# Shifting a Portion of Trinity River Spring Releases from Lewiston Dam to the Winter Period: A Flow Management Action to Benefit Juvenile Salmonid Habitat Availability, Growth, and Outmigrant Timing

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## Background

Congress authorized construction of the Trinity River Division (TRD) in Northern California for the Central Valley Project (CVP) in 1955 (Public Law 386, 84th Congress, 1st Session). TRD began operations in 1963, blocking 109 miles of important salmonid habitat above Lewiston and exporting as much as 90% of inflows of the Trinity River into Trinity Lake to the Sacramento River Basin (ROD 2000). Fisheries resource managers observed an almost-instantaneous decline in the numbers of naturally produced adult salmonids returning to spawn in the Trinity River basin (declines of 53-96%, depending on the salmonid species) (USFWS & HVT 1999).

In an effort to address the precipitous fishery declines, numerous pieces of legislation and a decades-long study led to the completion of the Trinity River Flow Evaluation study by USFWS and Hoopa Valley Tribe (1999) and the subsequent Trinity River Mainstem Fishery Restoration EIS/EIR (2000) and Record of Decision (ROD) (2000). The ROD recognized that salmon recovery required, "rehabilitating the river itself" by "restoring the attributes that produce a healthy, functioning alluvial river system" and selected a course of action that included variable annual instream flows, physical channel rehabilitation, sediment management, watershed restoration, and infrastructure improvements guided by an Adaptive Environmental Assessment and Management (AEAM) program.

Following the ROD, the U.S. Department of Interior (DOI) established the Trinity River Restoration Program (TRRP or Program) to restore the fisheries of the Trinity River affected by dam construction and related diversions. Administered by U.S. Bureau of Reclamation (USBR), TRRP is a partnership of federal and state resource agencies, Tribes, and Trinity County. The purpose of the Program is to mitigate impacts of the Trinity River Division of the Central Valley Project on anadromous fish populations in the Trinity River by successfully implementing the ROD and achieving congressionally mandated restoration goals (www.trrp.net). The long-term goals of the Program are to: 1) restore the form and function of the Trinity River; 2) restore and sustain natural production of anadromous fish populations in the Trinity River to pre-dam levels; and 3) to facilitate full participation by dependent tribal, commercial, and sport fisheries through enhanced harvest opportunities (www.trrp.net).

## Problem Statement

Flow regulation by dams on many California rivers has caused a distortion of the natural winter-flood, summer-drought hydrograph (Powers 1997). As a consequence, peak winter storm flows, particularly flows competent to mobilize riverbed substrates, are much reduced and summer base flows are artificially enhanced (Mount 1995). Flow regulation on the Trinity River after construction of the TRD removed nearly all high flows that are important for forming and maintaining the alluvial river and, notably, the scour by winter floods downstream of Lewiston Dam (Figure 1; USFWS & HVT 1999). Operation of the

TRD also changed the thermal regime of the Trinity River, providing warmer water temperatures during the winter and colder water temperatures during the late spring/summer than were present prior to the TRD because of hypolimnetic releases[1] from Trinity Dam (USFWS & HVT 1999).

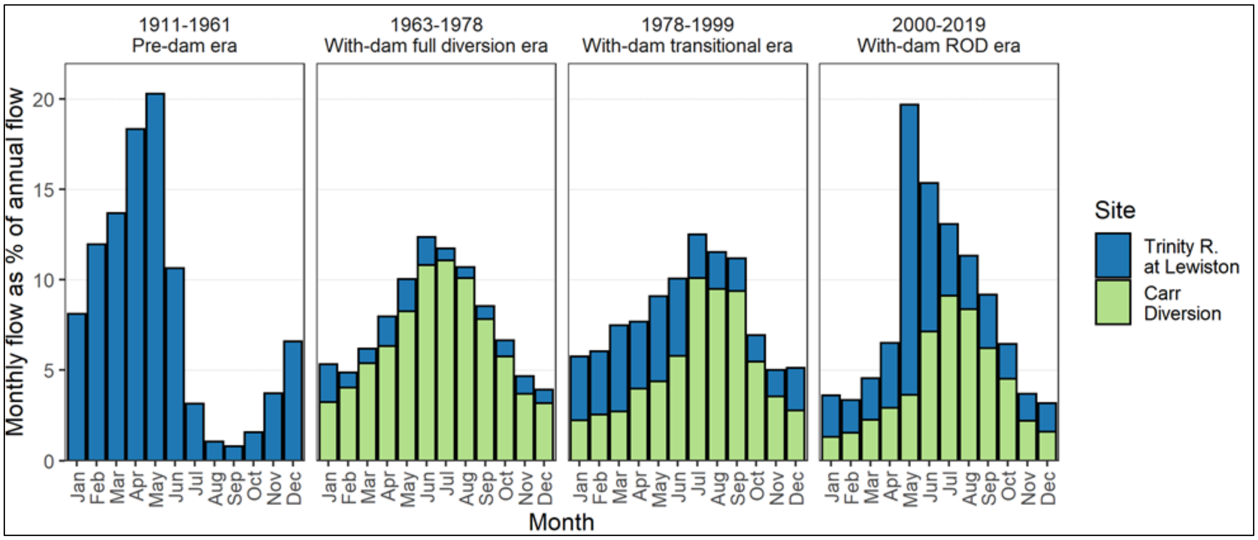


*Figure 1. Changes to the proportion of water upstream of Lewiston available to the Trinity River over time (from Asarian et al., in review).*

Variable annual instream flows (aka restoration flows or restoration releases) were first implemented by TRRP in 2004. ROD-recommended flow releases attempt to mimic snowmelt hydrology, create a more natural cycle of flow variability, promote alluvial processes, and provide water temperature and habitat benefits for fisheries resources (TRRP 2013). These restoration releases occur after the water year type[2] is determined in mid-April[3], based on an approved hydrograph developed by TRRP. Variable releases typically extend to early summer before returning to baseflow conditions and then remain at baseflow until the following April when a new water year is determined.

As implemented, the vast majority of flow is released after April 15 (Figure 1, ROD era), followed by a baseflow of 300 cubic feet per second (cfs) for seven months of the year (October to April), when unregulated streams in the region generally experience their largest and most variable flow events (Figure 1, pre-dam era). Undammed tributaries to the Trinity River naturally flow higher during winter storm events, and as high-elevation snowpack melts in early spring. Thus, natural flow contributions to the Trinity River from its tributaries are often receding by the time ROD flow releases from Lewiston Dam occur after mid-April (Figure 2).

