BUREAU OF RECLAMATION

2022 Seasonal Report for Shasta Lake Storage Rebuilding and Spring Pulse

Central Valley Project, California

California-Great Basin Region

U.S. Department of the Interior

June 2022

Shasta Dam Hydropower (Reclamation)

Mission Statements

The Department of the Interior (DOI) conserves and manages the Nation's natural resources and cultural heritage for the benefit and enjoyment of the American people, provides scientific and other information about natural resources and natural hazards to address societal challenges and create opportunities for the American people, and honors the Nation's trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities to help them prosper.

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.

2022 Seasonal Report for Shasta Lake Storage Rebuilding and Spring Pulse

Central Valley Project, California

California-Great Basin Region

Prepared by
Bureau of Reclamation
Central Valley Operations Office 3310 El Camino Avenue, Suite 300
Sacramento CA 95821

Bureau of Reclamation Bay-Delta Office
801 “I” Street, Suite 140
Sacramento, CA 95814

in coordination with
California Department of Water Resources, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and California Department of Fish and Wildlife

Contents

Appendices

Appendix A – 2021 Fall Keswick Flow Reduction Alternatives
Appendix B – Upper Sacramento River Spring Pulse Flow Monitoring

Purpose

This 2022 Seasonal Report for Shasta Lake Storage Rebuilding and Spring Pulse describes Shasta Lake operations and management in water year (WY) 2022 to support improvements, if necessary, to guidance documents for WY 2023, 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 Lake represents about 40 percent of the total reservoir storage capacity of the CVP and is 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.

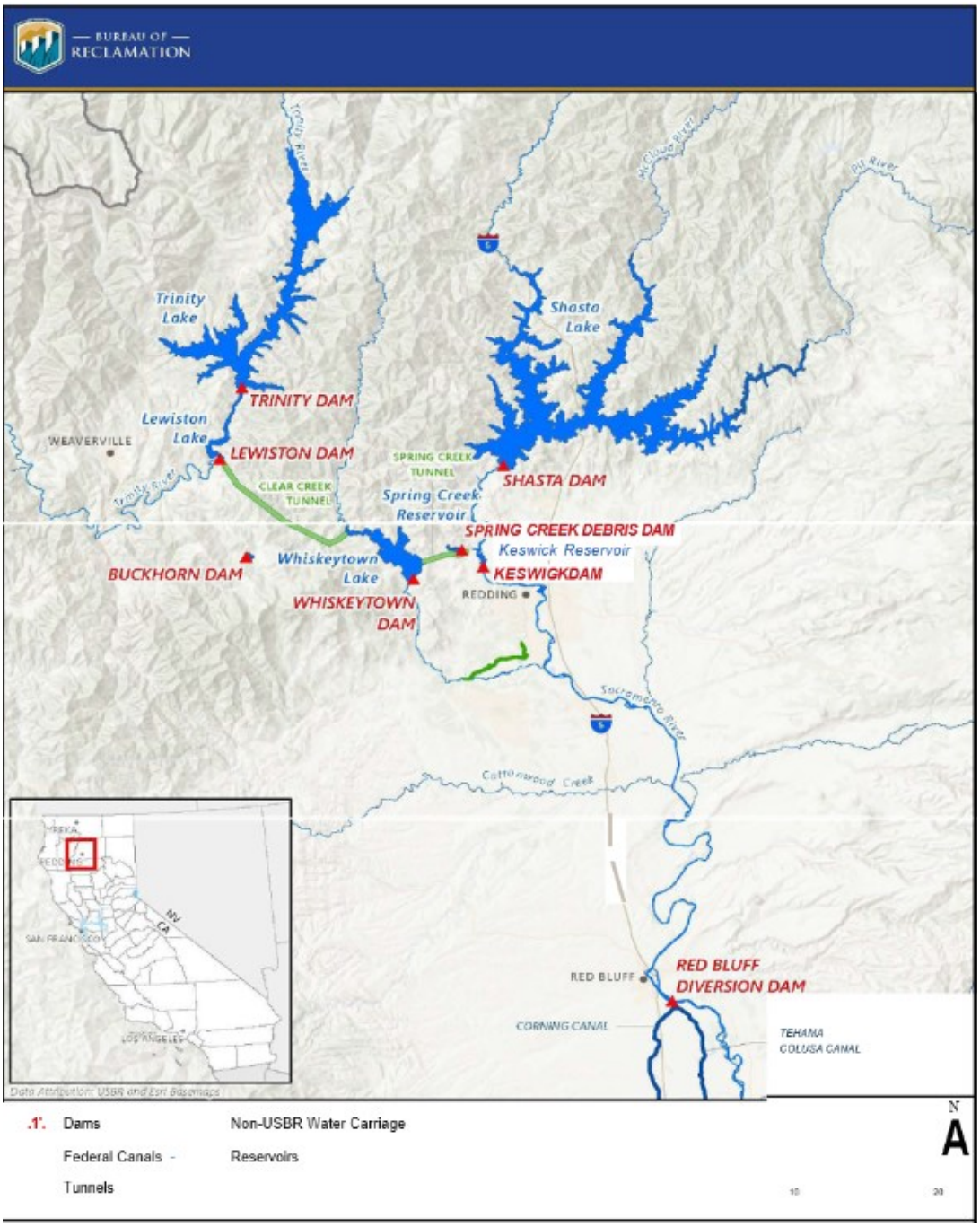

Figure 1. Shasta-Trinity System located in Northern California.

Figure 1 depicts the Shasta-Trinity water delivery system in northern California, showing dams, reservoirs, tunnels, federal canals, and non-USBR water carriage facilities. Key features include Trinity Dam, Lewiston Dam, Buckhorn Dam, and Whiskeytown Dam in the Trinity division, connected via the Clear Creek and Spring Creek tunnels to Shasta Dam, Spring Creek Debris Dam, Keswick Dam, and Red Bluff Diversion Dam in the Sacramento River division.

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 on October 21, 2019. 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 intended 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 considers whether the projected total May 1 Shasta Lake storage indicates a likelihood of sufficient cold water to support summer cold water pool management, and that the pulse does not interfere with the ability to meet performance objectives or other anticipated demands on the reservoir.

Seasonal Operations

This section details operations at Shasta Dam and hydrological conditions in the fall of 2021 through spring 2022.

Operational Background Information

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 Water Board Decision 1641 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 Upper Sacramento Scheduling Team (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 are 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 Dam Release (cfs)	Shasta EOS Storage (MAF)
3,250	≤ 2.2
4,000	≤ 2.8
4,500	≤ 3.2
5,000	> 3.2

Ramping rates are identified in Water Board Water Rights Order 90-5 (WRO 90-5). The release rate (ramping) from Keswick Dam shall not decrease more than the following rates to minimize stranding of salmon.

- Releases shall not be decreased more than 15 percent in a twelve-hour period.
- Releases shall not be decreased more than 2.5 percent in a one-hour period.
    - This term shall not be in effect during flood control events or other unforeseen emergency conditions.

In addition to these requirements, 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 exceed 100 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 – 2022 are shown in Figure 2. In WY 2021, the end of September daily average Shasta Lake storage volume was less than half the historic average (WY 1996 – 2021 average: 2.55 MAF; WY 2021 value: 1.08 MAF). In WY 2022, the May 1 daily average Shasta Lake storage volume was 47.5 percent of the historic average (WY 1995 – 2022 average: 3.81 MAF; WY 2022 value: 1.81 MAF). The northern Sierra 8-Station Index is shown in Figure 3. As of May 3, 2022, precipitation in WY 2022 is equal to approximately 73.9 percent of the average from

WY 1991 – 2020 (WY 1991 – 2020 average: 53.2 inches; WY 2022 value as of April 15: 39.3 inches).

Historic average air temperatures in Shasta County for the fall through spring (October through March for a period of record 1896 - 2022) is shown in Figure 4. According to the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information, Shasta County, California experienced higher than average air temperatures in the fall of 2021 through the spring of 2022. The average air temperature for October 2021 through March 2022 was 47.1 degrees F while the average for October through March 1896-2021 was 44.8 degrees F (NOAA 2022).

