning with growers
9/16–9/23	Decision point at flow reduction: 7,500-6,000- cfs	N/A	Winter-run redds protection: flows to cover shallow water redds	Flows for refuge habitat, bird habitat	N/A
9/24–9/30	N/A	Decision point for temperature management	Winter-run redds protection: flows to cover shallow water redds	Flows for refuge habitat, bird habitat	N/A
10/1–10/7	N/A	N/A	N/A	N/A	Delayed harvest for upstream Sacramento River growers due to smoke
10/8–10/15	N/A	N/A	N/A	Rice decomposition Flows – diversion flows for habitat, refuge, and fish food generation	Harvest for downstream Sacramento River growers
10/16–10/23	N/A	N/A	N/A	Rice decomposition Flows – diversion flows for habitat, refuge, and fish food generation	N/A
10/24–10/31	N/A	10/31/2020: End of temperature management season	Peak fall-run Chinook spawning: low flows as close as possible to winter base flows	Rice decomposition Flows – diversion flows for habitat, refuge, and fish food generation	N/A
11/1–11/7	N/A	N/A	Peak fall-run Chinook spawning: low flows as	Rice decomposition Flows – diversion flows for habitat,	Reclamation water rights cover SRSC diversions

Week (2020-2021)	Decision Points	Temperature Management (control at end of season)	Fisheries Objectives/ Interests & Timing	Water Users, Bird, Refuge Diversion Interest & Timing	Agricultural & Regulatory
			close as possible to winter base flows	refuge, and fish food generation	
11/8–11/15	N/A	N/A	Peak fall-run Chinook spawning: low flows as close as possible to winter base flows	Rice decomposition Flows – diversion flows for habitat, refuge, and fish food generation	N/A
11/16–11/23	N/A	N/A	Peak fall-run Chinook spawning: low flows as close as possible to winter base flows	Rice decomposition Flows – diversion flows for habitat, refuge, and fish food generation	N/A
11/24–11/30	N/A	N/A	Peak fall-run Chinook spawning: low flows as close as possible to winter base flows	Rice decomposition Flows – diversion flows for habitat, refuge, and fish food generation	N/A
12/1–12/7	N/A	N/A	Winter Base Flows	N/A	N/A
12/8–12/15	N/A	N/A	Winter Base Flows	N/A	N/A
12/16-12/23	N/A	N/A	Winter Base Flows	N/A	N/A
12/14-12/31	N/A	N/A	Winter Base Flows	N/A	N/A
1/1-1/31	N/A	N/A	N/A	N/A	N/A

Table 4. Minimum flow necessary at Wilkins Slough to meet Delta requirements and for SRSC facilities operations.

Week	Wilkins Slough minimum to meet Delta Requirements	Wilkins Slough SRSC minimum for facilities operation
08/01/2020 – 09/30/2020	4,000	4,000
10/01/2020 – 10/07/2020	5,100	4,000
10/08/2020 – 10/15/2020	4,400	4,000
10/16/2020 – 10/31/2020	4,000	4,000
11/01/2020 – 11/07/2020	5,750	4,000
11/08/2020 – 11/15/2020	4,775	4,000
11/16/2020 – 11/30/2020	4,750	4,000
12/01/2020 – 12/07/2020	4,600	4,000
12/08/2020 – 12/31/2020	4,250	4,000
01/01/2021 – 01/31/2021	5,250	4,000

Table 5. Historical Shasta Lake Storage Volumes and Cold Water Pool Volumes in Thousands of Acre Feet (TAF).

Water Year	Peak Storage Volume	Peak Storage Date	End of April Volume < 56°F	Date 1st Side Gate Opened	End of September Volume Storage	End of September Volume < 56°F	End of September Volume < 52°F	End of September Volume < 50°F
2010	4507	05/22	3771	09/17	3319	1216	744	516
2011	4492	06/02	3809	N/A	3341	1340	903	707
2012	4483	05/07	3791	09/21	2592	765	598	512
2013	3887	04/18	2809	09/11	1906	425	347	309
2014	2409	04/28	1770	08/07	1157	107	81	63
2015	2722	04/15	1912	09/13	1603	358	270	228
2016	4235	05/01	3267	10/23	2811	938	730	596
2017	4389	05/13	3975	N/A	3382	1146	806	594
2018	4200	04/26	3135	09/19	2405	607	485	388
2019	4477	05/31	3441	N/A	3425	1203	907	707
2020	3750	04/21	2986	08/13	2200	476	344	230
2021	2396	04/03	1581	N/A	N/A	N/A	N/A	N/A

Storage and Flood Conservation Space

Shasta Lake storage was not controlled by USACE flood reservation space requirements in late fall and early winter and therefore Keswick Dam releases were decreased to increase storage (Figure 7 and Figure 8). Due to very dry hydrology following December 2020, Shasta Lake did not refill, and May 1 storage was 2.28 MAF. Compared to other critically dry water years (2008, 2014, 2015), WY 2021 had higher storage volumes until early January (Figure 9). Further, compared to average critically dry water years (2008, 2014, 2015), Keswick Dam releases were below average from approximately mid-October until January 2021 (Figure 10).

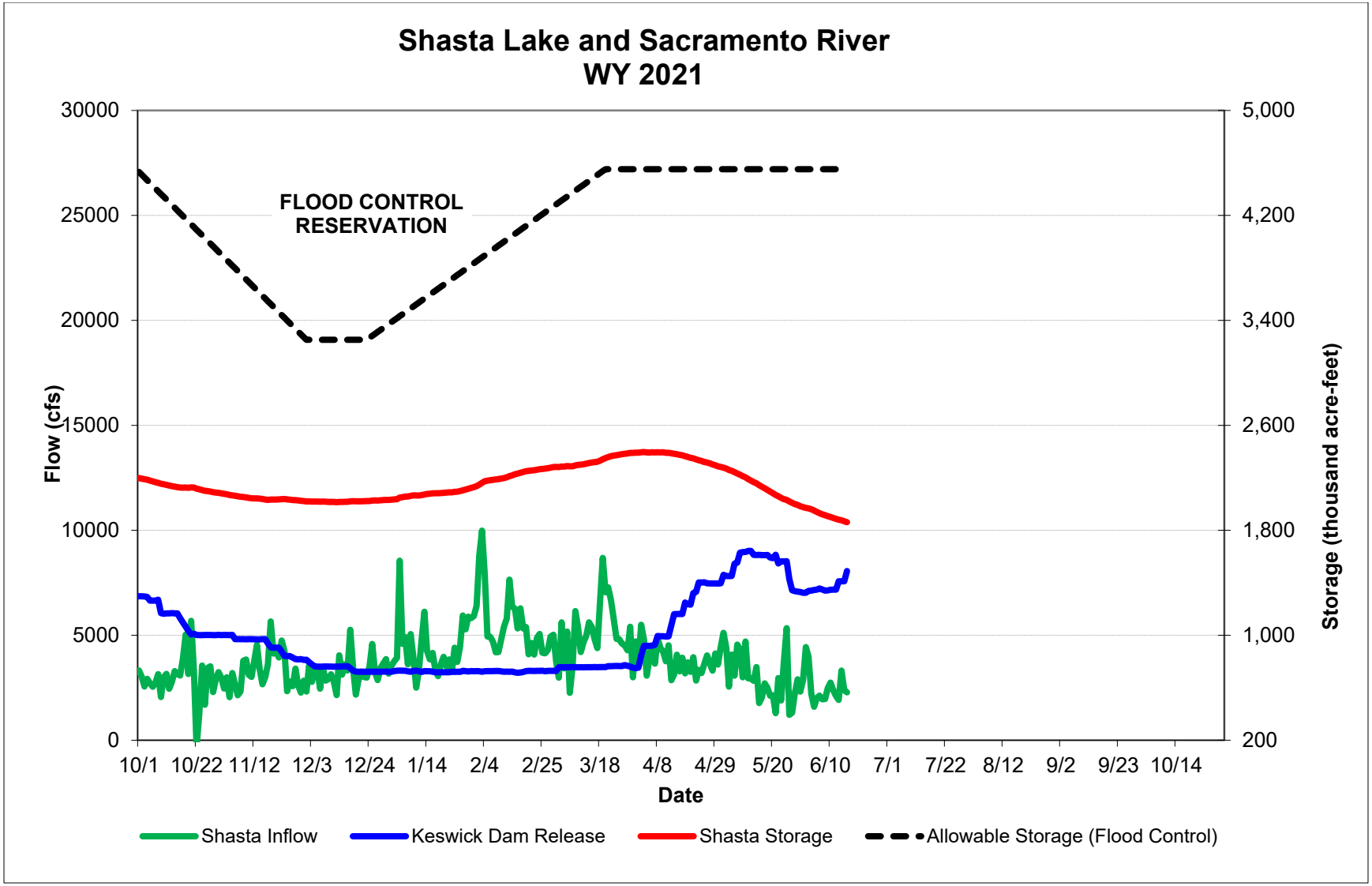

Figure 7. Shasta Lake Storage (red line), Allowable Storage for Flood Control (black line), Keswick Dam Release (blue line), and Shasta Inflow (green line) for 10/1/2020 – 6/16/2021.