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[1] The crest of Trinity Dam stands at an elevation of 2,370 ft., but the dam's outlet works intake is deep in the impoundment at an elevation of 2,100 ft. The reservoir thermally stratifies, forming a cool bottom layer known as the hypolimnion or cold-water pool, at the depth of the outlet works intake structure.

[2] TRRP uses five water year types to determine how much water will be available to the Trinity River each year. The five water year types are: Critically Dry, Dry, Normal, Wet, and Extremely Wet. A wetter water year means more water is available for restoration flow releases.

[3] The water year type is determined by the California Department of Water Resources' B120 (ca.gov) water supply forecast.

The thermal regime issue identified by USFWS and HVT in 1999 due to the hypolimnetic releases from Trinity Dam has not been resolved through the implementation of restoration releases. In fact, thermal impacts in late spring and early summer now extend farther downstream due to high magnitude flow releases under ROD management. Modifying the dam to include a temperature control structure or installation of a bulkhead with a multi-level intake structure would come at significant expense and is not currently being considered by USBR. Being limited to hypolimnetic releases is an operational reality when implementing variable flows in the Trinity River.

The asynchrony between flow management and the natural variability of pre-dam flows has cascading impacts on the river's form and ecology, and perhaps the most detrimental of the impacts is to young salmon. Pacific salmon's life history has adapted to the natural seasonal variability of flows and water temperature for millions of years (Groot & Margolis 1991). Current flow management keeps river conditions unnaturally cold, which suppresses metabolic rates during the key period of growth for young salmon. Later in the spring, the unnaturally cold river delays environmental cues that trigger smolts to outmigrate to the ocean before conditions in the lower Klamath River become too warm to support salmon migration. Maintaining baseflow through mid-April under current flow management also means that the inundation of rearing habitat, including floodplains, side channels and alcoves constructed by TRRP, does not occur until the majority of parr are downstream of the restoration reach (Petros et al. 2017).

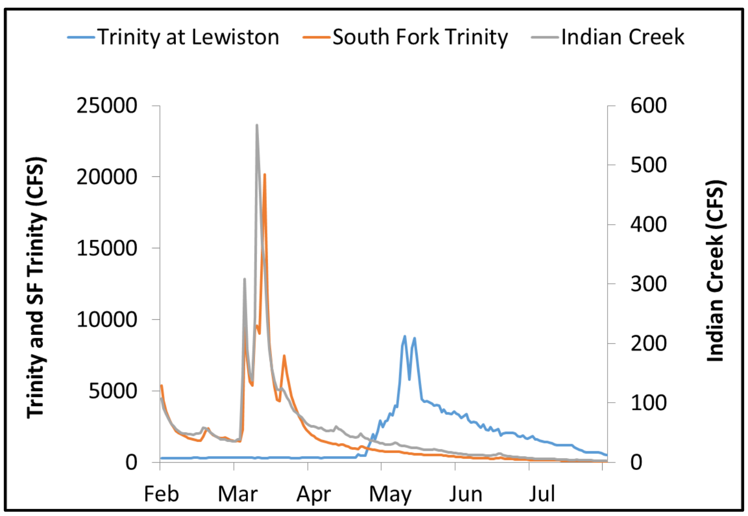


*Figure 2. 2016 hydrograph comparing flow timing of two tributaries to the Trinity River (South Fork Trinity and Indian Creek) to dam releases at Lewiston.*

# Objectives

•Increase growth of salmon fry and parr
•Synchronize flows of the regulated mainstem with its free-flowing tributaries
•Provide thermal cues for smoltification and downstream migration earlier in the year
•Increase nursery habitat availability for juvenile salmon
•Provide seasonally appropriate disturbance of the macroinvertebrate prey species for rearing salmonids
•Reduce effects of temperature suppression on growth of rearing salmonids
•Improve geomorphic response to restoration releases in areas where the greatest habitat gains can be achieved

## Proposed Action

Purpose and Need Statement: *To refine the timing of restoration flows using the principle of AEAM to better meet geomorphic, fish habitat, temperature, and floodplain habitat objectives of the ROD.*

The Implementation Plan and AEAM Plan, included as Appendix C of the 2000 Final EIS, states that the TRRP "will provide recommendations for the flow modifications for the Operations Criteria & Plan of the TRD of the Central Valley Project, if necessary." The ROD further describes that these recommendations are to be "based on subsequent monitoring and studies guided by the Trinity Management Council, the schedule for releasing water on a daily basis, according to that year's hydrology, may be adjusted but the annual flow volumes established in Table 1 [volume by water year class] may not be changed." As stated in the Trinity River Flow Evaluation Study (1999), "No high-flow release(s) are planned, but synchronization of peak releases with stormflows should be evaluated through the adaptive management program to assess opportunities to maximize benefits of high-flow releases while conserving water." The Proposed Action is in keeping with TRRP's foundational documents.

TRRP proposes to shift a portion of ROD flows to the winter period as an initial step towards natural flow variability in the regulated river system. Intended benefits of this action to the growth and survivability of juvenile salmon include inundating floodplains and other productive off-channel rearing habitats prior to fry emergence, reducing the effects of temperature suppression caused by high magnitude dam releases in late spring and early summer, creating seasonally appropriate disturbance of macroinvertebrate prey species to promote primary production and drift foraging opportunities, and providing thermal cues that encourage smolts to outmigrate prior to deterioration of environmental conditions in the lower Klamath River by allowing the river to warm earlier. Intended geomorphic benefits of this action include timing restoration releases when tributary events are likewise delivering flow and sediment to the mainstem and increasing bedload transport in reaches below Douglas City where the greatest habitat gains could be made through high-magnitude flow events. Under the Proposed Action, USBR would shift a portion of the ROD water for release during the winter to two distinct periods termed the Flow Synchronization Period and the Elevated Baseflow Period (Figure 3).