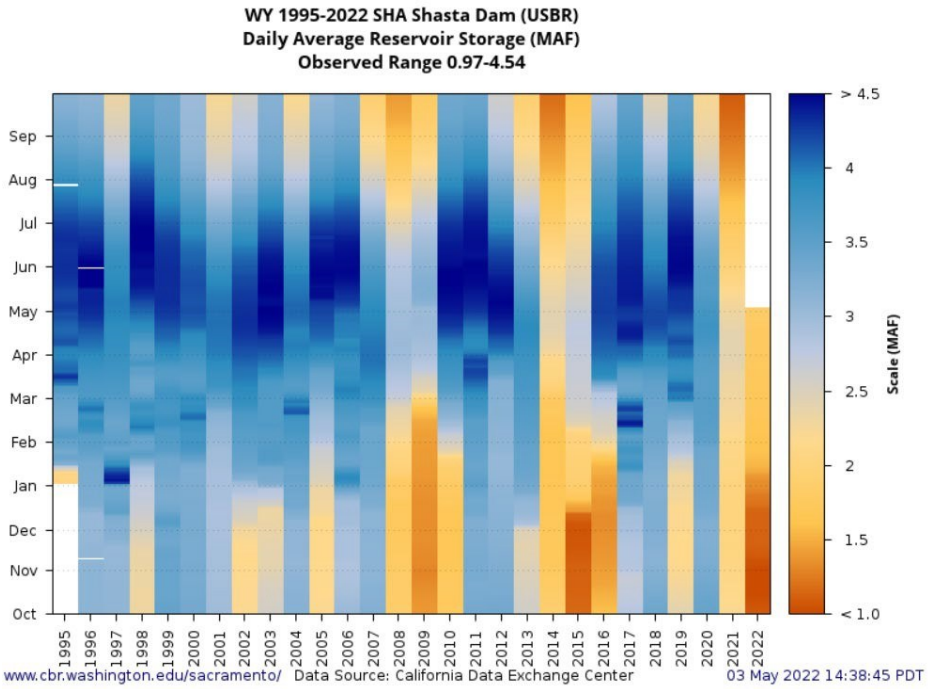

Figure 2. Shasta Lake Storage (MAF) from WY 1995-2022, as of May 3, 2022.

Figure 2 displays daily average reservoir storage at Shasta Dam from water years 1995–2022 as a heat map, with storage values ranging from below 1.0 MAF (orange) to above 4.5 MAF (dark blue). Storage is generally highest in late spring and lowest in fall, reflecting seasonal fill and draw patterns. Notable low-storage periods appear in the mid-2000s drought and 2021–2022, while above-average storage is visible in 2011 and 2017–2019.

Source: SacPAS Environmental Conditions All Years Query Website

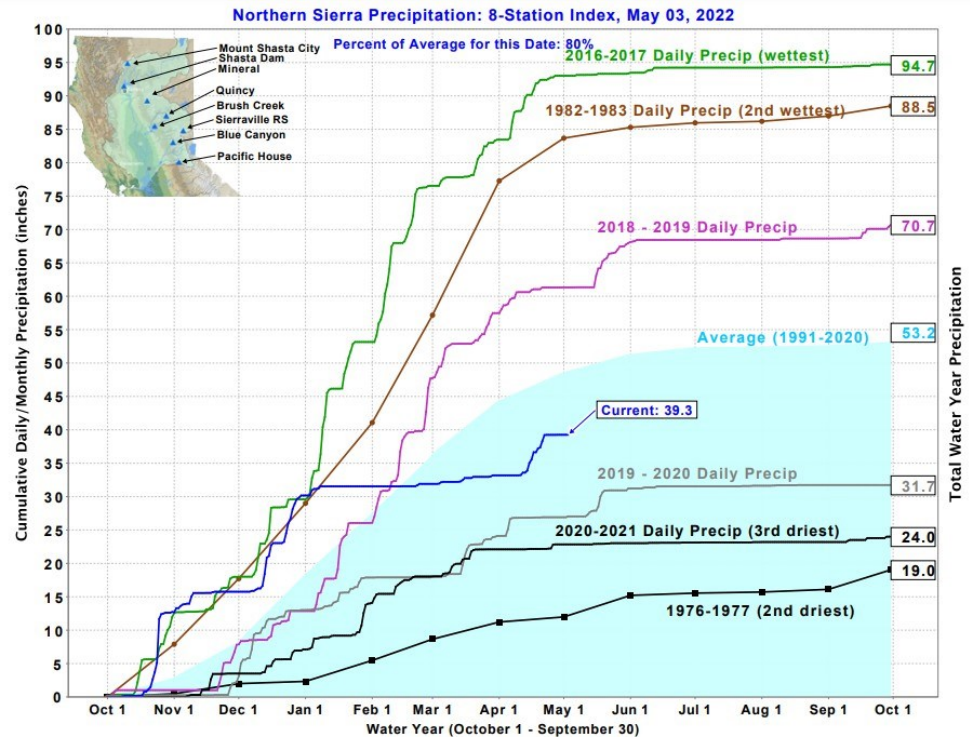

Figure 3. Northern Sierra Precipitation: 8-Station Index as of May 3, 2022.

Figure 3 displays cumulative daily precipitation for the Northern Sierra 8-Station Index through May 3, 2022, comparing the current water year against historical benchmarks. The current year (39.3 inches, 80% of average) tracks below the 1991–2020 average of 53.2 inches and well below the wettest years of 2016–2017 (94.7 inches) and 1982–1983 (88.5 inches). The driest comparisons are 1976–1977 (19.0 inches) and 2020–2021 (24.0 inches), with the current year falling between average and dry-year trajectories.

Source: [javareports (ca.gov)]

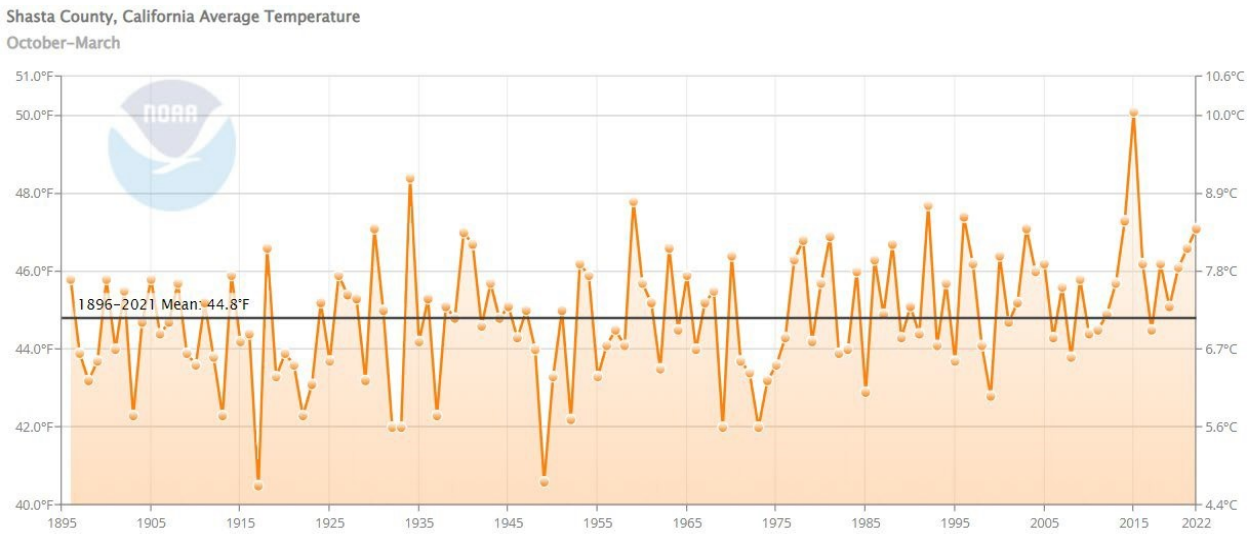

Figure 4. Average temperature for October through March for a period of record 1896-2022.

Figure 4 displays average October–March temperatures in Shasta County from 1896 to 2022, with a long-term mean of 44.8°F (1896–2021). Temperatures fluctuate considerably year to year but show a general warming trend, particularly from the 2000s onward, with the highest recorded value approaching 51°F around 2015 and recent years remaining predominantly above the long-term mean.

Source: NOAA Climate at a Glance County Time Series

General Water Year Conditions and Operations

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.

Large storm events occurred in October and December 2021, resulting in well above average observed monthly precipitation. However, the January through March timeframe that followed was the driest on record (DWR 2022a). Precipitation in April recovered some moisture in the system but fell short to make up for the lack of prior storm events. Snowpack for the Sacramento River region was poor, and was reflected in an average snow

water equivalent of 5.0 inches for the Northern region of the state, based on the DWR's April B-120 (DWR 2022b). Water supply indices reported the Sacramento River Unimpaired Runoff was a "Critical" year for the Sacramento Valley Index.