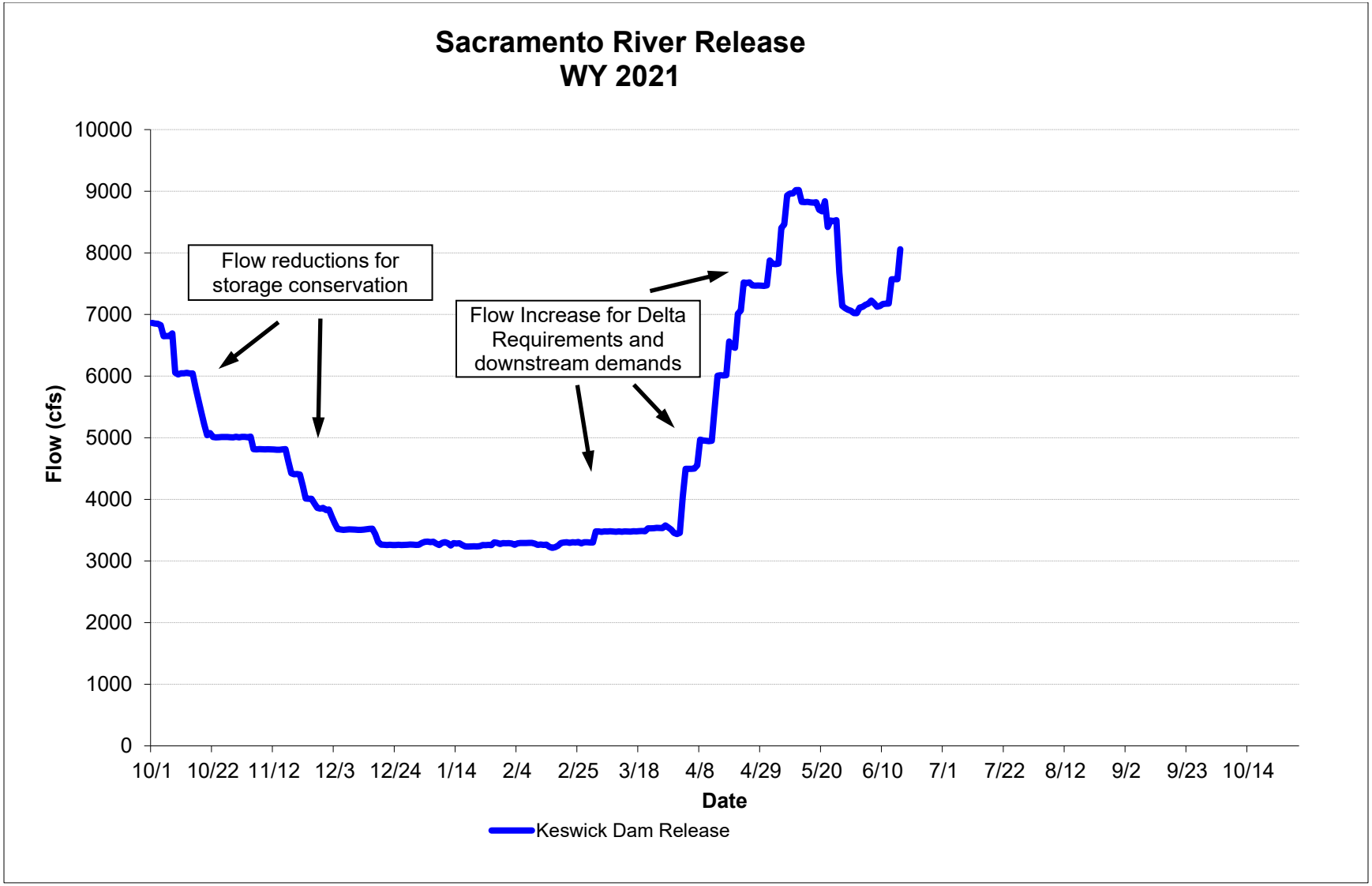

Figure 8. Sacramento River Releases from 10/1/2020 – 6/16/2021 with major events highlighte

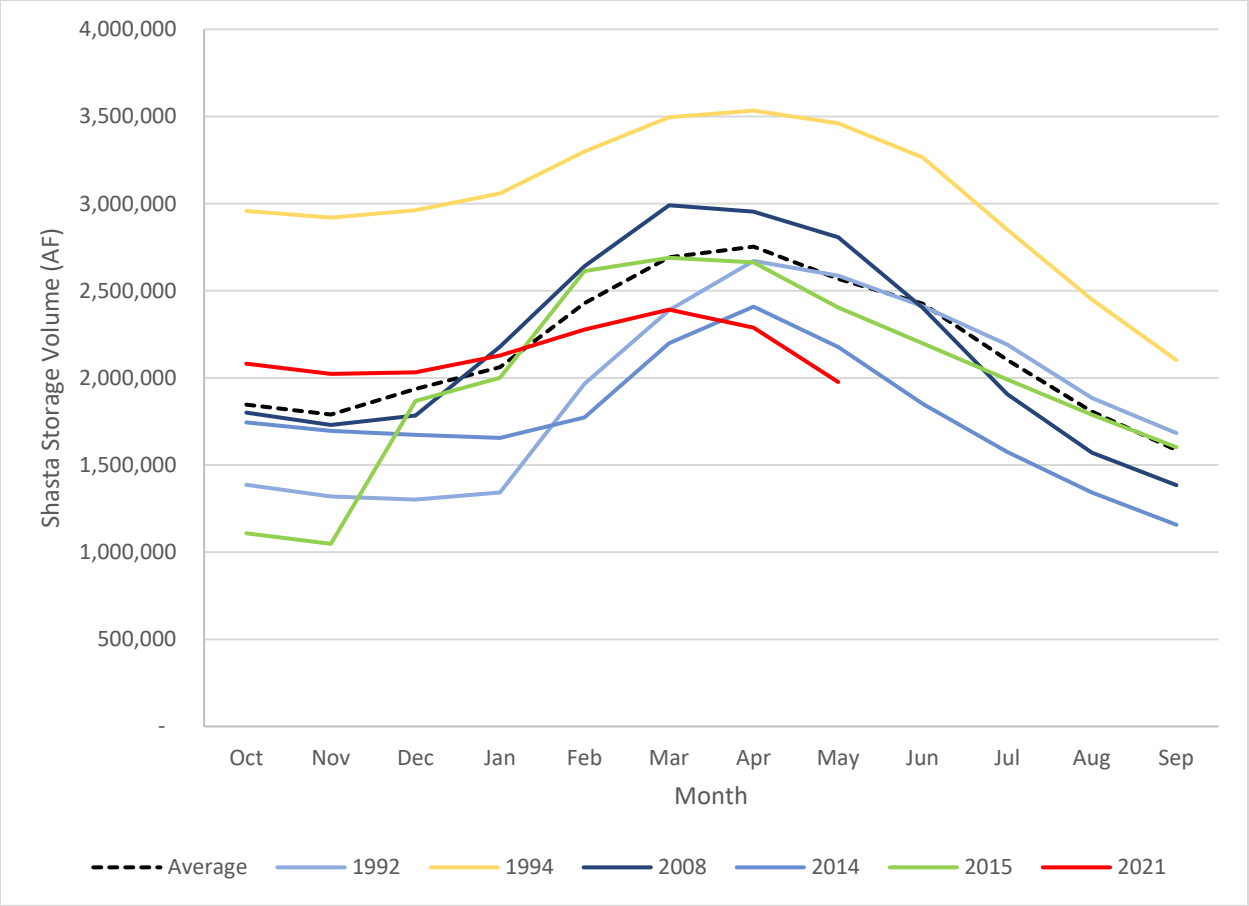

Figure 9. Historical Shasta Lake storage and WY 2021 for critically dry water year types since WY 1992.

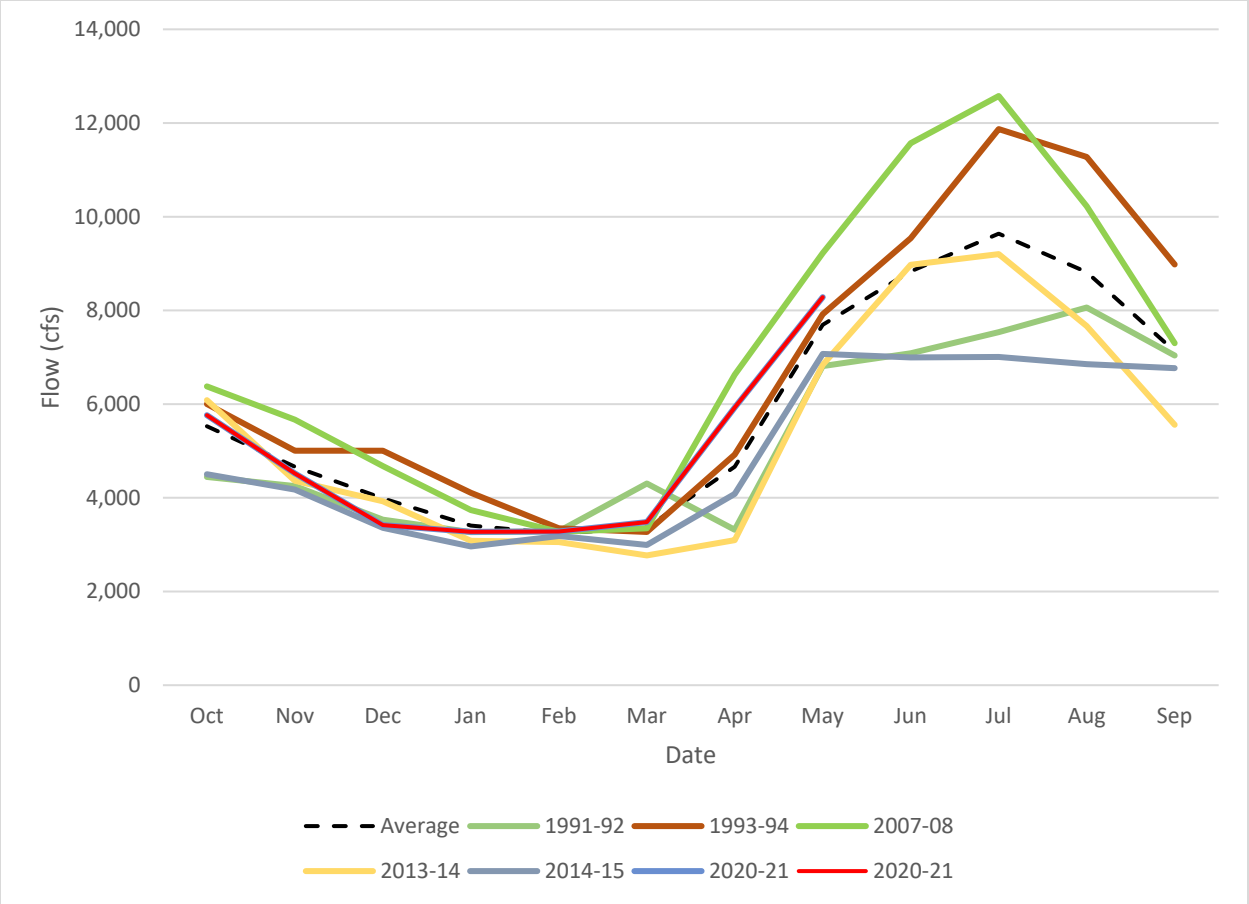

Figure 10. Keswick Dam historical monthly average releases and WY 2021 for critically dry water year types since WY 1992.