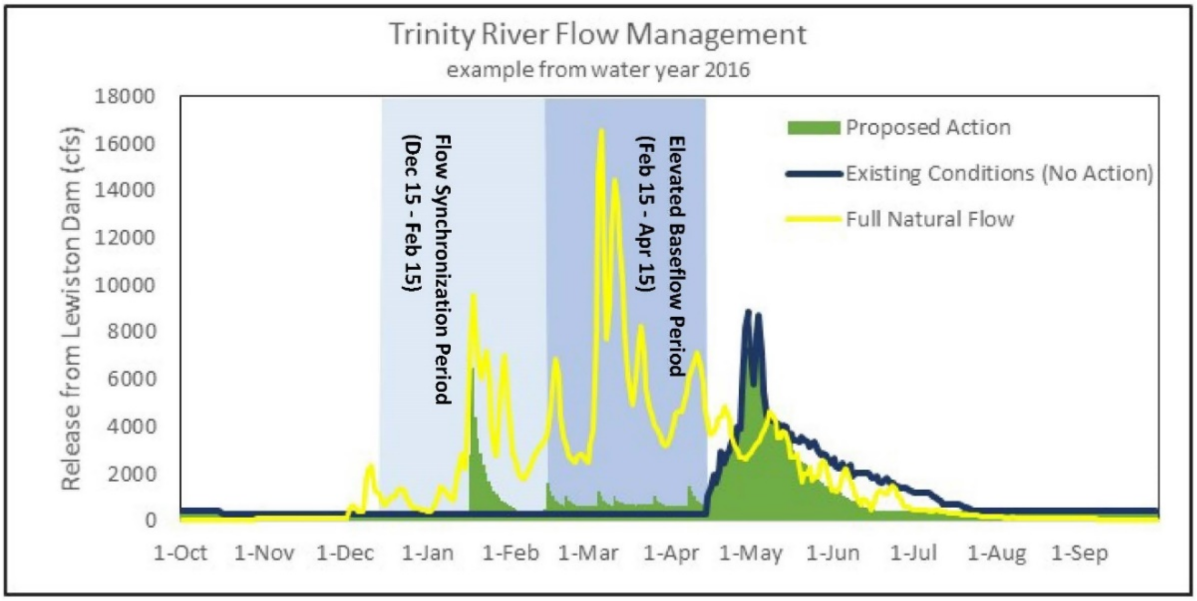


*Figure 3. The Proposed Action to current flow management, using the wet water year in 2016 as an example. The blue line represents the hydrograph that was implemented in 2016. Green represents the timing of hypothetical water releases that could occur under the Proposed Action. This graph also shows the full natural flow[4] (in yellow) from the 2016 water year for perspective.*

## Flow Synchronization Period

The purpose of the proposed flow action during this period is to synchronize a high magnitude dam release with a winter high flow event in the tributaries to mimic elevated flows that would have likewise occurred in the mainstem from the blocked watershed area above Lewiston Dam. Between December 15 and February 15, ROD water equivalent to 60,000-acre-feet (af) would be released from Lewiston Dam when forecasting tools at the North Fork gage anticipate a rise in river levels of 4,500 to 12,000 cfs. USBR set 6,500 cfs as the maximum flow from Lewiston Dam during this period when TRRP began investigating the winter flow action, and 60,000 af was determined to be the volume required for a peak of that allowed magnitude when EIS ramping rates for the ascending limb and naturally observed ramping rates on the descending limb were applied. Under current floodway infrastructure constraints, if the flow forecast exceeds 12,000 cfs at the North Fork gage, the synchronized flow release of 6,500 cfs would not be implemented until the receding limb of the flow event was predicted to be 12,000 cfs or less at the North Fork gage. Synchronizing flow releases from the dam to the receding limb of natural accretion events from tributaries is a more conservative approach that will avoid impacts to downstream properties and structures because there is no longer uncertainty in the peak magnitude of the flow event. Flow magnitude thresholds would be re-evaluated as floodway infrastructure constraints change.

[4] The full natural flow is the unimpeded contributions from the blocked watershed above Lewiston Dam which demonstrates when peaks in flow would have naturally occurred prior to dam construction.

The flow synchronization period would provide geomorphic benefits by increasing bedload transport to areas of the mainstem that have the highest potential for habitat gains and are more influenced by tributary accretions – generally below Douglas City, and by mobilizing tributary deposits from the accretionary event with elevated mainstem flows. Flow management in this period would also create seasonally appropriate disturbance (i.e., scour) of the macroinvertebrate community to promote primary production.

### Flow Forecasting during the Flow Synchronization Period

For implementing flow synchronization, the Program would need to know the uncertainty in the forecasts of streamflow to prevent flooding of downstream structures from synchronized releases. NOAA's California Nevada River Forecast Center (CNRFC) produces Hydrologic Ensemble Forecast Service (HEFS) products for use by water management agencies, such as the following example for New Bullards Bar in the Yuba River: https://www.cnrfc.noaa.gov/ensembleProduct.php?id=NBBC1&prodID=2. Notice this product is strongly predictive even four days prior to precipitation events, allowing the 72-hour notice that TRRP would provide USBR to orchestrate a winter synchronization event. The TRRP has requested this product be created for the Trinity River gage above the confluence of the North Fork because all major tributary accretions contributing to flood events in the TRRP focal reach enter the river by that point.

## Elevated Baseflow Period

Between February 15 and April 15 under the proposed action, ROD water would be released from Lewiston Dam based on, and in proportion to, the Department of Water Resource's 90% exceedance B120 water supply forecast[5]. Using the 90% exceedance B120 would prevent the overuse of ROD water should the water year end up being drier than expected.

The Program would rely on the Decision Tree (Appendix 1) to determine the volume of water appropriate for release twice annually during the elevated baseflow period; the first time with DWR's posting of the February B120, and the second with the posting of the March B120. DWR typically makes the B120 available about 8-10 days after the beginning of the new calendar month. The first point of divergence in the decision tree accounts for whether a 60,000 af flow trigger occurred during the Flow Synchronization Period. Accounting for that volume and whether it was released in the Flow Synchronization Period determines whether an additional release will occur from Lewiston Dam in February, based on the B120's prediction of the water year type. For example, if a flow trigger of 60,000 af did occur, the prediction of Dry or Critically Dry would mean no February release, while a Normal water year prediction would implement an additional 60,000 af release and a Wet or Extremely Wet water year prediction would prescribe a 120,000 af release. Should no weather event occur that would initiate a flow trigger during the Flow Synchronization Period that year, a B120 water year prediction of Critically Dry or Dry would result in a 60,000 af release in February, a Normal water prediction a 120,000 af release, and a Wet or Extremely Wet prediction a 180,000 af release.

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[5] The 90 percent exceedance B120 water supply forecast indicates that there is a 90 percent chance that the water supply will exceed the forecast, and a 10 percent chance that it will fall short of the forecast.