Insights to the hydrologic characteristics of WY 2022 are shown in Table 2 (DWR 2022c and 2022d).

Table 2. WY 2022 Northern Sierra precipitation, Sacramento Basin snowpack, and Sacramento Valley Index statistics by month.

Water Year 2022 Month	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)
October	12.7	453	NA	NA
November	15.8	58	NA	NA
December	30.2	144	NA	6.5
January	31.5	14	NA	7.5
February	31.9	4	75	6.2
March	33.2	16	65	4.8
April	39.3	141	35	4.2
May	39.9	21	23	4.5

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 Shasta Lake cold water pool 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 5). While Reclamation utilizes the projections from DWR in its forecasting, the CNRFC figure illustrates the wide variability of the runoff exceedances (i.e., 10 percent, 50 percent, and 90 percent) in the winter months and their convergence through time; by May the variability between the 10 percent, 50 percent and 90 percent exceedance forecasts has greatly decreased. The forecasts consider meteorological uncertainty and do not account for hydrologic uncertainties. By May 1, water supply forecasts for Shasta Lake inflow runoff ranged between 43 percent and 48 percent of the average for the 90 percent and 50 percent runoff exceedances, respectively (DWR 2022c).

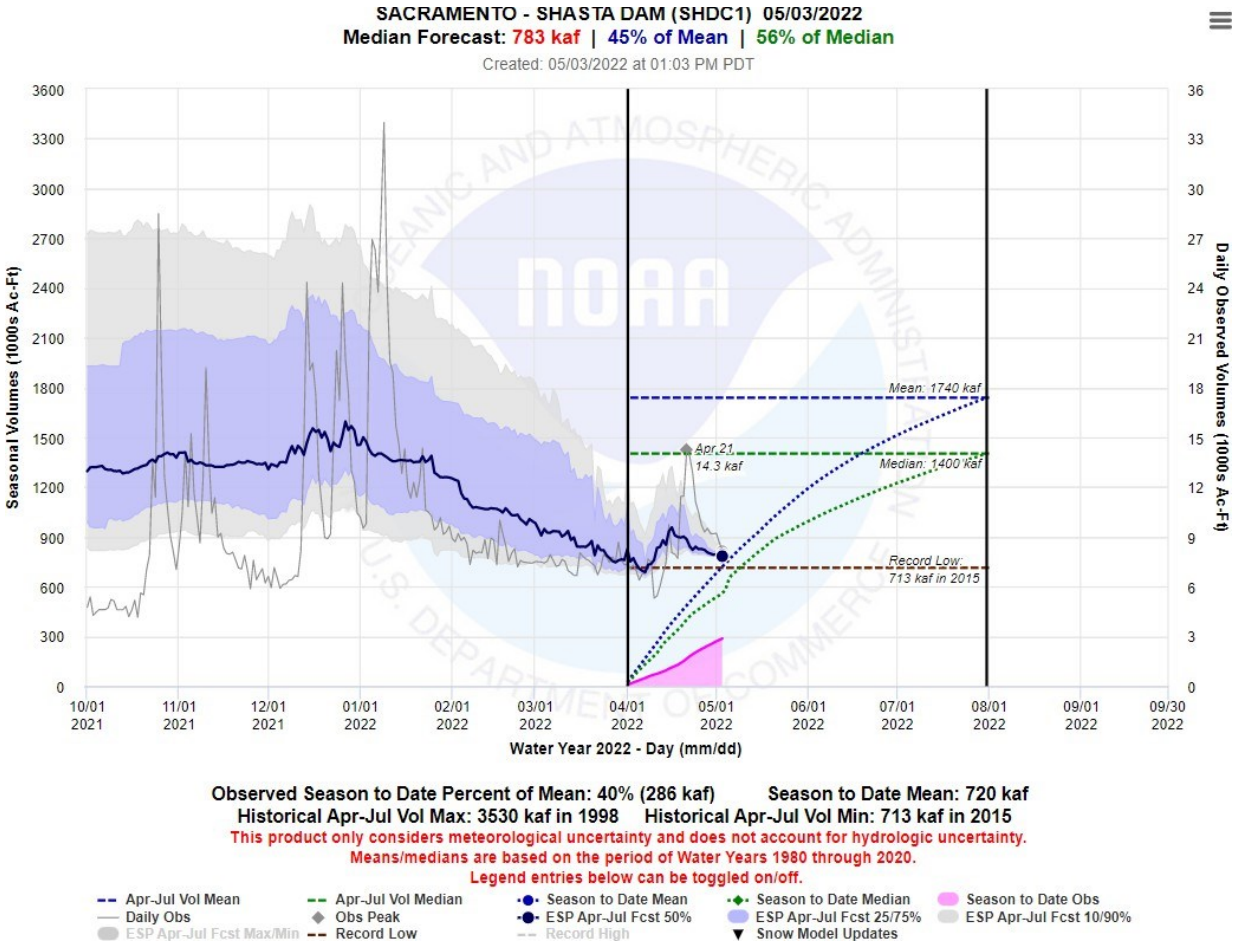

Figure 5. WY 2022 (as of May 3, 2022) forecasted (10 percent, 50 percent, 90 percent exceedance) and actual daily and cumulative inflow volume at Shasta Lake.

Figure 5 displays forecasted and observed seasonal inflow volumes at Shasta Dam through May 3, 2022. The median April–July inflow forecast is 783 kaf, representing 45% of mean and 56% of median. Observed season-to-date inflow of 286 kaf is 40% of the historical mean, with a season-to-date total of 720 kaf. Forecast exceedance ranges diverge from the forecast date through July, with the mean forecast at 1,740 kaf, median at 1,400 kaf, and the record low reference of 713 kaf from 2015 shown for comparison.

Source: [California-Nevada River Forecast Center]

Storage and Flood Conservation Space

Due to very dry hydrology in early 2022, Shasta Lake did not refill, and the peak storage volume was 1.828 on May 21, 2022 (Table 3). Relative to historical data since WY 2012, in WY 2022 Shasta Lake had substantially lower peak storage volume, much less end of April cold water pool volume, and a slightly later peak storage date. In WY 2022, Shasta Lake storage conditions were below the

U.S. Army Corps of Engineers flood control curve and therefore flood control space was not needed at any time in WY 2022 (Figure 6). WY 2022 had a lower storage volume compared to the average critically dry water years (2008, 2014, 2015, 2021) (Figure 7). Compared to average critically dry water years (2008, 2014, 2015, 2021), Keswick Dam releases were similar to the average from January through March (Figure 8).

Table 3. 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	End of September Storage Volume
2012	4483	05/07	3791	2592
2013	3887	04/18	2809	1906
2014	2409	04/28	1770	1157
2015	2722	04/15	1912	1603
2016	4235	05/01	3267	2811
2017	4389	05/13	3975	3382
2018	4200	04/26	3135	2405
2019	4477	05/31	3441	3425
2020	3750	04/21	2986	2200
2021	2396	04/03	1581	1077
2022	1828	05/21	1357	TBD