Fall and Winter Refill and Redd Maintenance

The USST was a new team developed under the ROD and included membership from Reclamation, DWR, NMFS, CDFW, Sacramento Central Valley Project Contractors and the SRSCs. The USST is intended to assist in planning in the fall and winter for Shasta Lake refill, redd dewatering minimization, and rice decomposition smoothing, and in the spring for spring pulse flow operations. Meetings were held approximately weekly to consider near real-time fisheries monitoring data shared by technical staff from USFWS, NMFS, CDFW, and field technicians from the Pacific States Marine Fisheries Commission (PSMFC). Using these data, the USST proposed various fall Keswick flow schedules for Reclamation's consideration. These flows were crafted to protect winter-run Chinook salmon eggs and juveniles, and develop a fall-run Chinook salmon redd maintenance flow schedule based on August and September hydrologic and Shasta Dam storage forecasts, known numbers of winter-run Chinook salmon redds dewatered by flow actions, and estimates of winter-run and fall-run Chinook salmon redd dewatering resulting from future flow reductions. The USST input these flow alternatives and monitoring data into a flow planning tool that was updated regularly based on new information.

The meeting notes are posted at following link: https://www.usbr.gov/mp/bdo/sacramento-river-temperature-task-group.html

2020 Fall Flow Reduction Coordination Interests identified by USST participants included the following:

Salmon

1. Minimize impacts to spring-run and fall-run Chinook salmon redds in the "impact reach" (roughly from Keswick Dam to the Cow Creek confluence or RM 302 to 280)
2. Minimize juvenile winter-run Chinook salmon stranding in the impact reach
3. Determine winter-run Chinook salmon spawning flows stabilization
4. Protect early fall-run Chinook salmon spawning in late October/early November (redds covered under winter-base flow conditions)
5. Avoid dewatering winter-run Chinook salmon redds in late October/early November
6. Limit Incidental Take of salmon (less than 1 percent of redds based on the population estimate)
7. Manage water temperatures to support survival, spawning, and rearing of Chinook salmon
8. Restore instream habitat

Water & Fish

1. Flood Releases
2. Subsequent Year Management Flexibility and Capacity (Rebuild the Cold-water Pool for Subsequent Year)
3. Coordinated communication with the public

Agriculture

1. Predictability of water deliveries for rice decomposition
2. Water deliveries for pacific flyway needs
3. Water deliveries for fish foodweb
4. Wilkins Slough Flow Standard

Delta

1. Delta Conditions/X2 action

August

The USST first met on August 14, 2020 to: (1) establish a shared understanding of USST objectives, membership, process, and schedule; (2) understand parties' interests and needs for the USST; and (3) develop an understanding of the guidance document. On August 18, 2020, Reclamation shared the initial rice decomposition flow proposal and solicited feedback on the flow planning tool. The USST discussed their interests and uncertainties with assessing incidental take of winter-run Chinook salmon redds.

The 90 percent and 50 percent exceedance forecasts suggested continually dry and warm conditions. Reclamation began fall flow reductions to conserve Shasta Reservoir storage for the next summer. Trade-offs were carefully considered between winter-run Chinook salmon redd dewatering, fall-run Chinook salmon redd dewatering, and Shasta Lake storage volume. Keswick Dam releases in early August were approximately 11,000 cfs and were reduced each week. From August 24, 2020 – August 31, 2020, Keswick Dam releases ranged from approximately 8,700 – 7,500 cfs.

September

Reclamation provided 90 percent and 50 percent exceedance forecasts suggesting continually dry and warm conditions. The projected Keswick Dam release for the first week of September was 7,500 cfs; however, it was reduced on September 7, 2020 to approximately 7,000 cfs and remained there through mid-September. On September 8, 2020, there was a decision point to reduce releases from 7,000 cfs to 6,600 cfs. Actual operations were reduced from 7,000 cfs to 6,800 cfs due to a mechanical issue with the metering system at the Reclamation facility shortly after the change order was issued. Keswick Dam releases remained at approximately 6,800 cfs for the remainder of September.

In early September, Reclamation provided to the USST an overview of the different alternatives for flow reductions in Keswick Dam releases to minimize dewatering of redds (Alternatives 1, 2, 3, 4, 4a, 5, and the SRSC proposal/Alternative 6). Appendix C includes the proposed Keswick Dam releases for alternatives as of September 30, 2020.

Reclamation calculated the cumulative redds dewatered for each alternative over time. Tradeoffs exist for each alternative; for example, Alternative 4a had the lowest predicted cumulative redds dewatered through October but also had the highest flows which could affect fall-run Chinook salmon redd dewatering and water temperature management in October.

Reclamation continued to refine potential flow reduction schedules by utilizing real-time fisheries monitoring data. By mid-September, Reclamation had identified Alternative 2a and 4a as the most favorable alternatives. Alternative 2a would dewater 10.4 percent of fall-run Chinook salmon redds while Alternative 4a would dewater one more fall-run Chinook salmon redd than Alternative 2a. Because Alterative 2a required approximately double the release volume of Alternative 4a, the USST agreed to move forward with the proposed Alternative 4a schedule.

By the end of September, the USST further refined the flow reduction schedule alternatives for consideration to include only Alternatives 1, 4d, and 6a (Figure 11). Alternative 1 was based on a longer-term outlook forecast. Alternative 4d combined several characteristics of previous Alternative 4s – previous versions contained flow projections at Wilkins Slough below 4,000 cfs in October, which is a concern to meeting Delta requirements and for operations of SRSC facilities. Alternative 4d had a slightly different flow pattern with similar depletions and accretions to Alternative 1 and maintains Wilkins Slough flows in late October at 4,000 cfs. Alternative 6a held flows higher initially and then dropped flows more rapidly in mid-October. This alternative contained different depletion numbers than other alternatives and implemented smoothing. After the September 30, 2020 USST meeting, WOMT discussed the tradeoffs and the agencies agreed on proceeding with implementation of Alternative 6a.

Reclamation coordinated water deliveries with the SRSC as Alternative 6a was selected in order to deliver contracted water in November. In September, the SRSCs began coordinating with landowners on rice decomposition smoothing activities. In the fall, the growers divert most of the water after harvesting; harvesting was delayed in 2020 due to smoke from fires. Smoke slows down a crop's maturity and pushed back harvest 1-2 weeks. Water cannot be used until after the bulk of the rice harvest is done.

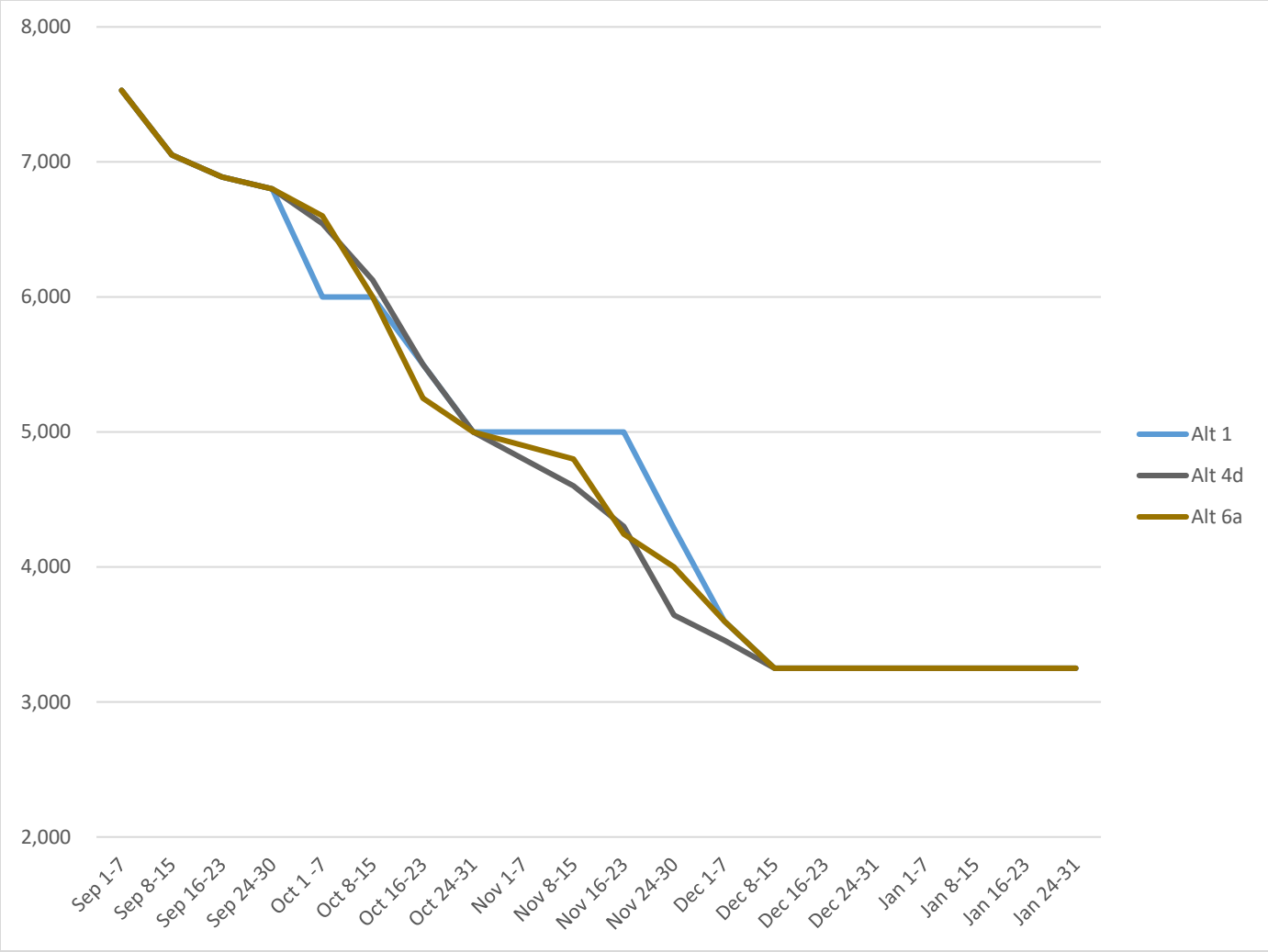

Figure 11. Flow reduction scenario comparison for Alternatives 1, 4d, and 6a.

October

The USST met weekly in October 2020. Forecasts suggested dry conditions and above average temperatures at the beginning of the month, with some opportunity for cooling and precipitation in mid-to-late October.