The process described in the above paragraph for February would be repeated the following month with DWR's posting of the 90% exceedance B120 water supply forecast. The Decision Tree guides the Program on the volume of release to be implemented, but it should also be considered a balance sheet that ensures the volume shifted during the winter period will represent the March 90% B120 prediction of water year type, and that volume prescribed in the winter period for that water year type is consistent across years (Table 1, third column). In other words, regardless of whether a flow trigger of 60,000 af was implemented, the overall volume of 120,000 af would be shifted to the winter period when the March 90% B120 water supply forecast predicts a Normal water year (Table 1, third column). This flow management action has been designed to safeguard against the possibility that the actual water year determination (made in April each year) ends up being less wet than predicted, as the overall volume of water to be shifted to the winter period (Table 1, fourth column) is considerably less than the ROD volume for that water year type. Much of the reason behind this initial winter flow management action would be to determine the degree of risk and the operational capability to pursue natural flow variability in the TRD while strictly adhering to ROD volumes.

Prior to this period, hydrographs would be developed by TRRP to schedule the elevated baseflow releases for the range of forecasts that could be expected.

| Water Year Type | ROD Water Volume (af) | ROD Volume Shifted to Winter Period under Proposed Action (af) | Percent ROD Volume Shifted from Summer to Winter under Proposed Action |
|---|---|---|---|
| Critically Dry | 369,000 | 60,000 | 16 |
| Dry | 453,000 | 80,000 | 18 |
| Normal | 647,000 | 120,000 | 19 |
| Wet | 701,000 | 180,000 | 26 |
| Extremely Wet | 815,000 | 220,000 | 27 |

*Table 1. Water volumes shifted under the proposed action for each water year type.*

## B-120 to Predict Water Year Type during Elevated Baseflow Period

Under the Proposed Action, additional baseflow increases would occur during the Elevated Baseflow Period after February 15, based on the predicted water year type. Since the implementation of ROD flows in 2004, the February and March 90% exceedance B-120 water supply forecast has never overpredicted the observed water year determination (Table 2). Table 2 shows that the B-120 often underestimates the April water year determination. This is denoted by the negative values of -1 and -2 in numerous years; a -1 in the "February Comparison to Observed" column for 2004, for example, means that a Normal water year was predicted when a Wet water year was observed. Likewise, in 2006 the February 90% exceedance B-120 water supply forecast predicted a Normal water year but the observed was Extremely Wet (-2). Using the B-120 90% confidence prediction to determine water volumes for elevated base flows after February 15 is conservative and would not result in "overspending" ROD volumes based on the available record.

| B-120 Water Year Predictions post-ROD | | | | | | | |
|---|---|---|---|---|---|---|---|
| Year | February 90% Forecast (taf) | February 90% Water Year Type | February Comparison to Observed | March 90% Forecast (taf) | March 90% Water Year Type | March Comparison to Observed | Observed Water Year Type |
| 2004 | 1050 | Normal | -1 | 1360 | Wet | 0 | Wet |
| 2005 | 910 | Dry | -1 | 920 | Dry | -1 | Normal |
| 2006 | 1278 | Normal | -2 | 1531 | Wet | -1 | Extremely Wet |
| 2007 | 550 | Critically Dry | -1 | 795 | Dry | 0 | Dry |
| 2008 | 813 | Dry | -1 | 880 | Dry | -1 | Normal |
| 2009 | 386 | Critically Dry | -1 | 643 | Critically Dry | -1 | Dry |
| 2010 | 386 | Critically Dry | -2 | 1055 | Normal | 0 | Normal |
| 2011 | 1040 | Normal | -1 | 1125 | Normal | -1 | Wet |
| 2012 | 425 | Critically Dry | -2 | 455 | Critically Dry | -2 | Normal |
| 2013 | 860 | Dry | 0 | 730 | Dry | 0 | Dry |
| 2014 | 145 | Critically Dry | 0 | 180 | Critically Dry | 0 | Critically Dry |
| 2015 | 600 | Critically Dry | -1 | 830 | Dry | 0 | Dry |
| 2016 | 1030 | Normal | -1 | 1085 | Normal | -1 | Wet |
| 2017 | 1515 | Wet | -1 | 1770 | Wet | -1 | Extremely Wet |
| 2018 | 500 | Critically Dry | 0 | 345 | Critically Dry | 0 | Critically Dry |
| 2019 | 810 | Dry | -2 | 1060 | Normal | -1 | Wet |
| 2020 | 635 | Critically Dry | 0 | 500 | Critically Dry | 0 | Critically Dry |

*Table 2. The reliability of DWR's B120 since the beginning of ROD restoration releases in 2004.*

## Spring ROD Releases

Under the proposed action, after April 15, the remaining ROD water would be released to the Trinity River using the same methodology that currently exists for the scheduling of restoration flows. Table 1 provides the restoration flow in acre feet and percent of restoration flow that would be shifted under each water year type. ROD objectives (i.e., peak magnitudes) can still be met under the Proposed Action by shortening the duration of the peak or truncating the receding limb of the historic hydrograph. In the 2016 water year example (Figure 3), shifting water to the winter period while maintaining peak flows after April was accomplished by truncating the receding limb so the river returned to 450 cfs summer baseflow by mid-June instead of the beginning of August.

# Justification for Winter Flow Action

## Habitat Availability

The timing of restoration releases is not conducive to juvenile fishes' use of naturally occurring and program-created rearing habitat (Table 3), as the lateral gains in rearing habitat occur when discharge increases and overspills from the river channel to the surrounding margins and floodplains (Table 4). Investigations into juvenile Chinook Salmon outmigration found that from 2003 to 2016, 60% (range 49% to 87%) had reared and outmigrated from the restoration reach prior to the increases in ROD flows at the end of April (Petros et al. 2017) and, thus, prior to any habitat gains above the 300 cfs baseflow (Table 4). As such, the majority of juvenile Chinook salmon are currently not able to access productive floodplains that provide habitat with vegetative cover, bolstering growth of juveniles (Sommer et al. 2005; Jeffres et al. 2008), nor can they take advantage of increases in drift forage opportunities that can occur with changes in discharge prior to outmigration.

| Year | % Outmigration (February 1) | Spring Flow Release Date | % Outmigration (release date) |
|---|---|---|---|
| 2003 | 11% | April 30 | 74% |
| 2005 | 14% | April 22 | 72% |
| 2006 | 0% | April 12 | 50% |
| 2007 | 0% | April 27 | 53% |
| 2008 | 1% | April 23 | 46% |
| 2009 | 2% | April 27 | 50% |
| 2010 | 8% | April 23 | 62% |
| 2011 | 14% | April 22 | 58% |
| 2012 | 1% | April 21 | 49% |
| 2013 | 5% | April 21 | 53% |
| 2014 | 0% | April 23 | 47% |
| 2015 | 16% | April 22 | 83% |
| 2016 | 46% | April 21 | 87% |
| Averages | 9% | April 22 | 60% |