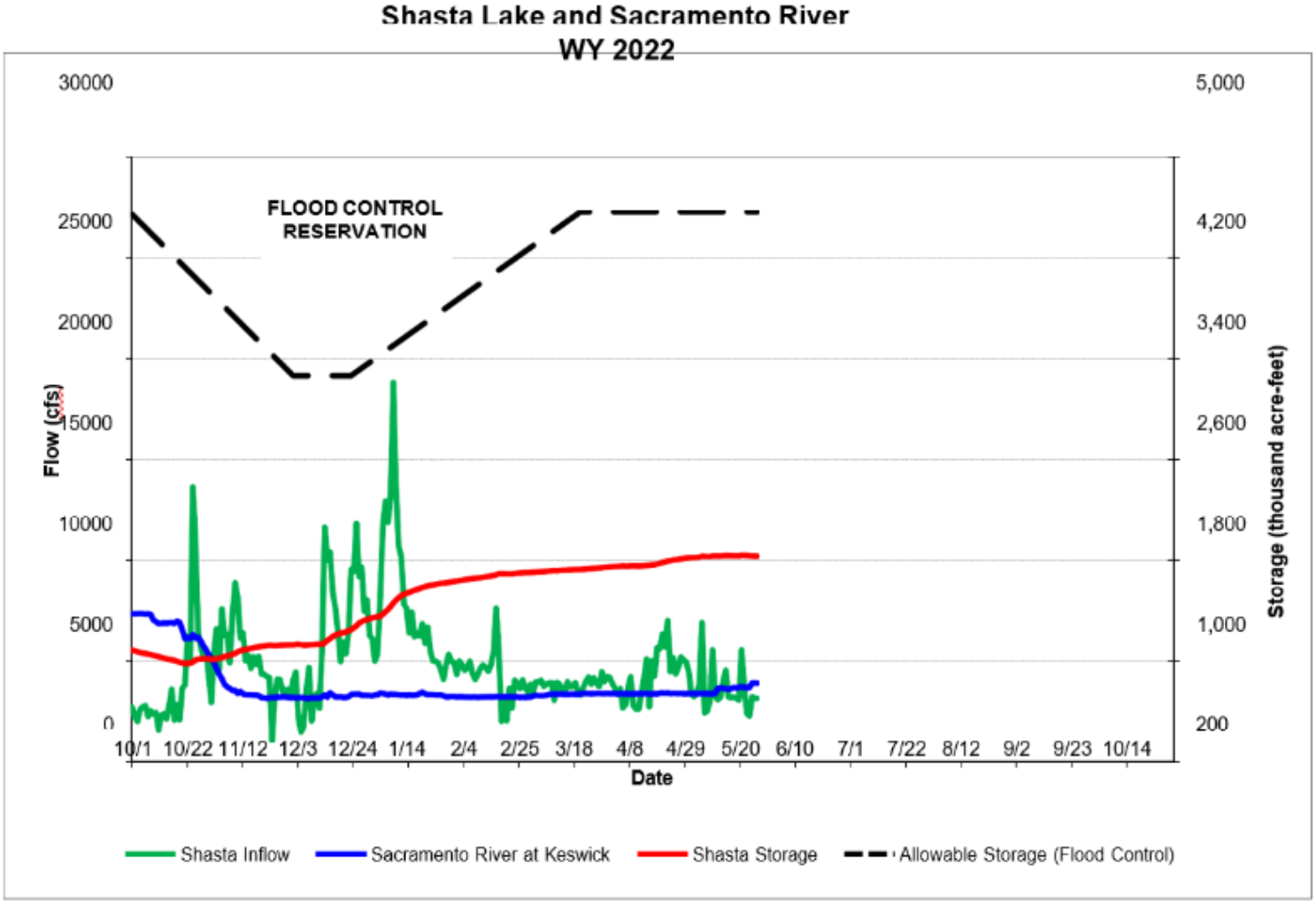

Figure 6. Shasta Lake Storage (red line), Allowable Storage for Flood Control (black line), Sacramento River at Keswick (blue line), and Shasta Inflow (green line) for 10/1/2021 – 5/26/2021.

Figure 6 displays Shasta Lake storage, flood control allowable storage, Sacramento River flow at Keswick, and Shasta inflow from October 1, 2021 through May 26, 2021. Shasta inflow (green) is highly variable, with peaks in late October and mid-January before declining through spring. Sacramento River flow at Keswick (blue) declines steadily from fall through winter then stabilizes at low levels. Shasta storage (red) rises gradually from approximately 1,000 to 1,800 thousand acre-feet through the period, remaining well below the flood control allowable storage curve (black dashed) throughout.

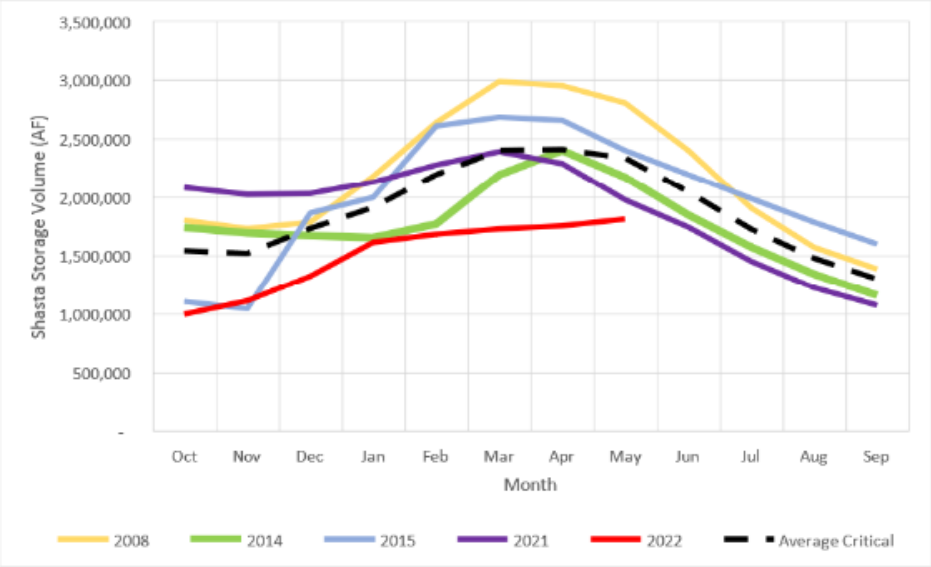

Figure 7. Historical Shasta Lake storage in WY2022 and other critically dry water years since 2008. Note: May 2022 value based on data through May 26, 2022.

Figure 7 displays Shasta Lake storage for WY 2022 compared to other critically dry years since 2008 and the average critical year (dashed). WY 2022 (red) tracks as the lowest of all years shown, remaining below 2,000,000 AF throughout and rising only modestly through spring, well below the average critical year curve. WY 2008 (yellow) recorded the highest storage of the comparison years, peaking near 3,000,000 AF in spring, while 2014, 2015, and 2021 fall between these extremes.

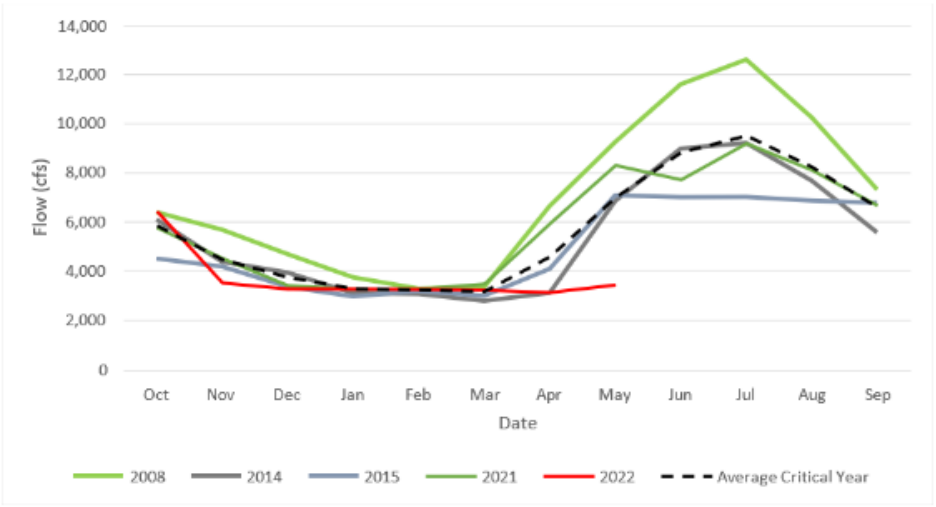

Figure 8. Keswick Dam historical monthly average releases in WY 2022 and other critically dry water years since 2008. Note: May 2022 value based on data through May 26, 2022.

Figure 8 displays Keswick Dam monthly average releases for WY 2022 compared to other critically dry years since 2008 and the average critical year (dashed). WY 2022 (red) records the lowest releases of all years shown, remaining below 4,000 cfs through May with no summer increase visible in the data through the reporting date. Most other years show releases rising substantially in summer, peaking near 8,000–12,000 cfs in June–August, with 2021 (green) recording the highest summer releases at approximately 12,000 cfs.

Fall and Winter Refill and Redd Maintenance

The USST included membership from Reclamation, DWR, NMFS, CDFW, Sacramento CVP Contractors and the SRSCs. The USST is intended to assist in planning in the fall and winter for Shasta Lake refill, redd dewatering minimization, 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 Lake 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 on the Sacramento River Temperature Task Group website.