Alternative 6a was the agreed upon flow reduction schedule. Flows in the first week of October ranged from approximately 6,800 cfs to 6,600 cfs with a water temperature target of 56°F at the Clear Creek gauge. Reclamation implemented a flow reduction to 6,000 cfs during the week of October 8, 2020- October 15, 2020. The USST agreed to a flow reduction to occur on October 9, 2020 and coordinated with CDFW and PSMFC field crews to measure impacts of the flow reduction on remaining redds. Since the Keswick flow was at 6,000 cfs, flow cuts did not exceed 200 cfs per day and 100 cfs per hour per ramping rates. On October 16, 2020, flows were reduced approximately 200 cfs per day until 5,000 cfs was reached on October 20, 2020; flows remained at approximately 5,000 cfs for the remainder of the month.

The peak spawning time for fall-run Chinook salmon is estimated to be in the second and third week of October; October is a critical month for fall-run Chinook redd construction. The last shallow water winter-run Chinook salmon redd was estimated to emerge on October 30, 2020. In addition to fisheries monitoring and concerns, additional operational constraints included the downstream outflow requirement of maintaining 4,000 cfs in the Sacramento River at Rio Vista in October, and maintaining a minimum flow of 4,000 cfs at Wilkins Slough for proper functioning of SRSC diversion facilities.

SRSC and Reclamation coordinated on contract delivery modifications and finalized plans for depletions in October. Average weekly SRSC scheduled depletions under normal contract deliveries and modified contract deliveries are shown in Figure 12. The largest reductions in water contracts occurred in the second half of October, where the daily average depletion flow was reduced by approximately 950 cfs per day.

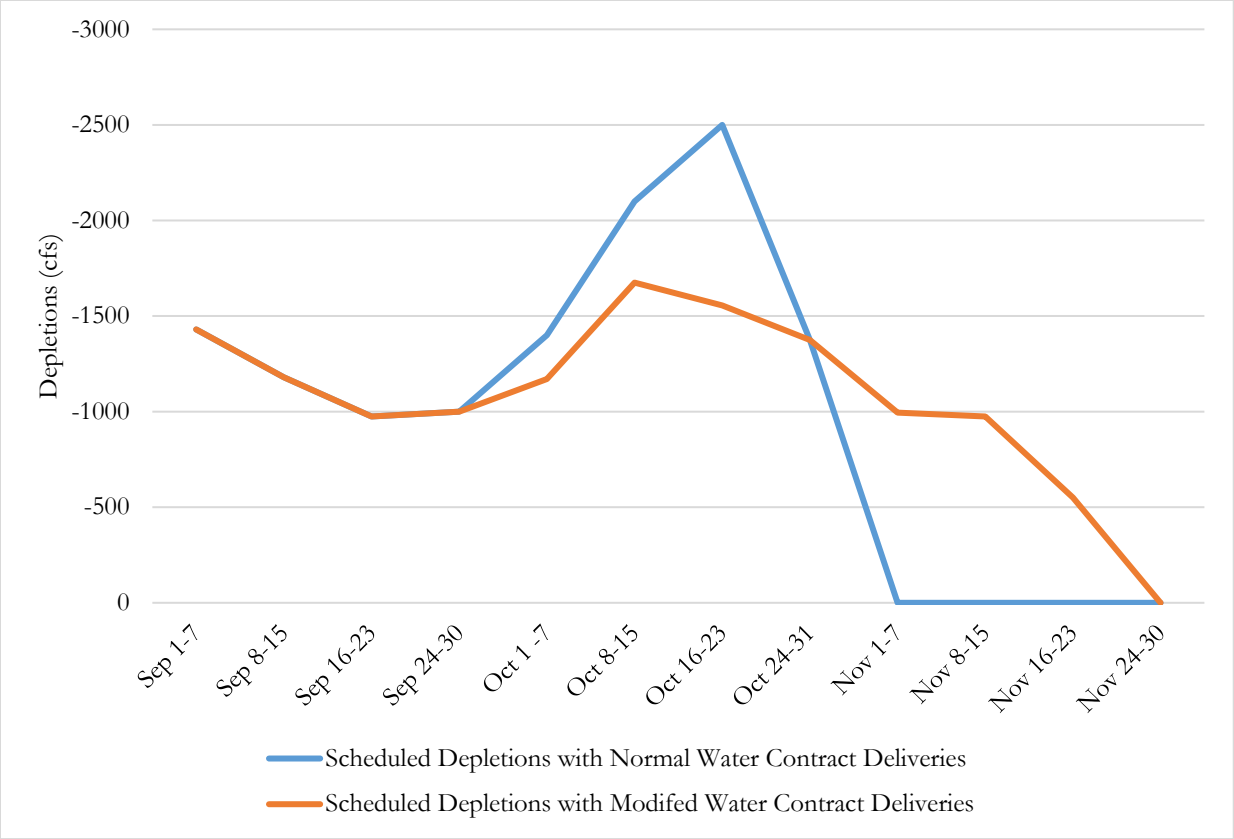

Figure 12. Rice decomposition smoothing effort in fall 2020; average weekly SRSC scheduled depletions with normal water contract deliveries (blue) and scheduled depletions with modified contract deliveries (orange).

November through April

Dry hydrology in November did not afford opportunities for Shasta Lake refill and the end of November storage in Shasta Lake was 2.02 MAF. Reclamation continued implementing the Alternative 6a flow reduction schedule. Keswick Dam releases were decreased to 4,800 cfs

during the first week of November and remained there through mid-November. Keswick Dam releases began to be ramped down for storage conservation in mid- November, and by the end of the month, the flow release was 3,800 cfs. ACID Dam removal was completed on November 12, 2020.

Dry hydrology continued into December and though there was intermittent precipitation towards the end of the month, this did not add significant gains to storage. End of December Shasta Lake storage was 2.03 MAF. Keswick Dam releases continued to decrease through mid-December when minimum releases (approximately 3,250 cfs) were met and maintained for the duration of the month.

January had wetter hydrology compared to previous months, and Keswick Dam releases were maintained at the minimum release requirement (3,250 cfs) for the entire month. This allowed for more opportunities to refill, and end of January storage had increased slightly to 2.11 MAF. February also maintained the minimum releases requirement (3,250 cfs) and end of February storage was 2.27 MAF.

Keswick Dam releases increased in March and April to meet Delta requirements. Combined with some precipitation, modest storage gains were achieved (end of March storage was 2.39 MAF; end of April storage was 2.29 MAF).

Spring Pulse Flows

The USST met frequently to discuss spring pulse flows. The meeting notes are posted at the following link: https://www.usbr.gov/mp/bdo/sacramento-river-temperature-task-group.html. A Pulse Flow Study Plan (Appendix D) was finalized in February 2021. The Pulse Flow Study Plan is designed to plan and monitor an annual pulse flow on the Sacramento River during 2021-2025. The USST developed this Study Plan to improve collaborative implementation of Spring Pulse Flows included in the 2020 ROD. USST technical staff have designed a multi-year study to evaluate the potential survival benefits for juvenile spring-run Chinook salmon and fall-run Chinook salmon during a managed spring pulse flow on the Sacramento River. Other work teams involved in the multi-year study will include, but not be limited to, the SRTTG and WOMT.

A framework/process for evaluating a series of pulse flow scenarios has been developed with the following parameters manipulated in the proposed pulse flow scenarios:

- Pulse frequency: 1 or 2 pulses
- Release timing: April, May, or April and May
- Pulse duration: 2, 3, or 4 days
- Pulse magnitude (at Wilkins Slough): 10,000 cfs or 10,800 cfs
- Pulse rate of change: Keswick downramping rates
- Quantity of water: up to 150 TAF

The impact of each pulse flow scenario on multiple key variables will be assessed to help with scenario selection process. This assessment includes the following variables: water use, Shasta Lake cold water pool, winter-run Chinook salmon temperature-dependent egg mortality, and outmigrating juvenile Chinook salmon travel time and survival rates. Annually, scenario selection for the Pulse

Flow Operations Plan will be iterative in nature during the later winter and early spring months. For details on the tasks associated by month, please see Appendix D.

February

The USST identified a subset of scenarios based on review of Reclamation's monthly operations forecasts. The 90 percent forecast was used to evaluate the May 1 Shasta Lake storage.

March

The USST used the Pulse Flow Study Plan to identify the pulse flow scenarios most likely to be achievable based on current conditions described by the monthly reservoir temperature measurements and modeling. Based on the March 90 percent forecast, May 1 Shasta Lake storage was predicted to be 2.38 MAF. The forecast indicated that none of the Study Plan's pulse flow scenarios for spring of 2021 were likely to provide sufficient cold water to support summer cold water pool management due to Shasta Lake storage volume of less than 4 MAF. Reclamation could also determine, in coordination with the USST, that while the reservoir is less than 4 MAF, there is sufficient water to do a pulse flow of up to 150 TAF; however, this was not the case in March 2021. Even though a spring pulse flow was not likely to occur the USST still developed a Pulse Flow Operation Plan for the months of both March and April (Appendix E) to document their reasoning and to ensure the Fish Monitoring Plan (Appendix F) was still implemented.

April

Based on the April 90 percent forecast, May 1 Shasta Reservoir storage was predicted to be 2.34 MAF. The forecasts indicated that none of the Study Plan's pulse flow scenarios for spring of 2021 were likely to provide sufficient cold water to support summer cold water pool management due to a Shasta Lake storage volume of less than 4 MAF. Although in some instances when Shasta Lake is less than 4 MAF, Reclamation, in coordination with the USST, potentially could determine that there is sufficient water to do a pulse flow of up to 150 TAF this was not the case in April 2021. No further pulse flow analyses, cold water pool modeling, or temperature dependent egg mortality modeling was conducted as a spring pulse flow action was not being considered. During the week of April 26, 2020, the first release group of spring-run Chinook salmon from the Feather River Fish Hatchery was tagged and released to evaluate environmental and fish variables (survival, travel time).

May

USST did not provide an updated May Pulse Operations Plan document to SRTTG as hydrology did not improve to implement a spring pulse flow action in WY 2021. During the weeks of April 26th and May 10th, two release groups of hatchery-origin fall-run Chinook salmon were tagged and released at Red Bluff Diversion Dam to evaluate environmental and fish variables (survival, travel time). Fish variables (survival and movement) of released acoustic-tagged spring-run Chinook salmon, in conjunction with environmental variables, will be evaluated to provide baseline conditions for comparison to future years. Preliminary results are found on the CalFishTrack Central Valley Enhanced Acoustic Tagging Project website (not enough detections as of 5/19/2021 to estimate minimum survival to Benicia Bridge East Span or minimum through-Delta survival). Collection of environmental and fish variables will be implemented annually regardless of a pulse flow action. Data collected in non-pulse action years (e.g., dry years with no action, average years with natural pulse events, wet years with flood flows and no pulses)

will inform baseline conditions for comparison with years with a pulse flow and be used to determine if certain conditions/results are due to pulse actions or other environmental conditions.