*Table 3. Comparison of percent juvenile Chinook Salmon outmigration at Pear Tree rotary screw traps by Feb 1 and the percent juvenile Chinook outmigration by onset date for spring flow releases above winter baseflow (from Petros et al. 2017).*

| Discharge (cfs) | Change in Predicted 40-Mile Habitat Capacity | Habitat Units with Predicted Capacity Increases |
|---|---|---|
| 300 | 0 | 0 |
| 500 | 3% | 58% |
| 700 | 7% | 61% |
| 900 | 10% | 66% |
| 1100 | 14% | 72% |
| 1300 | 19% | 78% |
| 1500 | 25% | 81% |

*Table 4. Predicted change (%) in habitat capacity for the 40-mile restoration reach, and the percentage of individual habitat units within the restoration reach predicted to have increased habitat capacity (from USFWS & NOAA Memo 2018). Changes are relative to the 300 cfs baseflow discharge that is currently implemented in each year during the period targeted by the winter flow action.*

## Food Availability

River food webs benefit from riverbed scour caused by flood disturbance (Wootton et al. 1996; Parker & Power 1997). Shortly after flood scour, stream insects are dominated by fast-growing taxa (e.g., chironomids and mayflies) that are vulnerable to predation by juvenile fish (Parker & Power 1997). These early successional species are reduced over many months as larger, slow-growing taxa, which are less vulnerable to predation, increase contributions to invertebrate assemblages and reduce prey availability (Parker & Power 1997).

Periodic channel bed scour is an objective of spring variable flow releases on the Trinity River (EIS/EIR 2000), but the timing of these scour events (often in May) might not temporally support prey availability when juvenile fish are present in the upper river (Table 3). While these disturbance events have similar benefits in providing land-borne nutrients to the system and resetting primary production, increases in macroinvertebrate species productivity and drift foraging for juvenile fish are mostly beneficial in the near term. A study of food web response following a controlled flood on the Colorado River found that concentrations of invertebrate drift increased 148% in the months following disturbance (Cross et al., 2016), but drift, like primary succession following disturbance, is most impactful to food availability in the short-term.

The extent to which the asynchrony between natural hydrology and imposed ROD flows impacts the overall macroinvertebrate assemblage and biomass on the Trinity River is unknown, but it is likely that juvenile fish in the regulated Trinity mainstem cannot take advantage of the short-term responses in primary production and increased drift forage that often occur prior to and during fry emergence in unregulated systems. Peak densities of juvenile salmonid prey species (e.g., chironomids) have been shown to be higher in ephemeral habitats continuously inundated for between 5 and 10 weeks (Merz et al. 2012), but that duration of inundation is currently not accomplished when most juveniles in the focal reach are foraging in ephemeral habitats (Table 3). Furthermore, hypolimnetic releases from Trinity Dam artificially lower water temperature, which increases the generation time of important prey species. Chironomidae generation time drops from 36 days to 25 days when water temps are doubled from 7.5 °C to 15 °C, with Baetidae generation time dropping from 250 days to fewer than 100 days (Asarian et al., in review). The effects of cold-water releases are discussed further in the next section of this report.

## Temperature & Growth

Temperature is one of the most important environmental influences on salmonid biology (Carter 2006). Most aquatic organisms, including salmon and steelhead, are poikilotherms, meaning their temperature and metabolism are determined by the ambient temperature of the surrounding water (Carter 2006). Temperature targets are widely used by fishery managers to accommodate the various life stages of Pacific salmonids (Carter 2006). Table 5 shows the various temperature targets for the Trinity River.

| Source | Reach | Dates | Target |
|---|---|---|---|
| Basin Plan for the North Coast Region (North Coast RWQCB 2011) and WR 90-5 | Lewiston to Douglas City | July 1–September 15 | ≤60 °F (15.5 °C) |
| | Lewiston to Douglas City | September 15–30 | ≤56 °F (13.3 °C) |
| | Lewiston to North Fork | October 1–December 31 | ≤56 °F (13.3 °C) |
| Springtime Objectives of the ROD for the TREIS/EIR (USFWS et al. 2000) | Lewiston to Weitchpec | **Normal & Wetter Water Years** | |
| | | April 15–May 22 | ≤55.0 °F (12.8 °C) |
| | | May 23–June 4 | ≤59.0 °F (15.0 °C) |
| | | June 5–July 9 | ≤62.5 °F (17.0 °C) |
| | | **Dry & Critically Dry Water Years** | |
| | | April 15–May 22 | ≤59.0 °F (15.0 °C) |
| | | May 23–June 4 | ≤62.5 °F (17.0 °C) |
| | | June 5–July 9 | ≤68.0 °F (20.0 °C) |

*Table 5. Trinity River temperature "targets".*

Although these temperature values are often considered "objectives" or "targets", they are more accurately thought of as thresholds because any water temperature lower than those in Table 5 would suffice (Naman et al. 2020). Consistently low water temperatures are assumed by most fishery managers to be either positive or at least not harmful, but anomalously cool water can limit growth (Lusardi et al. 2019). A recent publication illustrates the potential synergy between seasonally warm and perennially cool habitats, with fish that traverse these two types of thermal habitats growing much more than fish that were restricted to either habitat alone (Armstrong et al. 2021), but seasonally warm thermal habitats are largely unavailable on the Trinity River until floodplains are inundated by ROD restoration flows in mid-April. Lusardi et al. (2019) found that juvenile coho salmon growth rates peaked at a mean water temperature of 16.6 °C and Maximum Weekly Maximum Temperature (MWMT) of 21.1 °C and were six times greater than those observed at the coolest reach, which exhibited a mean temperature of 13.0 °C and MWMT of 16 °C. Naman et al. (2020) recommended utilizing a 7-Day Average of the Daily Average (7DADA) of 13 °C -16.5 °C (55.4°F to 61.7°F) as rearing temperature targets in the Trinity River upstream of the North Fork Trinity River from April 1 – July 31, though currently the Trinity River does not have established temperature targets for juvenile rearing.

Recent Trinity River water temperatures at the North Fork Trinity River are shown in Figure 4, along with the recommended target range developed by Naman et al. (2020). Note that for most water year types, just as the Trinity River begins to achieve the recommended targets in the optimal rearing range for juvenile salmonids, there is a large reduction in temperatures of 5°F to 7°F that occurs in the end of April. This is due to the large volume of water that is released annually from Lewiston Dam in accordance with the TRRP restoration flow releases. In some cases, water temperatures are nearly 10°C less than the recommended juvenile salmonid rearing temperature range.