July and August

The USST first met on July 29, 2021. In WY2020, the USST was focused on fall flows for rice decomposition and water transfers. In WY 2021, there was no rice decomposition smoothing due to the lack of available water for that purpose.. Trade-offs were carefully considered between winter-run Chinook salmon redd dewatering, fall-run Chinook salmon redd dewatering, Shasta Lake storage volume, and the effects of one of the drought actions for WY2021, the SRSC water transfer.

In the spring of 2021, in response to the critically dry conditions in California's Central Valley, the SRSCs proposed 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 releases from Shasta Lake in the summer to satisfy SRSC diversions and would instead provide for releases for delivery in the late summer and early fall of 2021. Reclamation coordinated with the fisheries agencies and determined that the additional spring and summer reservoir storage (estimated at approximately 175 TAF) would support colder water temperatures downstream for winter-run Chinook salmon egg incubation. These transfers require approval from Reclamation which included verifying the water made available, agreeing to temporarily store this water in Shasta Lake, and then increasing releases from Shasta Dam for delivery later in the summer and early fall.

The USST objectives identified in July 2021 included:

1. Protecting winter-run and fall-run Chinook salmon eggs and fry emergence;
2. Preserving Shasta Lake carryover storage for WY 2022;
3. Meeting Delta requirements; and
4. Meeting SRSC water transfer volume.

The USST analyzed multiple alternatives (Table 4) that moved various volumes of the SRSC transfer water in the September through November timeframe. Keswick Dam releases peaked in July at 9,300 cfs and flows in August decreased throughout the month to approximately 6,800 cfs.

Table 4. Fall Flow Reduction Alternatives Considered by USST in August 2021.

Alternative	Description
Alternative A	Baseline July 90% exceedance forecast
Alternative B	Baseline July 90% exceedance forecast with smoothing weekly flow transitions
Alternative C	Maintain higher flows in September
Alternative D	Decrease flows in September and delay water transfers from October to November
Alternative E	Spread water transfers through September through November
Alternative F	Maintain flows at 6,800 cfs until dropping to 3,250 cfs in early October
Alternative G	Maintain flows at 6,800 cfs until dropping to 3,250 cfs in mid-October

September through December

As the season progressed and system conditions became drier, the estimated water transfer quantity increased to approximately 200 TAF. As such, Keswick Dam releases in the fall needed to be held higher for longer and likely had greater impacts on fall-run Chinook salmon redd dewatering than initially considered in the spring. There were few options for flow alternatives due to need to deliver the water transfer quantity. Given this constraint, new alternatives were developed for USST consideration (Table 5). The USST determined Alternative H may exacerbate fall-run Chinook salmon redd dewatering when flows drop in December after the water transfers are completed.

While Alternative I maintained a stable flow to protect fall-run Chinook salmon egg emergence and minimized redd dewatering, this alternative would result in higher releases from Shasta Dam, further drawing down carryover storage. Ultimately, of these three feasible alternatives, Alternative J was chosen as it maintained higher flows into October in order to move the water transfer volume more quickly, then dropped to winter base flows quicker than Alternative I to reduce redd dewatering impacts.

Table 5. Fall Flow Reduction Alternatives Considered by USST in September 2021.

Alternative	Description
Alternative H	Ramp down flows in October to 4,000 cfs and hold until mid-December
Alternative I	Maintain flows at 6,800 cfs until end of October and then drop to 3,250 cfs by November 12, 2021
Alternative J	Maintain flows at 6,800 until mid-October and then drop to 3,250 cfs by November 8, 2021

Fall flow alternatives and actual Keswick Dam releases in September through December 2021 are shown in Figure 10. Around October 19, flows began to ramp down in accordance with Alternative

J. Flows deviated from the flow schedule in mid-to-late October due to a large incoming storm event, where flows were held at 6,000 cfs for approximately a week before being ramped down to 3,250 cfs as quickly as possible. Flows reached approximately 3,250 cfs on November 13, 2021. These minimum flows were held through approximately April 2022. End of month storage in Shasta Lake from December 2021 – March 2022 was the lowest compared to other recent critically dry years (Figure 7).

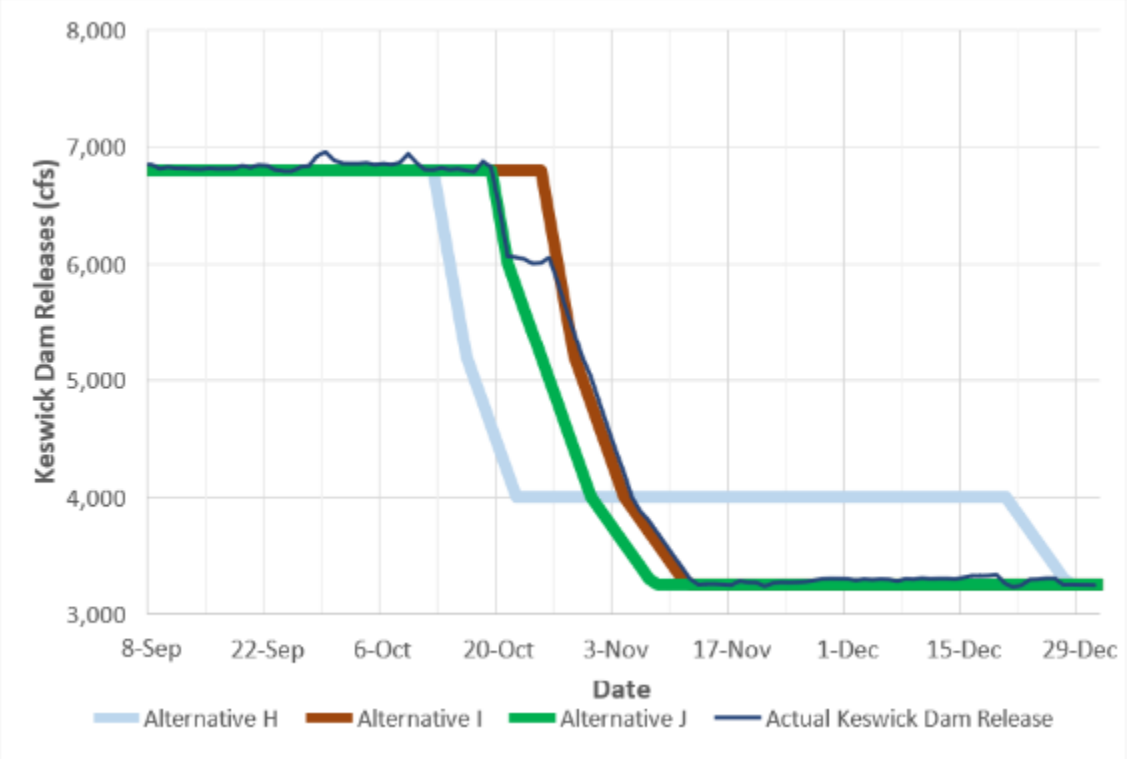

Figure 9. Fall flow reduction alternatives and actual Keswick Dam releases for September through December 2021.

Figure 9 displays fall flow reduction alternatives and actual Keswick Dam releases from September through December 2021. All scenarios begin near 6,800 cfs before declining in late October–November. Alternative H steps down gradually to approximately 4,000 cfs then 3,250 cfs, while Alternatives I and J and the actual release decline more steeply to approximately 3,150 cfs by early November, remaining there through December.

Spring Pulse Flows

The USST first met in March and April 2022 to discuss spring pulse flows. In both months, the 90 percent exceedance forecasts for May 1 storage in Shasta Lake was 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 and April 2022. Due to dry hydrology and low storage, the group did not recommend a spring pulse flow action in either month.

Collection of environmental and fish variables are 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. Monitoring relevant to the spring pulse flow includes acoustic telemetry, rotary screw traps, and environmental parameters. Real-time data analytics for tagged salmonids are accessible via the Enhanced Acoustic Telemetry for Salmon Monitoring site for each group, and the website provides a preliminary assessment of salmonid survival in real-time. This CalFishTrack web page has preliminary survival, routing, distribution, and travel time for salmonids released in winter and spring 2022 irrespective of implementation of a spring pulse flow.

Fish 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 redd dewatering, 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 and Sacramento River Chinook salmon redds are identified through a combination of aerial and boat-based surveys completed throughout each run's 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 Chinook salmon redd dewatering and schedule Keswick Dam releases which would minimize the potential for fall-run Chinook salmon redd dewatering. Stage discharge relationships allow the group to predict which redds are likely to dewater with a given flow reduction. Winter-run redd dewatering estimates have not reached 0.1% of total estimated redds over the last nine years that redd dewatering has been monitored.