Fish and Environmental Monitoring

Winter-run Chinook salmon spawn in the Sacramento River from approximately May through early August; while fall-run Chinook salmon in the Sacramento River spawn the first week of September through the second week of December, with peak spawning occurring the second week of October through the fourth week of October. Annual population estimates are generated based on a cooperative mark-recapture carcass survey conducted by the USFWS, CDFW, and PSMFC. Results of this carcass survey provide an estimate of the number of female winter-run Chinook salmon which successfully spawned in-river. An assumption that each female constructs a single redd allows the USST to forecast when the one percent take limit for winter-run Chinook salmon, described in the NMFS 2019 Biological Opinion, may be reached. Sacramento River Chinook salmon redd dewatering surveys are completed by PSMFC field technicians working under guidance of CDFW, Sacramento River Chinook salmon redds are identified through a combination of aerial and boat-based surveys completed throughout each runs spawning season. "Shallow redds", or redds constructed in two feet of water or less, are marked using a numbered, physical marker and GPS waypoint. Date of construction and current Keswick Dam flow release are also recorded. Chinook salmon redds are susceptible to dewatering in dam-controlled rivers when flows are reduced before fry have emerged. Lack of flowing water through redds can kill incubating eggs and alevins, and trap emerging fry. Using the redd construction date and water temperatures near the redd locations, a fry-emergence or "redd expiration" date is estimated, and this information was used by the USST to avoid or minimize winter-run redd dewatering and schedule Keswick Dam releases which would minimize the potential for fall-run Chinook salmon redd dewatering.

CDFW conducts aerial redd surveys to measure distribution and timing of Chinook salmon spawning. These surveys occur weekly year-round depending on aircraft availability. For winter and spring-run Chinook salmon, reaches surveyed include Sacramento River from Keswick Dam to Tehama Bridge. The boundaries of the fall-run Chinook salmon carcass survey are Balls Ferry Bridge to Keswick Dam. Additionally, fall-run Chinook salmon spawn downstream of Balls Ferry, and these fish are accounted for by bi-weekly aerial redd flights from Princeton Ferry to Keswick Dam. Redds counted by air downstream of Balls Ferry are included in the annual female estimate. A majority of fall-run Chinook salmon spawn within the boundaries of the carcass survey and a majority of shallow fall-run Chinook salmon redds are identified within the carcass survey area. However, due to physical and budget restraints, shallow redd monitoring downstream of Balls Ferry is limited and some dewatered redds below Balls Ferry may not be accounted for.

The goal of these projects is to provide real-time data and impacts of Keswick Dam on salmonid health and survival during the incubation and rearing life stages associated with Keswick Dam flow schedules. For more information on the stranding surveys, please refer to the Redd Dewatering and Juvenile Stranding in the Upper Sacramento River Year 2020-2021(anticipated release Summer 2021). Winter-run and fall-run Chinook salmon redd dewatering surveys started on August 11, 2020 and were monitored as flows were reduced.

Figure 13 illustrates the daily average Keswick Dam releases from August through December 1, 2020 and Sacramento River fall-run spawn timing. The flow schedule from Alternative 6a was

largely implemented as scheduled, with some variance due to real-time biological and water operations considerations.

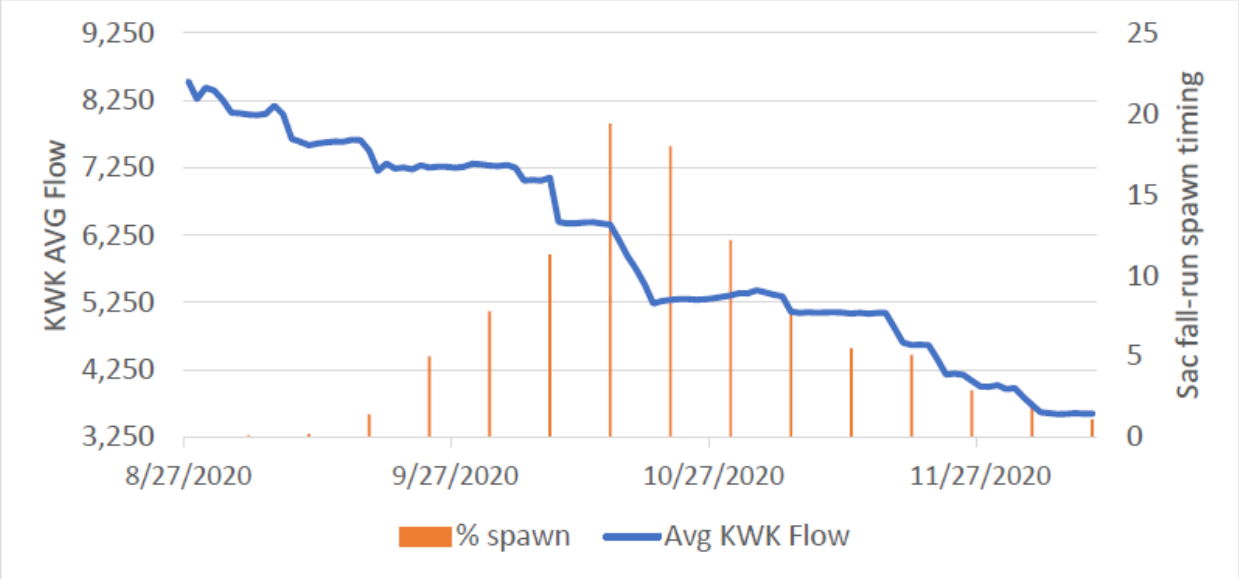

Figure 13. Daily average Keswick Dam releases (KWK) from August through December 2020 and Sacramento River fall-run Chinook salmon spawn timing. Data are preliminary and subject to revision.

Monitoring relevant to the spring pulse flow includes acoustic telemetry and rotary screw traps and environmental parameters (Table 6 and Table 7). This has been described in the Spring Pulse Flow Study Plan.

Table 6. Collected environmental parameters measured at specific locations relevant to a spring pulse flow.

Location	Flow	Velocity	Turbidity	Dissolved Oxygen	Water Temperature
Keswick	X	-	X	X	X
Sacramento River upstream of Hwy 44	-	-	-	-	X
Sacramento River above Clear Creek	-	-	X	X	X
Sacramento River at Balls Ferry Bridge	-	-	X	X	C
Sacramento River at Jellys Ferry	-	-	X	X	X
Sacramento River at Bend Bridge	X	-	X	X	X
Sacramento River at Red Bluff Diversion Dam	-	-	X	X	X
GCID (side channel, near RST)	-	-	X	-	X

Location	Flow	Velocity	Turbidity	Dissolved Oxygen	Water Temperature
Sacramento River below Wilkins Slough	X	-	-	-	X
Sacramento River at Knights Landing	-	-	-	-	-
Sacramento River at Verona	X	-	X	-	X
I80/I50 Bridge	-	-	-	-	-
Sacramento Trawls	-	-	-	-	-
Chipps Island	-	-	-	-	-

Table 7. Collected fish parameters measured at specific locations relevant to a spring pulse flow.

Location	Fish Passage Counts	Fish Presence Fish Survival (telemetry receivers)
Red Bluff Diversion Dam	X	X
Mill/Deer Creek	X (partial)	-
GCID	X	X
Wilkins Slough	-	-
Knights Landing	X	X
Verona	-	X
I80/I50 Bridge	-	X
Sacramento Trawls	X	X
Chipps Island	X	X

Operations Summary

WY 2021 was the first year fall and early winter operations were guided by the 2020 ROD. The USST assisted in planning in the fall and winter for Shasta Lake refill, redd dewatering minimization, and rice decomposition smoothing. In the fall of 2020, a coordinated effort to reduce Keswick Dam releases was undertaken by the USST. Reclamation modified water contracts for the SRSC in an effort to reduce dewatering impacts on winter-run and fall-run Chinook salmon.

The USST created a Spring Pulse Subteam to analyze the effects of implementing a spring pulse action. Very dry hydrology in WY 2021 afforded few opportunities for Shasta Lake refill and storage remained low throughout the year. There were no flood control releases in WY 2021. Shasta Lake storage was not sufficient to conduct a pulse flow this year. Thus, the Spring Pulse Subteam analyzed proposed pulse scenarios on historic data to develop a process to be utilized in upcoming water years.

Performance

This section describes the success of Shasta Lake storage rebuilding efforts, redd dewatering numbers from the fall, and spring pulse flow outcomes.

Shasta Lake Storage

Cumulative inflow (TAF) to Shasta Lake from October 1 to May 1 compared to the increase in storage (TAF) from October 1 to May 1 for a period of record of WY 2009 – WY 2021 is shown in Figure 14. Compared to the period of record, WY 2021 has the lowest cumulative inflow and lowest increase in storage. Shasta Lake cold water pool volumes for WY 2021 are shown in Figure 13. As a result of the warm water power bypass, WY 2021 has a similar cold water pool volume to previous critically dry years (WY 2014 and WY 2015).