In many regions throughout the US, a positive relationship between stream order and water temperature has been reported, unless the stream has a high baseflow index (Segura et al. 2015). However, due to the constant releases from Lewiston Reservoir, as well as the current temperature thresholds imposed by regulatory processes, the mainstem Trinity River is now colder than most, if not all, of the tributaries upstream of the North Fork Trinity River. For example, in 2017 (Extremely Wet water year) and 2018 (Critically Dry water year), Rush Creek was often 10°C warmer than the mainstem Trinity River (Figure 5). Low water temperatures can mean slow fish metabolism and slower growth (Iwama & Tautz 1981). This is important because larger Chinook smolts are thought to have a better chance at survival during ocean entry (Pearcy 1992), as well as through the first ocean winter (Beamish and Manken 2001).

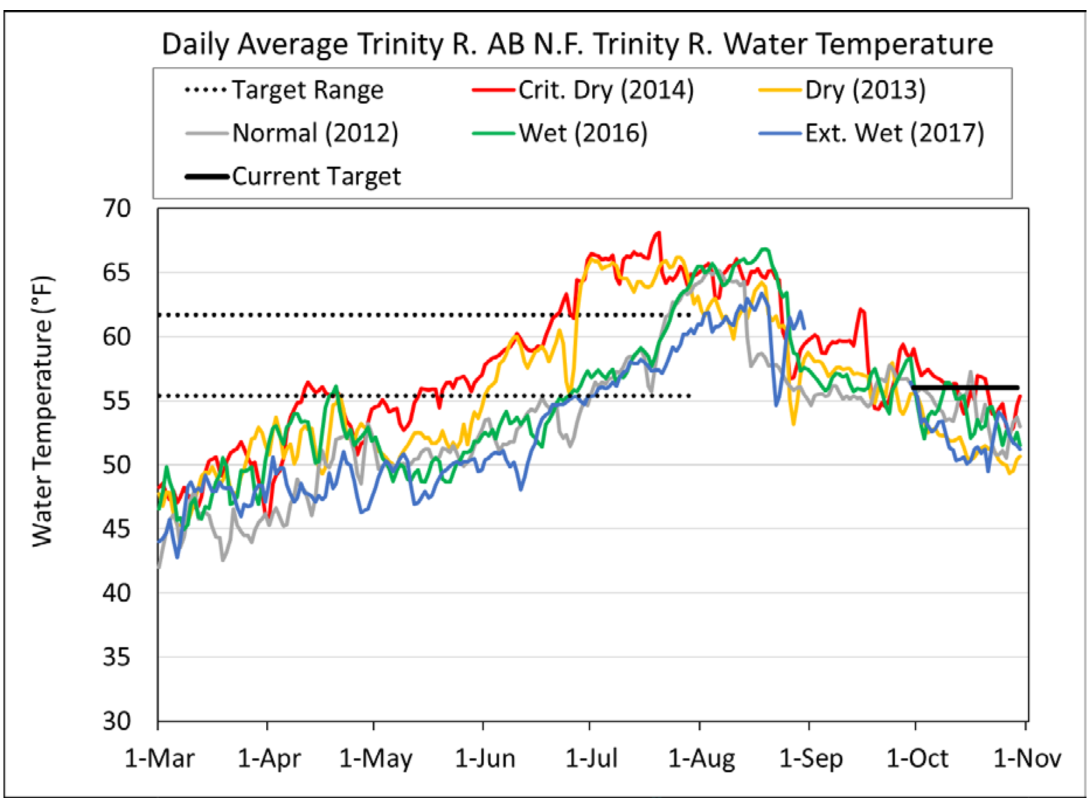


*Figure 4. Water temperatures for one of each of the five water year types in the Trinity River above the North Fork Trinity River. Note the 5°F to 7°F reduction in temperature that occurs in all water year types in the end of April coincident with the onset of TRRP restoration flow releases from Lewiston Dam (from Naman et al. 2020).*

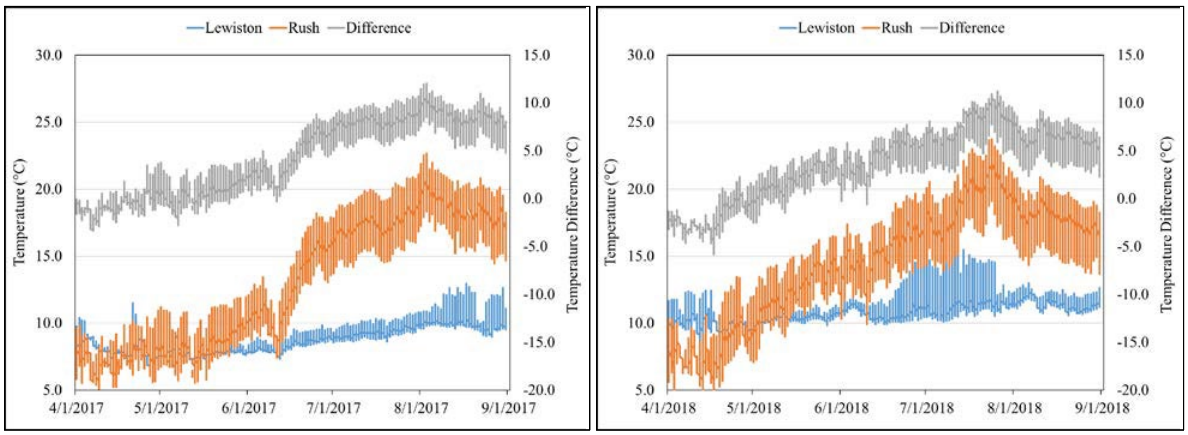


*Figure 5. Water temperature and temperature difference of the Trinity River at Lewiston and Rush Creek from April - September of 2017 (left graph) in an Extremely Wet year and 2018 (right graph) in a Critically Dry year (from Naman et al. 2020).*

Figure 6 depicts the temperature dependence function for Chinook salmon for the normal range of temperature recorded at the Pear Tree/Helena station during the modeling period (2005-2016) used by Thomas Gast & Associates (2021). The highest proportion of the maximum potential food consumption (Cmax) is achieved between 15 °C (59 °F) and 18 °C (64 °F). The proportion of Cmax (pCmax) that a Chinook can consume at 5 °C is approximately a third of that at 15 °C. Food consumption does not translate directly into growth since additional energy is required for metabolism, egestion, and excretion; however, the maximum potential for growth does occur at the temperatures where Cmax is near 1.0 (Thomas Gast & Associates 2021).