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. In 2021, the flow schedule from Alternative J was largely implemented as scheduled, with some variance due to meteorological considerations. The daily average flow on the Sacramento River at Keswick Dam (KWK) in 2021 and average spawn timing for winter-run and fall-run Chinook salmon are shown in Figure 10 and Figure 11. Data for freshly spawned female carcasses of winter-run Chinook salmon were averaged for a time period of 2000 – 2021. Data for freshly spawned female carcasses of fall-run Chinook salmon were average for a time period of 2003 – 2021. On average, the majority of carcasses for winter-run Chinook salmon were observed from mid-June through mid-August. The high flows in July may have induced spawning at higher elevations, resulting in an increased redd dewatering risk in the fall. However, the proportion of the population of winter-run Chinook salmon redds dewatered in 2021 was low (0.03 percent). On average, the majority of carcasses for fall-run Chinook salmon are observed in mid-October through mid-November. During this period in 2021, Keswick Dam releases were steadily declining until reaching the minimum release on November 13, 2021. The proportion of the population of fall-run Chinook salmon redds dewatered in 2021 was lower than the previous year than the average (2011-2021 average = 2.07 percent; 2021 value = 2.45 percent; 2020 value = 3.13 percent). Additional information on redd dewatering is provided in the Performance section below.

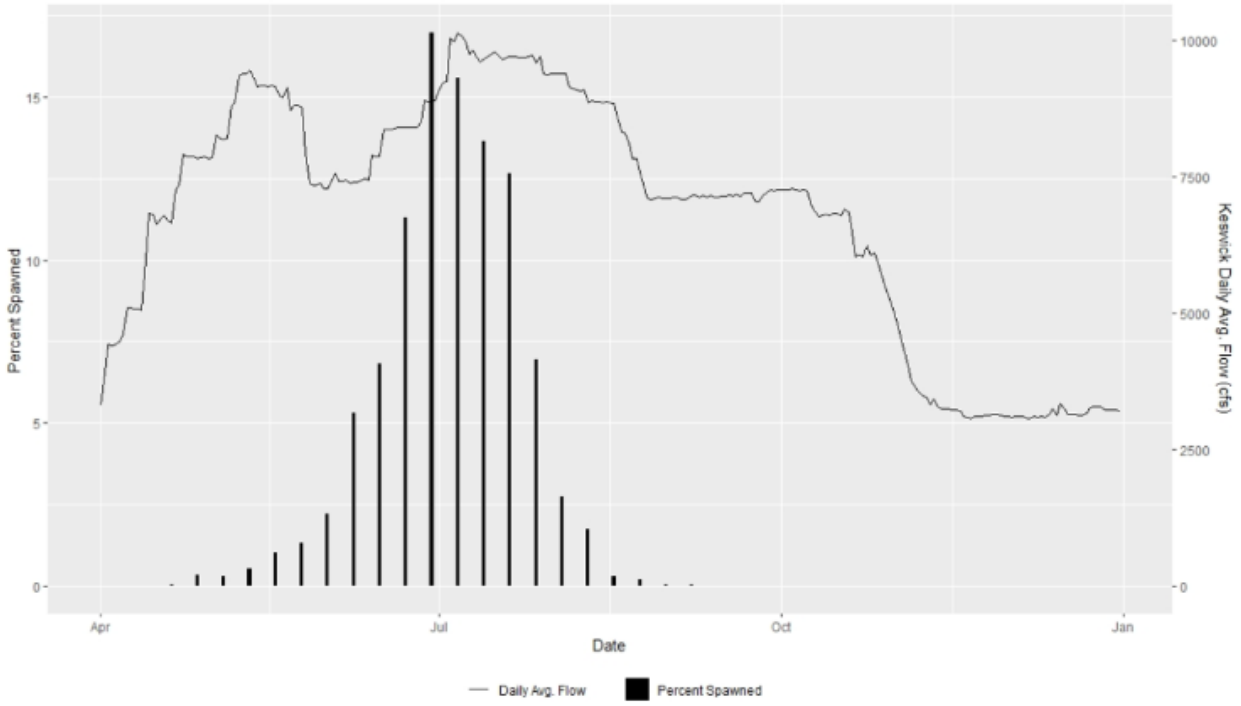

Figure 10. Winter-run Chinoook salmon fresh spawned female carcasses (2000 – 2021) and Sacramento River at Keswick Dam (KWK) daily average flow (cfs) from April through January 2022.

Figure 10 displays winter-run Chinook salmon percent spawned (black bars) and daily average flow at Keswick Dam (gray line) from April through January 2022. Flow rises from approximately 5,000 cfs in spring to a peak near 10,000 cfs in summer before declining steeply in fall to around 2,500 cfs. Spawning activity concentrates between June and August, peaking near mid-July, and tapers off by September.

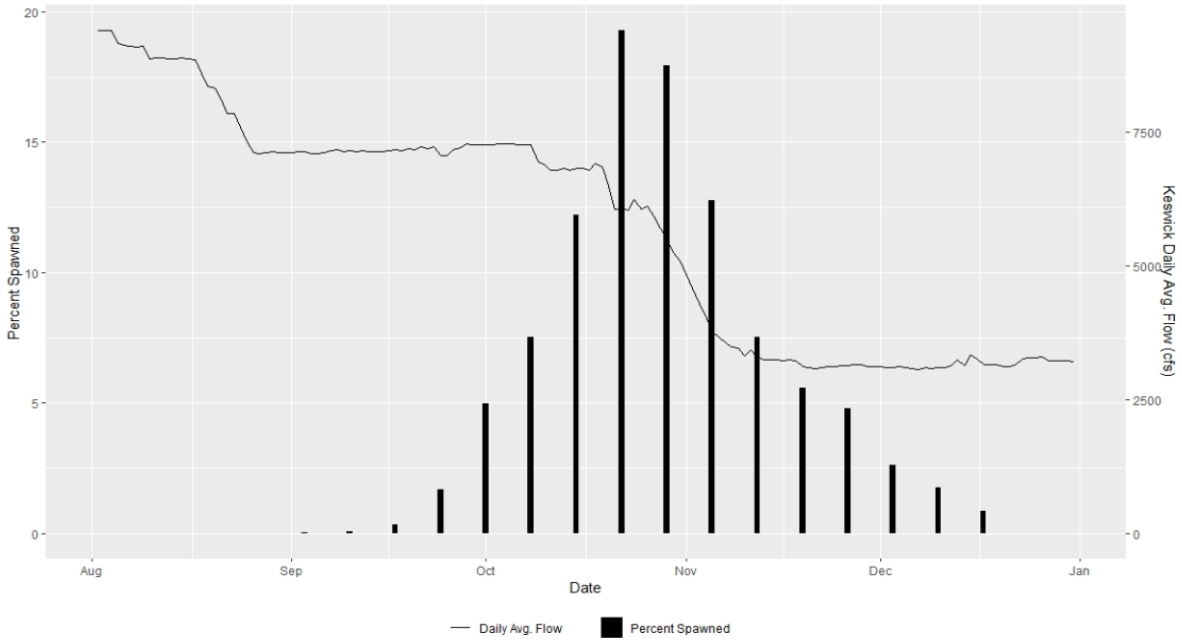

Figure 11. Fall-run Chinook salmon fresh spawned female carcasses (2003-2021) and Sacramento River flow at Keswick Dam (KWK) daily average flow (cfs)from August 2021 through January 2022 and Sacramento River fall-run Chinook salmon carcass observations.

Figure 11 displays fall-run Chinook salmon percent spawned (black bars) and daily average flow at Keswick Dam (gray line) from August 2021 through January 2022. Flow declines steadily from approximately 7,500 cfs in August to around 2,500 cfs by November, remaining low through January. Spawning activity is minimal through September, increases through October, and peaks in early-to-mid November before tapering through December and January.

Operations Summary

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

- Dry Hydrology and Low Runoff: While October and December 2021 had above average precipitation, January through March 2022 was the driest three month period on record. Water supply indices reported the Sacramento River Unimpaired Runoff was a “Critical” year for the Sacramento Valley Index.
- SRSC Water Transfers: This action supported cold water temperatures downstream of Keswick Dam for winter-run Chinook salmon during the summer of 2021. While there was a cold water benefit in the summer, there were tradeoffs in the early fall that led to higher than anticipated redd dewatering, Early season projections made in April 2021 underestimated the total water transfer volume by about a third, and minimum releases were not reached until mid-November.