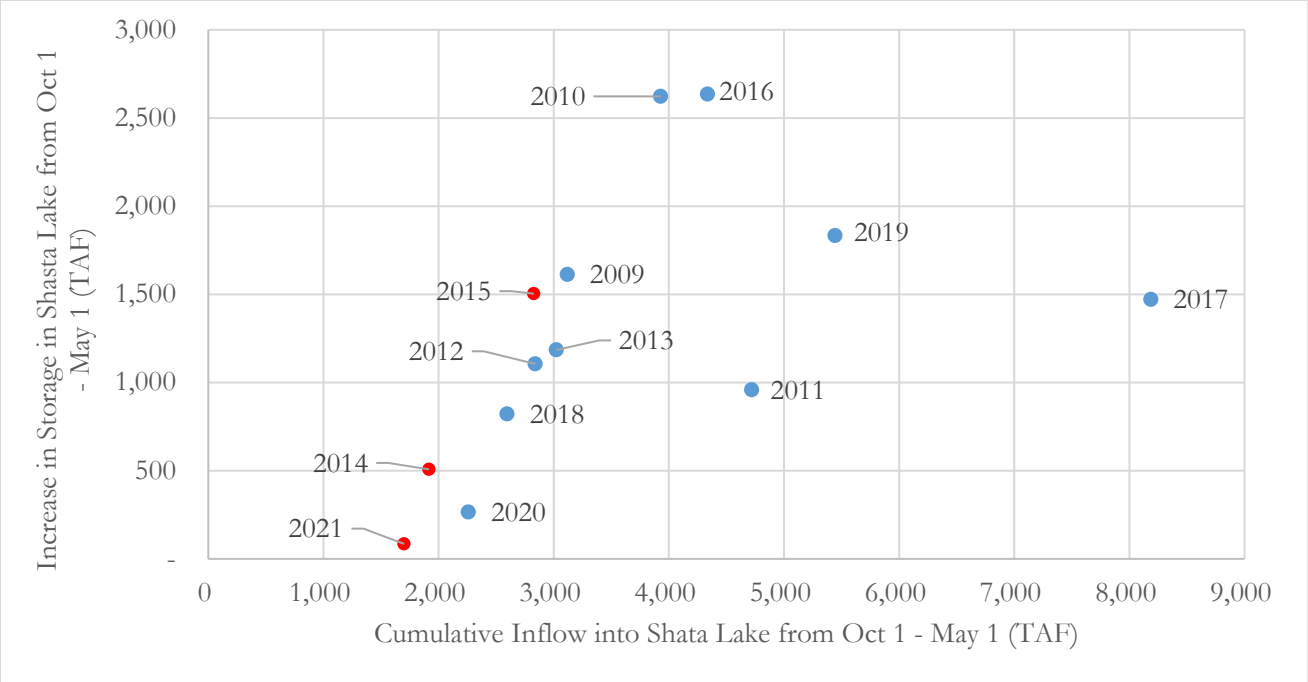

Figure 14. Shasta Lake Storage Performance from WY 2009 – WY 2021. Critically dry water year types are shown in red; all others are shown in blue.

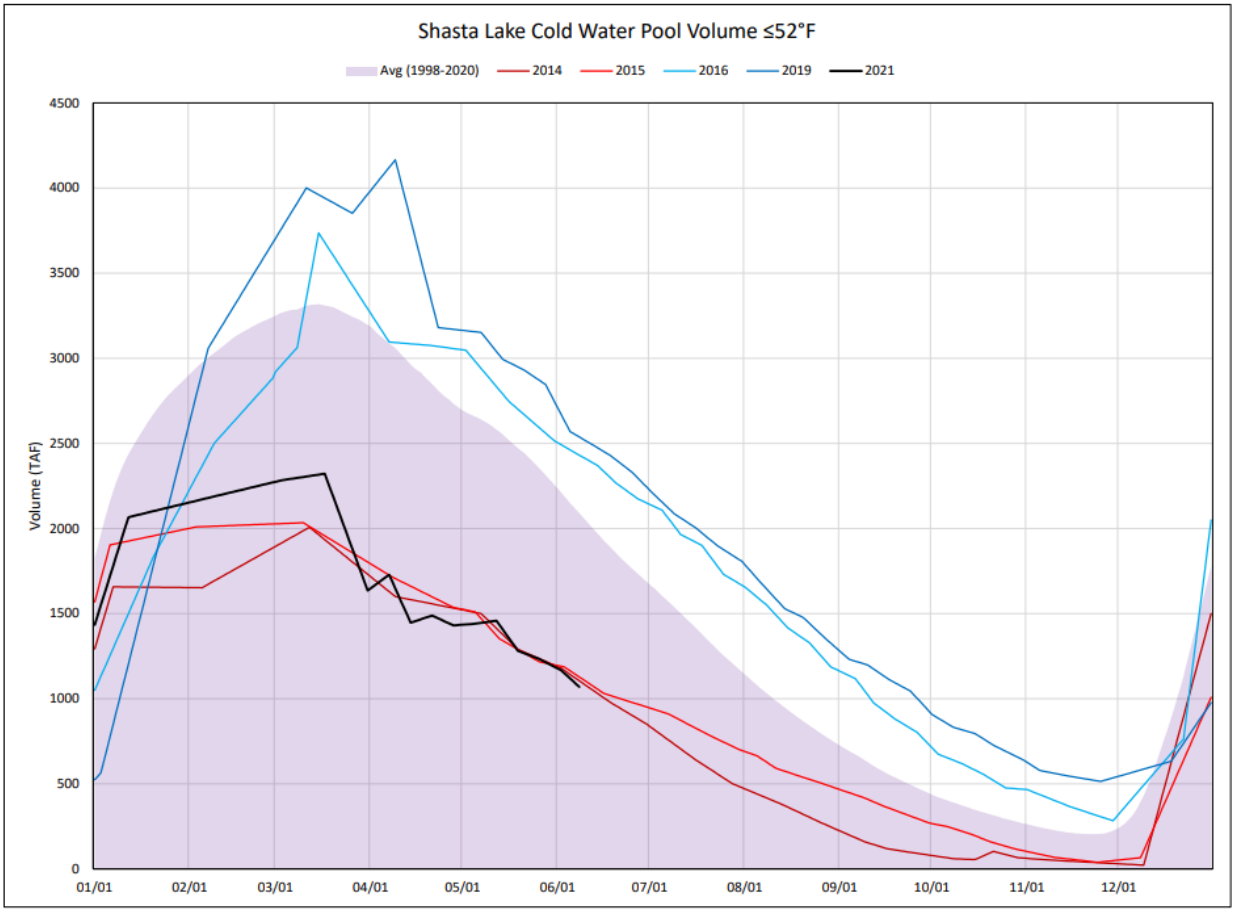

Figure 15. Shasta Lake cold water pool volumes <52 degrees F for select years and WY 2021.

Fisheries

The USST discussed several flow reduction scenarios during the fall. Hydrology and demands on the system, winter-run Chinook salmon redd dewatering estimates, fall-run Chinook salmon redd dewatering estimates, and Shasta Lake storage volume were key items guiding selection of a preferred scenario. Winter-run Chinook salmon dewatered redd estimates were based on real-time monitoring. Fall-run Chinook salmon dewatering estimates were based on historical fall-run spawning periodicity from 2003-2017, and a report describing the relationship between Sacramento River flows and their relationship to Chinook salmon redds and juvenile stranding (USFWS 2006). This information was updated and presented to the USST as new data became available. Ultimately, alternative 6a was selected as the preferred alternative.

All 2020-2021 data are preliminary and subject to revision. In September, when scenarios were first developed, 45 winter-run redds were forecasted to be dewatered by the end of October, but a total 26 (0.67 percent) were actually dewatered during the fall of 2020. In early September, Reclamation estimated that 7.7 percent of fall-run Chinook salmon redds would be dewatered; however, 3.23

percent were actually dewatered. Reclamation forecasts overestimated redd dewatering and appear to be conservative.

The 2019 NMFS Biological Opinion concludes that operations are expected to result in the take of juvenile listed salmonids through stranding or redd dewatering throughout the upper Sacramento River from Keswick Dam to Red Bluff Diversion Dam. Take of Sacramento River winter-run Chinook salmon from changes in flow during the temperature management season is reasonably expected to result in egg mortality from the dewatering of one percent of redds. Less than one percent (0.67 percent) of winter-run Chinook salmons redds were dewatered during the summer/fall 2020. Reclamation did not exceed this take limit (Table 8).

Take of adult CV spring-run Chinook salmon resulting from flow changes from summer releases down to 3,250 cfs is reasonably expected to result in egg mortality from the dewatering of up to three percent of redds. The anticipated level of take will be exceeded if flow decreases occur at a rate greater than the ramping rates described in the proposed action with the exception of flood control and emergency conditions. The ROD describes that ramping rates for Keswick Dam between July 1–March 31 would be reduced between sunset and sunrise:

- Keswick Dam releases > 6,000 cfs, reductions in releases may not exceed 15 percent per night, and no more than 2.5 percent per hour.
- Keswick Dam releases 4,000 cfs to 5,999 cfs reductions in releases may not exceed 200 cfs per night, or 100 cfs per hour.
- Keswick Dam releases between 3,250 cfs and 3,999 cfs; reductions in releases may not exceed 100 cfs per night.
- Ramping rates do not apply during flood control or if needed for facility operational concerns. The working groups may also determine a need for a variance.

Keswick Dam release change orders adhered to the ramping rates described in the ROD and, therefore, did not exceed the established take limit of three percent for spring-run Chinook salmon.

In 2020-2021, the estimated total number of winter-run Chinook salmon female spawners that spawned within the Sacramento River was 3,904 (Table 8). In 2020, 65 winter-run Chinook salmon shallow water redds were monitored. 39 of these redds contained fry that emerged successfully and 26 redds were dewatered. Five redds were modified after dewatering to aid emergence of fry (for purposes of tracking dewatered redds, once a redd has been dewatered it is counted toward the total number of dewatered redds). The proportion of the population of winter-run Chinook salmon redds dewatered (0.67 percent) were greater than the average of previous years' data (0.07 percent; Table 8).

In 2020, the estimated total number of fall-run Chinook salmon female spawners that spawned within the Sacramento River was 5,455 (Table 9). In 2020, 620 shallow fall-run Chinook salmon redds, constructed in two feet of water or less, were monitored. 176 fall-run Chinook salmon redds were dewatered. The proportion of the population of fall-run Chinook salmon redds dewatered (3.2 percent) was greater than the average of previous years' data (1.8 percent; Table 9).

In 2020-2021, the estimated total number of late-fall-run Chinook salmon female spawners that spawned with the Sacramento River was 977 (Table 10). Shallow and dewatered redd information for the 2020-2021 season was not yet available.

Table 8. Summary of dewatered redd information for mainstem Sacramento River winter-run Chinook salmon redds from 2013-2020. Total redd estimates are based on post season estimate of all female spawners in the population for a given year (does not include unspawned females). 2020 data are preliminary and subject to revision.