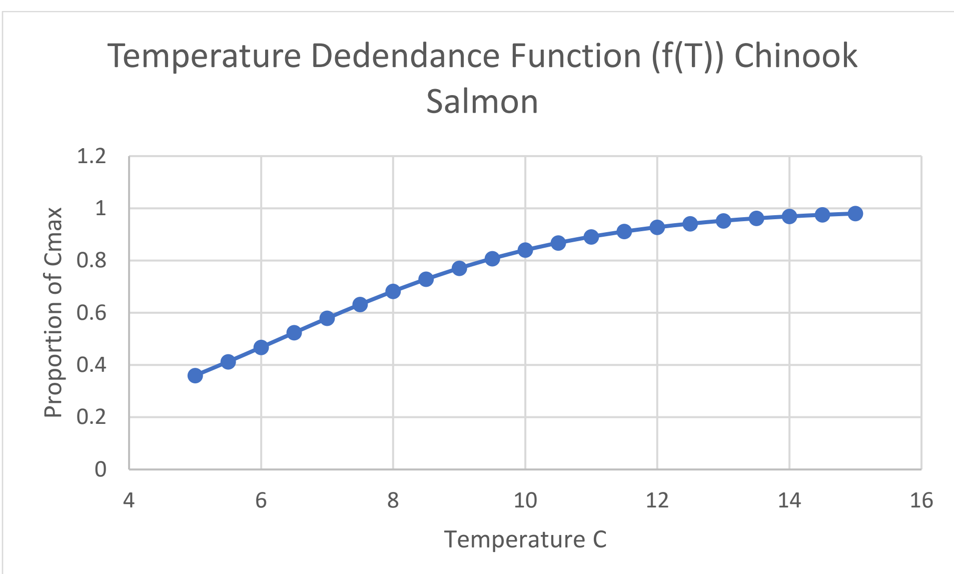


*Figure 6. Temperature dependence function for Chinook Salmon for the normal range of temperature recorded at the Pear Tree/Helena station during the 2005-2016 modeling period (from Thomas Gast & Associates 2021).*

Thomas Gast & Associates (2021) also developed a multiple regression model to assess the influences of population density and river flow on the total food consumption by juvenile Chinook Salmon caught at Willow Creek rotary screw trap in week 22, as predicted by the bioenergetics simulations (2005-2016). The results suggest that higher discharge in February, March and April positively influences consumption, whereas the number of redds and discharge in May negatively influence consumption (Figure 7). Discharge in April (+), discharge in May (-), and number of redds (-) were the most important factors. Including Year, either as a random or fixed effect, did not improve this model (likelihood ratio tests; p=0.158 and p=0.635), indicating that changes in consumption over time were best explained by the predictors in Figure 7.

To drive the point home on how elevated hypolimnetic releases post ROD have negatively influenced stream temperatures, Figure 8 demonstrates the effect of cold-water suppression on juvenile fish caught in the Willow Creek rotary screw trap by Julian week (Pinnix et al. 2021). Individual fork length values were pooled by week of the year across the pre-ROD (1989-2003) and post-ROD (2004-2018) periods for the Willow Creek trap site to create pre-ROD and post-ROD time series of mean weekly fork length of non-adipose fin-clipped age-0 Chinook Salmon. Only weeks of the year 10-39 (approximately March through September) were used as this is prior to the October release of hatchery fish. Comparisons of fork length at Willow Creek pre-ROD vs. post-ROD showed significant differences in most weeks (Figure 8). Post-ROD fork length was significantly larger than pre-ROD values in weeks 13, 15, 16, and 18. Pre-ROD fork length was significantly larger in weeks 20 and 22 through 36. Week 20 correlates to the calendar month of May, which has the highest release volumes for the post-ROD flows. In both pre-ROD and post-ROD periods, fork length increased significantly in week 23 and 24 due to the arrival of unmarked hatchery fish.

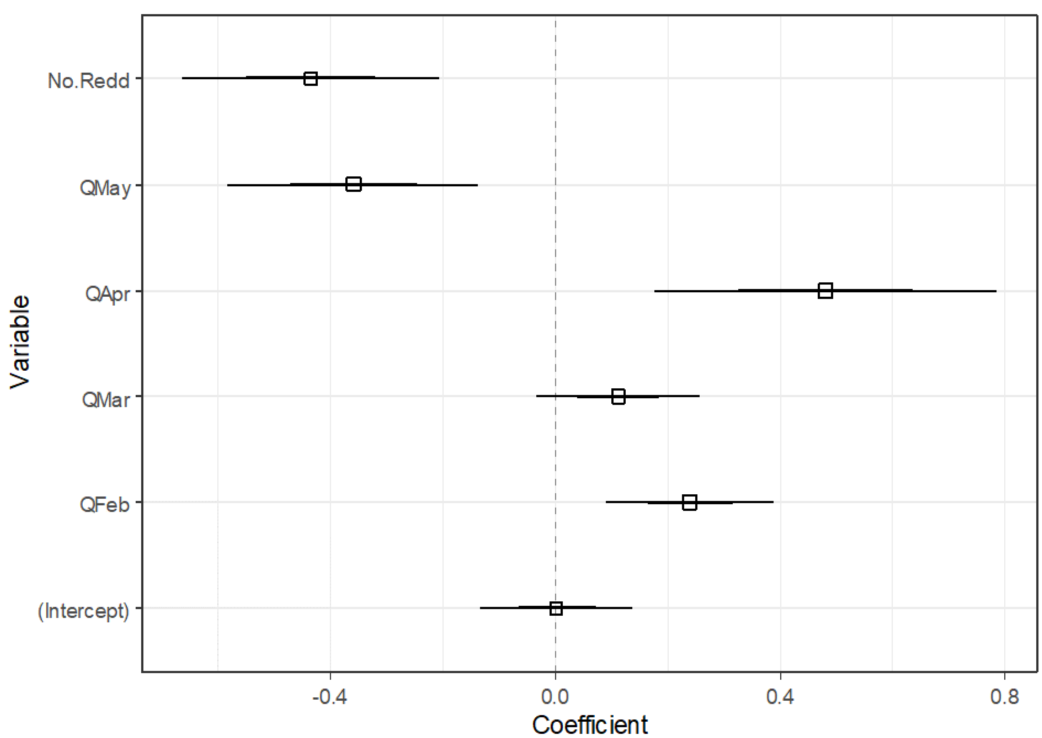


*Figure 7. Coefficient plots showing the value of the standardized regression coefficient ± 2 SE for each fixed effect included in the generalized least squares GLM model for describing changes in juvenile Chinook Salmon consumption, along with the 95% confidence interval for fixed effects (from Thomas Gast & Associates 2021).*