- Shasta Storage: By late March 2022, 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. The May 1 storage in Shasta Lake was 1.81 MAF, approximately 47.5 percent of the average.
- Spring Pulse Determination: Since the projected May 1 storage of Shasta Lake was less than 4 MAF (indicating insufficient cold water pool for a Tier 1 year), a Spring Pulse flow was not pursued in order to protect the cold water pool for the 2022 water temperature management season.

Performance

This section describes the success of Shasta Lake storage rebuilding efforts and Chinook salmon redd dewatering numbers from fall 2021. Spring pulse flow outcomes are not discussed since the action was not taken in WY 2022.

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 2022 is shown in Figure 12. In WY 2022, Shasta Lake had slightly more cumulative inflow than WY 2014; however, WY 2020, 2021, and 2022 have three of the lowest cumulative inflow volumes for the period of record 2009 – 2022. Shasta Lake cold water pool volumes for WY 2022 are shown in Figure 13. As of May 2022, cold water pool volumes in WY 2022 are less than half of the average (1998 – 2021).

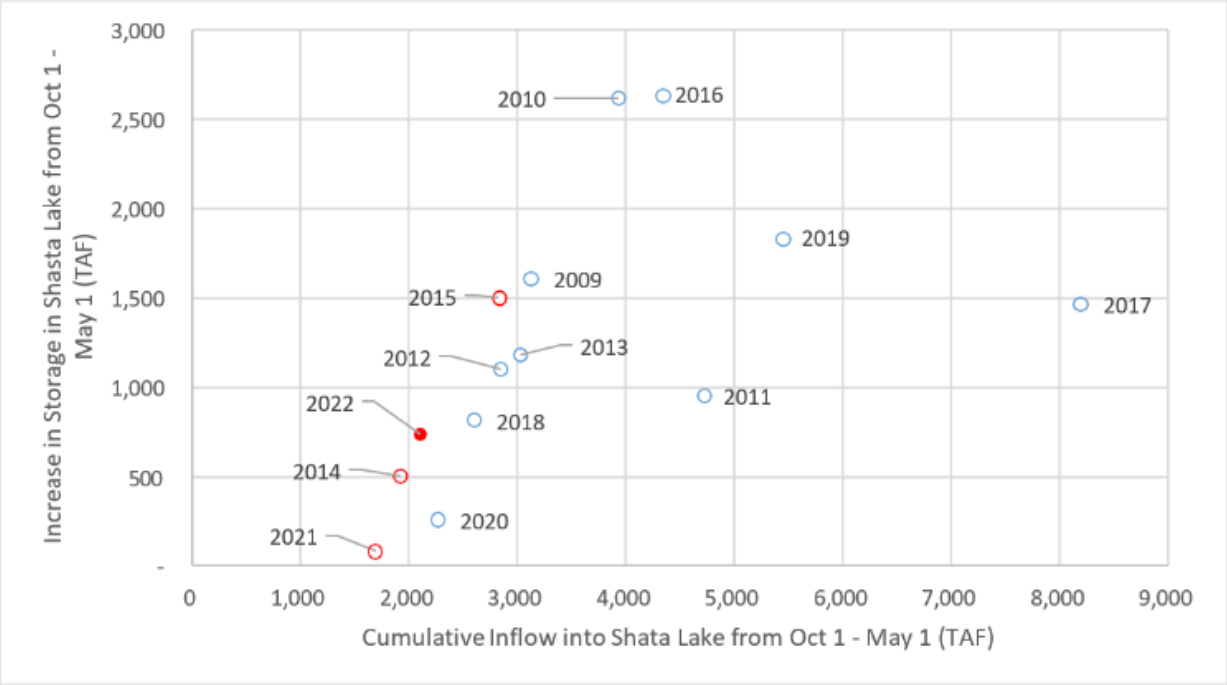

Figure 12. Shasta Lake Storage Performance from WY 2009 – WY 2022. Critically dry water year types are shown in red; all others are shown in blue.

Figure 12 displays Shasta Lake storage increase versus cumulative inflow from October 1 through May 1 for water years 2009–2022, with critically dry years shown in red and all others in blue. Critically dry years (2014, 2021, 2022) cluster in the lower left, reflecting both low inflow and minimal storage gains. Wet years such as 2017, 2019, and 2016 show high inflows but moderate-to-low storage increases, while 2010 and 2016 achieved the greatest storage gains relative to inflow.

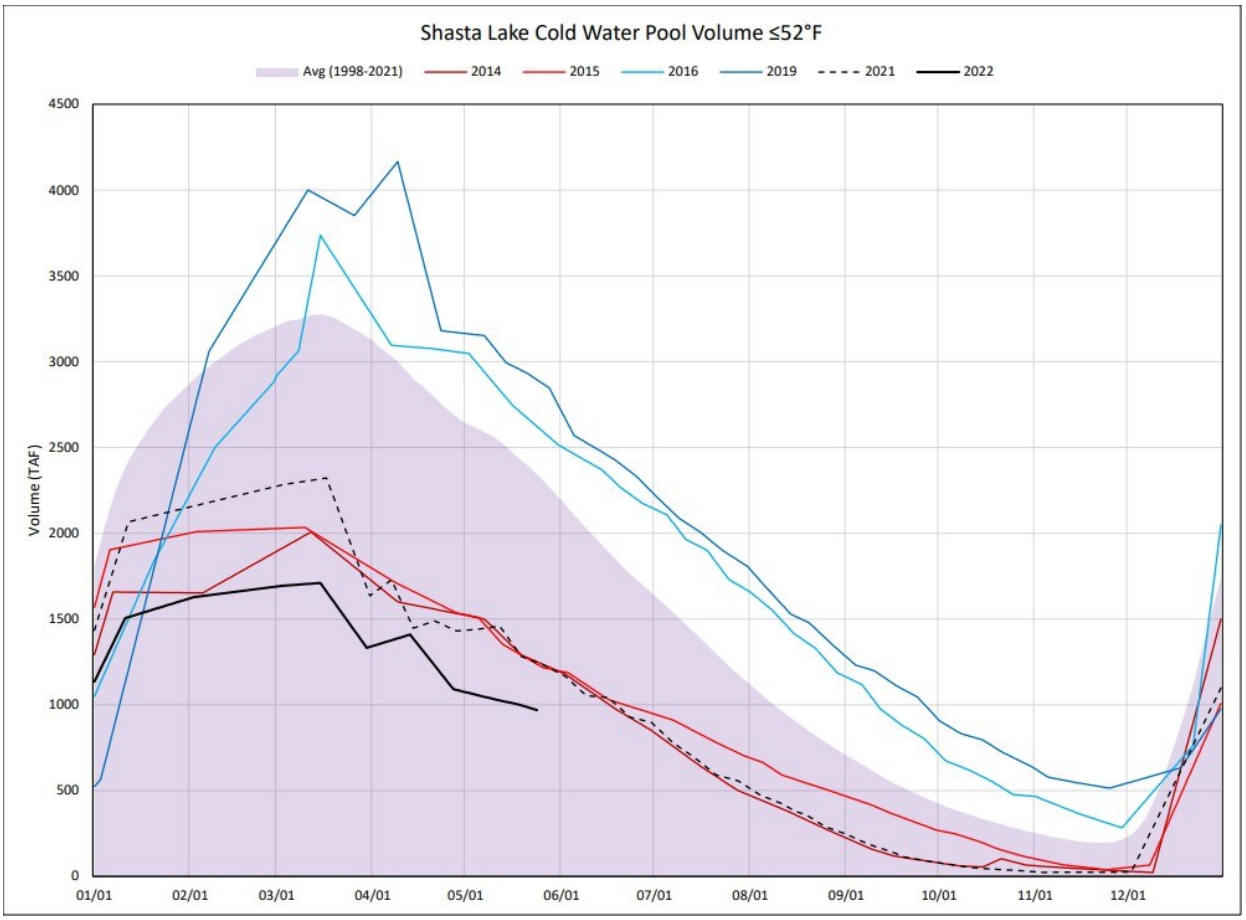

Figure 13. Shasta Lake cold water pool volumes <52 degrees F for select years and WY 2022 (as of May 22, 2022).