Year	Shallow Redds Actively Monitored	Dewatered	Total Redds	Proportion of Shallow Wate Redds Dewatered	Proportion of Population Redds Dewatered
2013	30	5	3,645	17%	0.14%
2014	32	1	1,727	3%	0.06%
2015	19	0	2,022	0%	0%
2016	28	0	653	0%	0%
2017	24	0	367	0%	0%
2018	31	2	1,080	6%	0.19%
2019	109	5	4,884	5%	0.10%
2020	65	26	3,904	40%	0.67%

Table 9. Dewatered redd information for mainstem Sacramento River for fall-run Chinook salmon redds. Total redd estimates are based on post season estimate of all female spawners in the population for a given year (does not include unspawned females). 2020 data are preliminary and subject to revision.

Year	Shallow Redds Actively Monitored	Dewatered	Total Redds	Proportion of Shallow Water Redds Dewatered	Proportion of Population Redds Dewatered
2002	n/a	145	4,420	n/a	3.28%
2003	n/a	9	3,832	n/a	0.23%
2008	n/a	189	n/a	n/a	n/a
2009	n/a	92	205	n/a	45%
2010	228	23	2,166	10%	1.06%

Year	Shallow Redds Actively Monitored	Dewatered	Total Redds	Proportion of Shallow Water Redds Dewatered	Proportion of Population Redds Dewatered
2011	83	25	1,900	30%	1.32%
2012	348	123	4,783	35%	2.57%
2013	743	538	17,368	72%	3.10%
2014	311	44	13,814	14%	0.32%
2015	774	291	13,771	38%	2.11%
2016	101	0	2,415	0%	0%
2017	36	15	772	42%	1.94%
2018	407	202	3,702	50%	5.46%
2019	433	35	10,557	8%	0.33%
2020	620	176	5,455	28%	3.23%

Table 10. Dewatered redd information for mainstem Sacramento River for late-fall-run Chinook salmon redds. Total redd estimates are based on post season estimate of all female spawners in the population for a given year (does not include unspawned females). 2020-2021 data on total redds is preliminary and subject to revision; the remaining data are not yet available.

Year	Shallow Redds Actively Monitored	Dewatered	Total Redds	Proportion of Shallow Water Redds Dewatered	Proportion of Population Redds Dewatered
2010-2011	23	23	1,748	100%	1.32%
2011-2012	4	0	1,183	0%	0%
2012-2013	81	12	1,891	15%	0.63%
2013-2014	45	31	2,830	69%	1.10%
2014-2015	3	2	1,008	67%	0.20%
2015-2016	0	0	1,216	n/a	0%

Year	Shallow Redds Actively Monitored	Dewatered	Total Redds	Proportion of Shallow Water Redds Dewatered	Proportion of Population Redds Dewatered
2016-2017	1	0	1,693	0%	0%
2017-2018	47	1	667	2%	0.15%
2018-2019	46	2	1,245	4%	0.16%
2019-2020	n/a	n/a	675	n/a	n/a
2020-2021	TBD	TBD	977	TBD	TBD

In WY 2021, a spring pulse flow action was not implemented. However, data were collected in non-pulse action years (e.g., dry years with no action, average years with natural pulse events, wet years with flood flows and no pulses) to inform baseline conditions for comparison with years with a pulse flow and used to determine if certain conditions/results were due to pulse actions or other environmental conditions. Real-time data analytics and download data are accessible via the Enhanced Acoustic Telemetry for Salmon Monitoring site for each group (https://calfishtrack.github.io/real-time/index.html), and provides a preliminary assessment of the pulse flow's success in real-time. This CalFishTrack web page will have preliminary survival, routing, distribution, and travel time for spring pulse flow study by June 2021. Final information on the effectiveness of a pulse flow action (if one is implemented) will be available by September.

Acoustic tagging projects were conducted in WY 2021 tagging multiple salmonid species and runs throughout the season and the Delta/watersheds (Table 11). Minimum survival to Benicia Bridge (east span) and minimum survival through-Delta varied widely by study (Table 12).

Table 11. Project details for WY 2021 acoustic tagging.

Project	Release Date(s)	Fish Released	Groups (*n*) and description	Release Location(s)
Hatchery-origin winter-run Chinook salmon	1/30/2021	556	*n* = 3 thiamine boost, thiamine control; release 3	Caldwell Park
Hatchery-origin Battle Creek winter-run Chinook salmon	3/8/2021 – 3/18/2021	900	*n* = 3 release groups 1 – 3	North Fork Battle Creek

Project	Release Date(s)	Fish Released	Groups (*n*) and description	Release Location(s)
Feather River Hatchery Spring-run Chinook salmon	3/19/2021, 4/1/2021	590	*n* = 2 release groups 1 – 2	Feather River Boyds
6-Year Study San Joaquin River Steelhead - March	3/23/2021 – 3/26/2021	400	*n* = 3 Durham Ferry, Stockton, HOR	Durham Ferry, Stockton, HOR
6-Year Study San Joaquin River Steelhead - April	4/13/2021 – 4/16/2021	500	*n* = 3 Durham Ferry, Stockton, HOR	Durham Ferry, Stockton, HOR
Mill and Deer Creek wild steelhead, Spring Releases	3/16/2021 – 5/7/2021	96	*n* = 2 Deer Creek, Mill Creek	Deer Creek, Mill Creek
Butte Creek wild spring-run Chinook salmon	4/7/2021 – 4/23/2021	99	*n* = 2 upstream, downstream	Laux Road (up), Parrot-Phelan Diversion Dam (down)
Hatchery-origin fall-run Chinook salmon May Release	4/28/2021 – 5/14/2021	961	*n* = 2 release groups 1 – 2	Red Bluff Diversion Dam
Natural-origin Red Bluff RST captured Chinook salmon	4/29/2021 – 5/7/2021	61	*n* = 2 release groups 1 – 2	Altube Island
6-Year Study San Joaquin River Steelhead - May	5/4/2021 – 5/7/2021	598	*n* = 3 Durham Ferry, Stockton, HOR	Durham Ferry, Stockton, HOR

Table 12. WY 2021 acoustic tagging: minimum survival, SE, and 90 percent confidence intervals (CI) to Benicia Bridge East Span and minimum through-Delta survival (City of Sacramento to Benicia) estimated using a Cormack-Jolly-Seber (CJS) survival model. Data recorded from the CalFishTrack Central Valley Enhanced Acoustic Tagging Project website on 5/17/2021.

Project	Benicia Bridge Survival (%)	Benicia Bridge SE	Benicia Bridge 95% lower CI	Benicia Bridge 95% upper CI	Through-Delta Surviv (%)	Through-Delta SE	Through-Delta lower CI	Through-Delta upper CI
Hatchery-origin winter-run Chinook salmon	3.6	0.8	2.3	5.5	35.7	6.4	24.3	49.0
Hatchery-origin Battle Creek winter-run Chinook salmon	0.2	0.2	0.1	0.9	6.7	4.6	1.7	23.1
Feather River Hatchery Spring-run Chinook salmon	2.2	0.6	1.3	3.8	7.7	2.0	4.5	12.8
6-Year Study San Joaquin River Steelhead - March Releases	3	0.9	1.7	5.2	-	-	-	-
6-Year Study San Joaquin River Steelhead - April	5.0	1.0	3.4	7.3	-	-	-	-
Mill and Deer	13.5	3.5	8.0	21.9	63.2	11.1	40.3	81.3

Project	Benicia Bridge Survival (%)	Benicia Bridge SE	Benicia Bridge 95% lower CI	Benicia Bridge 95% upper CI	Through-Delta Surviv (%)	Through-Delta SE	Through-Delta lower CI	Through-Delta upper CI
Creek wild steelhead, Spring Releases								
Butte Creek wild spring-run Chinook salmon	No detections yet	NA	NA	NA	NA	NA	NA	NA
Natural-origin Red Bluff RST captured Chinook salmon	No detections yet	NA	NA	NA	NA	NA	NA	NA
6-Year Study San Joaquin River Steelhead - May	2.2	0.6	1.3	3.8	-	-	-	-

Conservation Measures

The purpose of this section is to provide a status update on the conservation measures identified in the ROD related to Shasta Lake storage rebuilding and the spring pulse flow action.

- Rice Decomposition Smoothing: The purpose of this action is to lower peak rice decomposition demand by working with the Sacramento Valley CVP contractors and the SRSCs to synchronize their diversions. The rice decomposition smoothing effort was successfully coordinated in 2020 in USST meetings, as described within the Seasonal Operations section of this report.

- Drought and Dry Year Toolkit: The purpose of this action is to develop a voluntary toolkit to be exercised at the discretion of Reclamation, DWR, other agencies, participating water users, and/or others for the operation of Shasta Reservoir during critical hydrologic year

types. The approach for development of the drought and dry year toolkit was further outlined in an implementation charter finalized in May 2020. The LTO Coordination team is developing the drought and dry year toolkit with input from the agencies and anticipating a final document in August 2021. In addition, WOMT requested the development of a team charter to describe the Drought Response Year (DRY) Team process for reviewing the drought toolkit potential actions and recommending appropriate actions during drought conditions. The DRY team charter was finalized on April 29, 2021.

- Spring Management of Spawning Locations: The purpose for this action is to establish experiments to refine the state of the science and determine if colder water releases in April and May induces earlier peak winter-run Chinook salmon spawning in the Sacramento River, and if warmer April and May Sacramento River temperatures induces later peak spawning. Experiments and studies will help Reclamation evaluate potential actions to improve temperature management with the relevant technical teams. The final charter for this action was finalized on April 23, 2021. Additionally, Reclamation in coordination with fish agencies and other stakeholders, assessed warm spring temperature scenarios (i.e., warm water Shasta power bypass) by estimating temperature-dependent egg mortality and discussing temperature criteria. Temperature differences during a Shasta power bypass was also investigated during April of 2021.

Discussion

Shallow fall-run Chinook salmon redd monitoring showed that the fall Keswick Dam releases schedule adopted by the USST in 2020 resulted in the second highest percentage of dewatered redds for the period of record 2013 through 2020. Scheduled lower releases in October and early November 2020 minimized fall-run redd dewatering since fall-run Chinook salmon were less likely to spawn in shallow areas that would be subject to dewatering following the lower flows in December. These fall season release reductions balanced the conflicting requirements of minimizing impacts to winter-run Chinook salmon, fall-run Chinook salmon, and the need to re-build cold water pool storage in Shasta Lake.