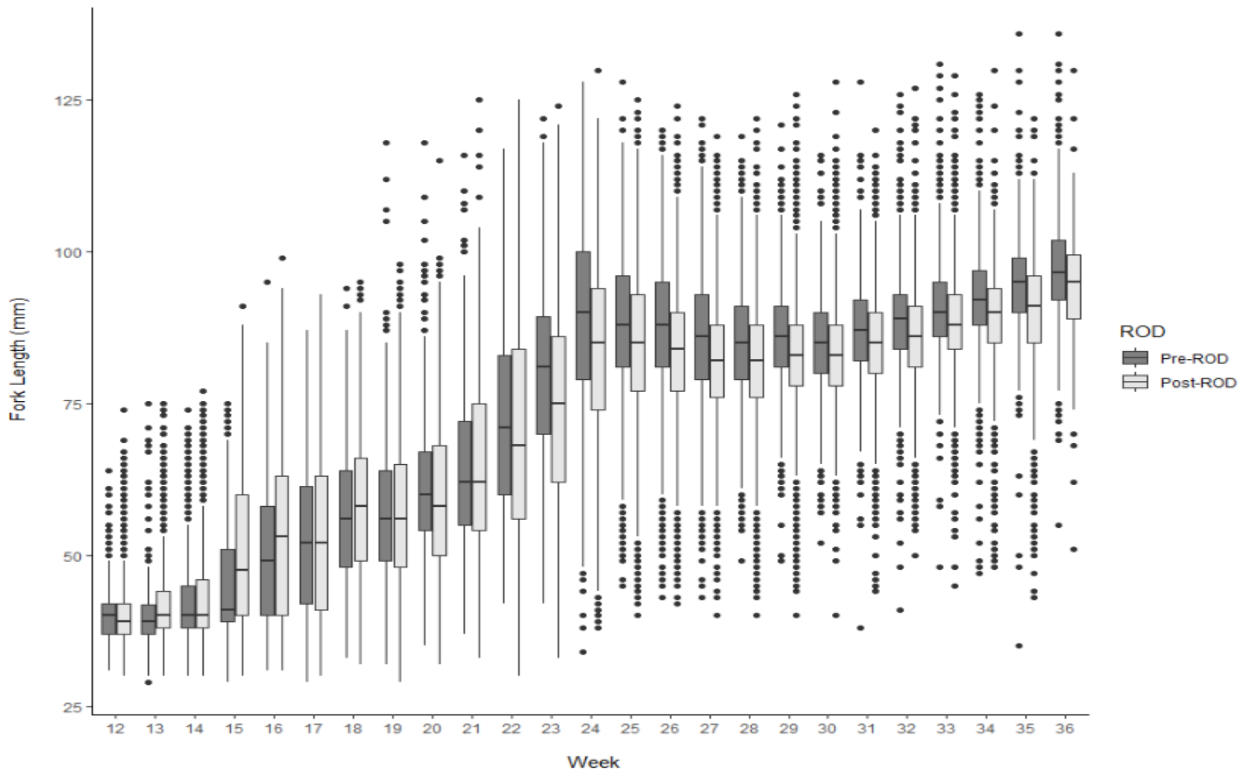


*Figure 8. Box plot of non-adipose fin-clipped age-0 Chinook Salmon captured at the Willow Creek trap site grouped by week and ROD period (from Pinnix et al. 2021).*

## Outmigrant Timing

The Willow Creek outmigrant trap on the Trinity River has been operated annually since 1989. It was installed and continues to be operated primarily to assess outmigration timing and duration of salmonids, Chinook in particular. Hayden and Heacock (2014) developed the HDAT Model that predicts RT80 (which is defined as the point when 80% of the Chinook juveniles have passed the trap) based on accumulated daily averaged water temperatures at Hoopa. In quantifying the predictive ability of the HDAT Model, Thomas Gast and Associates (2021) found that the best single-variable model for predicting RT80 used a threshold accumulated daily averaged thermal unit (ATU) determined from the Pear Tree temperature time series. The Pear Tree site is further upstream, where the water temperature is colder than at Hoopa, and may be more indicative of the temperature that initiates outmigration. These analyses suggest that warmer water temperatures during the initial time of the ROD-flows would encourage earlier outmigration (Thomas Gast and Associates 2021).

## Redd Scour

A perceived concern for implementing peak flow releases during the winter rainy season is predicting the potential scour of redds downstream of Lewiston Dam. To address this issue, an understanding of the relationships among river discharge, bed mobility, and scour depths in areas of the streambed heavily utilized by spawning salmon is needed (May et al. 2007). Spatial patterns of bed mobility based on model-predicted Shields stress at Sheridan Bar near Junction City indicate that a zone of full mobility is limited to a central core along the thalweg, which expands with increasing flow strength (May et al. 2007). Statistical analysis indicates that redds are preferentially located in shallow, high velocity areas with relatively coarse substrate and in close proximity to streambanks. These site selection preferences correspond to areas of the streambed that are least likely to become mobilized or risk deep scour during high flow events because the bed is not fully mobile, and the scour potential line does not exceed the average depth to the top of egg pocket (23 cm) (May et al. 2007).

Evenson (2001) measured egg pocket depths on the Trinity River using freeze core sampling and documented an average depth of 23 cm to the top of the egg pocket, and an average of 30 cm to the bottom of the egg pocket. Results from 268 scour chain measurements indicate that scour was not widespread and was rarely deep enough to result in redd scour at the range of flows experienced during the study (May et al. 2007). The study indicates that Chinook salmon are well adapted for reproductive success in flood-prone systems (May et al. 2007).

# Conclusion

The need to shift regulated flow releases to an earlier period that better-mimics the observed natural seasonal variability of unimpeded tributaries to the Trinity River has been increasingly accepted by TRRP program partners in recent years. This white paper was drafted to evaluate the shortcomings of current flow management and suggest meaningful adjustments so the underlying issues could be reassessed. With the completion of this paper, Reclamation is moving forward with the proposed action as an initial step to implement a more natural flow regime using releases from Lewiston Dam. A draft EA based on this paper is expected for public release in September 2021.

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# Appendix 1

**Decision Tree for Winter Flow Action**

60 thousand-acre feet (TAF) in Critically Dry, 80 TAF in Dry, 120 TAF in Normal, 180 TAF in Wet and 220 TAF in Extremely Wet