Figure 13 displays Shasta Lake cold water pool volume at or below 52°F for select years and WY 2022 through May 22, 2022. The 1998–2021 average (purple shaded) peaks near 3,000 TAF in spring before declining through fall. WY 2016 (blue) substantially exceeds the average, peaking above 4,000 TAF, while WY 2022 (black) and the critically dry years 2014 and 2015 (red) remain well below average throughout, with WY 2022 declining to approximately 900 TAF by May.

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 projected 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 J was selected as the preferred alternative.

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 (0.03 percent) of winter-run Chinook salmons redds were dewatered during the summer/fall 2021. Reclamation did not exceed this take limit (Table 8).

In Brood Year 2021, the estimated total number of winter-run Chinook salmon female spawners that spawned within the Sacramento River was 5,860 (Table 8). In 2021, 68 winter-run Chinook salmon shallow water redds were monitored and two redds were dewatered. The proportion of the population of winter-run Chinook salmon redds dewatered in 2021 (0.03 percent) was less than each of the previous three years (2018, 2019, 2020).

In 2021, the estimated total number of fall-run Chinook salmon female spawners that spawned within the Sacramento River was 4,001 (Table 9). In 2021, 145 shallow fall-run Chinook salmon redds, constructed in two feet of water or less, were monitored. 99 fall-run Chinook salmon redds were dewatered. The proportion of the population of fall-run Chinook salmon redds dewatered (2.45 percent) was less than the average of previous years' data ([3.13 percent; Table 9).

In 2021-2022, the estimated total number of late-fall-run Chinook salmon female spawners that spawned with the Sacramento River was not quantified (Table 10). Shallow and dewatered redd information for the 2021-2022 season was not collected due to river conditions not allowing the annual survey.

Table 6. Summary of dewatered redd information for mainstem Sacramento River winter-run Chinook salmon redds from 2013-2021. 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).

Year	Shallow Redds Actively Monitored	Dewatered	Total Redds	Proportion of Shallow Water 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%

Year	Shallow Redds Actively Monitored	Dewatered	Total Redds	Proportion of Shallow Water Redds Dewatered	Proportion of Population Redds Dewatered
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%
2021	68	2	5,860	3%	0.03%

Table 7. 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).

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%
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	171	5,455	28%	3.13%
2021	145	98	4,001	68%	2.45%

Table 8. 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). 2021-2022 data on total redds is not available because no surveys took place due to river conditions.

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%
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	n/a	n/a	676	n/a	n/a
2021-2022	n/a	n/a	TBD	n/a	n/a

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. In most years, there is a demand for fall rice decomposition water; however in fall of 2021, essentially no rice decomposition water was used.
- 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, Water Operations Management Team (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. The 2021 Drought and Dry Year Actions Report can be found at: https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/State-Water-Project/Endangered-Species-Protection/2021-Drought-and-Dry-Year-Actions-Report_FINAL_ay11.pdf

- 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. A subgroup of the USST met from July – October 2021 and developed a final research strategy to inform this effort. The meeting notes and research strategy can be found at the Spring Management of Spawning Locations website.

Discussion

One of the drought actions implemented in 2021 was an agreement to retain a portion of SRSC water in Shasta Lake during the spring in order to provide cold water pool benefits for winter-run Chinook salmon; this water would be delivered later in the season instead. In order to meet the SRSC water transfer volume in the fall, Keswick Dam releases were held higher for a longer period, which complicated fall-run Chinook salmon redd dewatering. Fall-run Chinook salmon redd monitoring showed that the fall Keswick Dam release schedule in 2021 resulted in 2.45 percent of total redds being dewatered.

WY 2022 is the third consecutive dry year and the January through March timeframe was the driest on record. Available forecasting methods, parched watershed soils, and extremely low rainfall with continued dry and warm conditions challenged Shasta Dam operations. May 1 storage was 1.81 MAF. In WY 2022, Shasta Lake had slightly more cumulative inflow than WY 2014; however, WY 2020, 2021, and 2022 have three of the lowest cumulative inflow volumes for the period of record 2009 – 2022.

In WY 2022, 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.

Short-Term Improvements

Monitoring Improvements

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). The forecasts for fall-run Chinook salmon dewatering could possibly benefit from updated bathymetry which may have changed over the past 15 years, and fish habitat use has changed since the opening of the RBDD gates. Recent measurements and modeling from Keswick to Clear Creek will be extended to Red Bluff in the next couple of years.

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 would be to develop better tools (spreadsheets, web applications, etc.) that can quickly forecast redd dewatering for different flow scenarios. Currently there can be a lag between getting new redd depth survey information, manually recalculating the redd dewatering, and reporting it out to the USST/SRTTG. Standardizing or smoothing out this process could help seasonal planning and real-time management.

CalFish

CDFW Upper Sacramento River Basin Salmonid monitoring data can be found at the CDFW Upper Sacramento River Basin Salmonid Monitoring website.

The total number of redds and final redd dewatering estimates for winter-run Chinook salmon are calculated at the end of the season after the mark recapture estimate and downstream redd (if any) expansions are developed. In order to track estimated redd dewatering in-season, an approach using the minimal redd counts could be used. The minimal redd count approach sums the number of total female spawners seen to date. By late July, it is typically known if the number of minimal redd counts will be greater than the total shallow redds as yet unexpired and be able to estimate the consequences of flow drops dewatering these shallow redds. While some number of winter-run Chinook salmon

spawn in August into very early September, these are typically very small percentages of the June/July counts.

In order to more easily track winter-run Chinook salmon redd dewatering during the fall, CDFW will now include the total minimal “raw” redd count as the season progresses. This count will give an indication of the minimum number of winter-run Chinook salmon redds that will be expanded as part of the final estimate and allow a “real-time” count for estimating the 1% take limit. In addition, CDFW provides actual monitoring of all winter-run Chinook salmon shallow redds with the possibility of being dewatered also in this file which allows users to focus in on the potential number to be dewatered as the season progresses based on future flow drops. Together these two sources provide tools to forecast the number of redds that might be dewatered as a result of flow management actions.

USST

The following are four process improvements for consideration in subsequent years. First, there could be improved coordination between agency representatives on the USST and the agency representatives on the SRTTG to ensure consistency. Second, the scope of the USST could be clarified to better understand the roles and responsibilities of the group, and to limit overlap with the SRTTG. Third, the USST could develop a process that better recognizes the pace of real-time operations such that agency representatives can review modeling results in advance of meetings. Lastly, the agency representatives of USST need to communicate with their agency WOMT representatives on which operational flow scenarios are being implemented.

Long-Term Improvements

No long-term improvements were identified for WY 2021.

Conclusion

The USST coordinated fall flow management in 2021 to minimize dewatering of Chinook salmon redds. In 2021, 2.45 percent of fall-run Chinook salmon redds were dewatered and 0.03 percent of winter-run Chinook salmon redds were dewatered. Water transfers likely benefitted winter-run Chinook salmon egg incubation by deferring the required releases from Keswick Dam; however, this created later season tradeoffs that complicated fall-run Chinook salmon redd dewatering. WY 2022 is a critically dry water year and May 1 storage at Shasta Lake was 1.81 MAF. No need was identified by the agencies for an independent panel review for WY 2022 as it pertained to Shasta Storage Rebuilding and Spring Pulse Flows.

References

Department of Water Resources, 2022a. Challenges of Forecasting Water Supply in a Hotter Climate. April 11. https://water.ca.gov/News/Blog/2022/April-22/Forecasting-Water-Supply-Hotter-Climate

DWR, 2022b. Bulletin B-120 for April 2022. http://cdec4gov.water.ca.gov/reportapp/javareports?name=WSFCastDiscussion.pdf

DWR, 2022c. California Department of Water Resources, California Data Exchange Center. Runoff Data for Water Year 2022. https://cdec.water.ca.gov/reportapp/javareports?name=FLOWOUT.202103 and https://cdec.water.ca.gov/reportapp/javareports?name=WSI

DWR, 2022d. California Department of Water Resources, California Data Exchange Center. 8-Station Precipitation Index. https://cdec.water.ca.gov/reportapp/javareports?name=TAB_ESI.pdf

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.

NOAA National Centers for Environmental information. Climate at a Glance: County Time Series, published April 2022, retrieved on April 15, 2022 from https://www.ncdc.noaa.gov/cag/county/time-series/CA-089/tavg/6/3/1895-2022?base_prd=true&begbaseyear=1895&endbaseyear=2021

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