WY 2021 is a critically dry year and, as of May 2021, is the second driest year on record since 1977. The May 90 percent exceedance forecast for the Sacramento Valley Four River Index was 685 TAF lower than the forecast made in April. Available forecasting methods, parched watershed soils, and extremely low rainfall with continued dry and warm conditions challenge Shasta Dam operations this year. Significant increases in Keswick Dam releases began in April 2021 in order to meet Delta requirements and downstream demands. May 1 storage was 2.28 MAF; the total increase in storage from October – May in WY 2021 was approximately 90 TAF, the lowest increase for the period of record WY 2009 - WY 2021.

Fall and winter Shasta Dam operations are focused on refilling storage, flood control, and meeting Delta requirements. When Shasta Dam is operating toward refilling storage while downstream Delta requirements need to be met, releases from other CVP or SWP reservoirs may be increased, potentially leaving other reservoirs with less water come spring and summer.

In WY 2021, no spring pulse flow action was implemented due to low storage conditions. Survival of acoustic-tagged juvenile Chinook salmon may have been higher if flows were higher or if WY 2021 was not a drought year. In other years with improved Shasta Lake storage conditions, Reclamation may implement a spring pulse flow.

Improvements

Improvements listed in this section may be evaluated as potential future updates to Shasta Dam fall, winter, and spring operations, including updating the guidance documents that could assist operations in upcoming water years. Improvements may also be considered or evaluated by the four-year independent review panels.

Guidance Documents

Reclamation's Proposed Action and NMFS 2019 Biological Opinion differ in the language regarding spring pulse flows and a change in temperature tiers. The Proposed Action states that "Reclamation would not make a spring pulse release if the release would cause Reclamation to drop into a Tier 4 Shasta summer cold water pool management…" (pg. 4-28); the NMFS 2019 Biological Opinion states "Reclamation shall not implement the Spring Pulse Flow if the release would cause Reclamation to drop into a lower Tier of the Shasta summer temperature management" (pg. 815). The USST suggested revising the guidance document in the LTO Coordination Group to clarify language on this topic.

Pilot Projects

Potential ideas for pilot project studies that are relevant for improvement include:

Targeted Gravel Injections to Reduce Redd Stranding: A potential study could be to investigate the feasibility of targeted gravel injections and their ability to reduce redd dewatering.

Seasonal Survival Trends Study: an additional tagging effort to elucidate the relationship between important environmental drivers and survival. 200 acoustic tagged fall-run Chinook salmon will be released weekly in the weeks leading up to and following the spring pulse flow study fish releases. This study's objective is to estimate routing probability and reach-specific survival of Sacramento basin Chinook salmon during the spring in response to environmental covariates and water operations.

Monitoring Improvements

Temperature-dependent egg mortality and take estimates from dewatered redds described as a percentage of the cohort rely on annual escapement estimate. If a high number of redds are in deep water or somewhere they are not detected then these performance and compliance estimates will be inaccurate. Existing carcass and redd surveys could be supplemented by using enhanced boat and in-water surveys. Additional information on pre-spawning mortality and distribution of Chinook

salmon spawning would be helpful for supporting escapement and egg survival estimates. Additional surveys may be helpful in spawning reaches too deep to be adequately surveyed by carcass surveys or aerial redd surveys. Additional methods may include SCUBA diver or remote underwater video surveys. Helicopter or drone methods may also be effective in detecting redds or salmon carcasses. An initial investigation to determine what data are being missed with existing surveys would be valuable.

Analysis Tools

Fall Flow Reduction Schedule Tool

The USST utilized the fall flow reduction schedule tool to provide dewatering estimates associated with various Keswick Dam release schedules. The tool is continuously updated with real-time monitoring information; an improvement for subsequent years will be to better archive data and show changes in the flow schedules and redd dewatering estimates through time.

SacPAS

Reclamation provides funding support to the University of Washington to develop a webtool to provide information integration services. The web-based services relate fish passage to environmental conditions and provide resources for evaluating the effects of river management and environmental conditions on salmon passage and survival. These tools will be further developed to provide for a new system of forecasting in-season impacts of water temperature and flow management. This system will integrate existing monitoring systems and should provide insight into the biological results and effectiveness of actions implemented as part of the CVPIA, including temperature management, flow management, and potentially habitat restoration.

SacPAS is publicly-accessible at: http://www.cbr.washington.edu/sacramento/

The SacPAS website includes the Fish Model, which predicts the timing and survival of juvenile salmon from spawning through smolt passage into the San Francisco Bay at Chipps Island. It links together four model systems:

1. CVTEMP model forecasts the temperature in the winter-run Chinook habitat
2. Emergence model predicts fry emergence timing and egg-to-RBDD survival
3. Migration Model predicts the movement and survival of smolts to the Delta
4. STARS model predicts the movement and survival of fish through the delta.

The current Fish Model and associated life-stage tools predict consequences of water operations on juvenile fish passage and survival. The Fish Model will be further developed with the aim of producing a more integrated system analysis and forecast system for fishes of the Central Valley. New features are being developed that would help evaluate performance of cold water pool management. These features include:

- Real-time redd data
- RBDD Passage Model: The life segment between fry emergence and RBDD passage is critical in determining early life survival and ultimately cohort success. The current Fish Model characterizes winter-run Chinook salmon survival in this segment by a fixed

background value. Fish survival and growth will be modeled to better resolve time-dependent changes in survival over the migration season. The approach will use a stochastic movement equation that characterizes the movement, growth, and survival of fish from fry emergence to passage at RBDD.
The proposed RBDD Model will link the fry emergence distribution (timing, location) to the RBDD passage distribution (size-number-frequency) by a stochastic process that characterizes the protracted arrival distribution and size-frequency distribution of fish at RBDD. The spatio-temporal distribution of fry emergence is generated by the Emergence Model, and the RBDD passage data are depicted by the daily/weekly size-frequency distributions reported by the fish monitoring program. The two distributions will be linked by four free parameters of a stochastic moment model: fish growth rate, mean and variance of fish migration velocity, and mortality rate.

- Another improvement to this tool is potentially calibrating the redd dewatering estimate tool within the SacPAS Fish Model.

CVTEMP

CVTEMP is a webpage developed by the NOAA-NMFS-Southwest Fisheries Science Center to help inform temperature management operations in the Upper Sacramento River. It shows modeled and observed water temperature and flow data for the Sacramento River associated with Shasta Reservoir, Shasta Dam operations, and meteorological conditions. The site displays water temperature scenarios for the Upper Sacramento River and the associated forecasted estimates of temperature-dependent egg mortality for Sacramento River winter-run Chinook salmon. An additional feature may be developed to incorporate pulse flow scenarios and estimated forecasts for winter-run Chinook salmon temperature-dependent egg mortality associated with those proposed spring pulse flow alternatives.

https://oceanview.pfeg.noaa.gov/CVTEMP/

Calfish Track Central Valley Enhanced Acoustic Telemetry

Calfish Track Central Valley Enhanced Acoustic Telemetry is a webtool that provides in-season and historical acoustic telemetry information to inform real-time operations and helps assess impacts of CVP and SWP water operations on salmonids and green sturgeon. The website displays information on acoustically-tagged fish to describe their distribution, travel time, and route selection, and survival. Additional releases of acoustically-tagged fish will be displayed on this site to help inform how the Spring Pulse flow action affects Chinook salmon.

https://calfishtrack.github.io/real-time/

Conclusion

The planning process conducted through the USST allowed for frequent communication and transparent decision-making among the federal and state agencies and the SRSC. The USST

coordinated fall flow management, including the rice decomposition smoothing effort, in fall 2020 to minimize dewatering of Chinook salmon redds. In 2020, 3.23 percent of fall-run Chinook salmon redds were dewatered and 0.67 percent of winter-run Chinook salmon redds were dewatered. While the fall flows minimize dewatering, these actions may result in higher fall flow, and subsequently less winter refill and a lower cold water pool volume. WY 2021 is a critically dry water year and May 1 storage at Shasta Lake was 2.28 MAF. No need was identified by the agencies for an independent panel review for WY 2021 as it pertained to Shasta Storage Rebuilding and Spring Pulse Flows.

An improvement recommendation to the guidance documents and/or future operations that may be considered includes:

- Clarifying language in the Spring Guidance Document around spring pulse flows and a potential change in temperature tiers, as the NMFS Biological Opinion and Reclamation's Proposed Action differ.

References

Abatzoglou, J.T., D.J. McEvoy, and K.T. Redmond, 2021. In press, The West Wide Drought Tracker: Drought Monitoring at Fine Spatial Scales, Bulletin of the American Meteorological Society. https://wrcc.dri.edu/wwdt/index.php?region=ca and https://wrcc.dri.edu/wwdt/index.php?folder=pon6per

DWR, 2021a. California Department of Water Resources, California Data Exchange Center. Runoff Data for Water Year 2021. https://cdec.water.ca.gov/reportapp/javareports?name=FLOWOUT.202103 and https://cdec.water.ca.gov/reportapp/javareports?name=WSI

DWR, 2021b. California Department of Water Resources, California Data Exchange Center. 8-Station Precipitation Index. http://cdec.water.ca.gov/cgi-progs/queryMonthly?s=8si&d=today

NMFS, 2019. Biological Opinion for the Reinitation of Consultation on the Long-Term Operation of the Central Valley Project and State Water Project. NMFS West Coast Region, California. 872 pages plus appendices.

U.S. Bureau of Reclamation, 2020. Record of Decision, Reinitation of Consultation on the Coordinated Long-Term Operation of the Central Valley Project and State Water Project. https://www.usbr.gov/mp/nepa/nepa_project_details.php?Project_ID=39181

USFWS, 2006. Relationships between flow fluctuations and redd dewatering and juvenile stranding for Chinook salmon and Steelhead in the Sacramento River between Keswick Dam and Battle Creek. Available from:

Sacramento River Keswick Dam to Battle Creek - redd dewatering and juvenile stranding Final Report .pdf (fws.gov)

USFWS, 2019. U.S. Fish and Wildlife Service. Red Bluff Fish and Wildlife Office annual reports and real time monitoring updates. Available from https://www.fws.gov/redbluff/rbdd_jsmp.html

Supporting Links

Reclamation's Central Valley Office - https://www.usbr.gov/mp/cvo/

Upper Sacramento Scheduling Team - https://www.usbr.gov/mp/bdo/sacramento-river-temperature-task-group.html

SacPAS - http://www.cbr.washington.edu/sacramento/
CVTEMP - https://oceanview.pfeg.noaa.gov/CVTEMP/

CalFishTrack - https://oceanview.pfeg.noaa.gov/CalFishTrack/pageLSWR_2021.html