Management of Trinity River Winter Flows to Meet Programmatic Goals and Objectives in WY2024

Following conversations with Trinity River Restoration Program (TRRP) partner staff concerning hydrographs for WY 2024, it became apparent to me that some historical perspective on the development of the flow recommendations included in the Trinity River Flow Evaluation (TRFE, USFWS and HVT 1999) might be helpful. In the 23 years since the finalization of the TRFE and the signing of the Trinity River Record of Decision (ROD, USDOI 2000) there has been substantial turnover of staff and an incomplete transfer of knowledge concerning the development of the flow recommendations contained in the TRFE and ROD.

Development of Trinity River ROD Flow Recommendations

The U.S. Fish and Wildlife Service (Service) initiated the Trinity River Flow Study (Flow Study) in 1985 (USFWS and HVT 1999, Appendix B and I) to determine the instream flow needs for anadromous salmonids in the mainstem Trinty River below Lewiston Dam. This effort was conducted to meet legislative and administrative directives to restore and maintain the fishery resources of the mainstem Trinity River adversely affected by the construction and operation of the Trinity River Division of the Central Valley Project, and to meet tribal trust and public trust obligations. The Service utilized the Instream Flow Incremental Methodology/Physical Habitat Simulation (IFIM/PHABSIM; Stalnaker et al. 1995, Bovee et al. 1997) to determine instream flow needs for anadromous salmonids. Additionally, flow recommendations to restore riverine functions, within existing infrastructure constraints, for fluvial geomorphic and riparian processes were incorporated into the flow recommendations (McBain and Trush 1997).

During 1996-1997, the final flow recommendations contained in the TRFE (USFWS and HVT 1999) were developed using physical and biological data collected as part of the IFIM/PHABSIM study, as well as water temperature monitoring/modeling, physical process monitoring/modeling, and riparian vegetation monitoring/modeling.

During this time, I was contacted by LeRoy Poff (Poff et al. 1997) who was compiling information on instream flows and restoration efforts, specifically interested in recommendations that mimicked natural flow regimes. Through our discussions, I relayed to him that the Trinity River recommendations contained only two features of a natural flow regime; timing and magnitude (within infrastructure constraints) of the spring snowmelt hydrograph and the descending limb of the snowmelt hydrograph. The other components of the hydrograph were driven by PHABSIM information (spawning and rearing flows), summer flows needed to meet adult spring-run Chinook Salmon holding temperature objectives, and fluvial geomorphic process objectives.

During the development of the TRFE recommendations there were significant discussions concerning the spawning/rearing and summer flow recommendations. These discussions primarily focused on the "unnaturalness" of these flow recommendations when compared to the natural flow regime that existed prior to the construction and operation of Trinity and Lewiston dams.

To address the issue of riparian encroachment and subsequent establishment of sediment berms, summer flows between 300 cfs (wetter years) and as low as 100 cfs (driest year) were recommended by the Trinity River Maintenance Flow Study (McBain & Trush 1997). Lower summer flows that were more representative of unimpaired flows would help prevent the establishment of substantial riparian vegetation lower in the river channel which was occurring during the constant summer flows of 450 cfs. While summer low flows are an important aspect of a functioning natural river system, the need to sustain suitable water temperatures during the summer and early fall for adult salmonids overrode the any low flow recommendations during this period. Since adult spring Chinook salmon are forced to hold and spawn in the mainstem Trinity River below Lewiston Dam, rather that migrating to the upper Trinity as they had done prior to dam construction, the river below Lewiston Dam needs to have suitable thermal regimes to support adult spring-run Chinook holding and spawning.

The spawning and rearing flows of 300 cfs were established using PHABSIM using data collected within the degraded, U-shaped channel. Substantial concerns over these flow recommendations were discussed, especially considering the recommended channel rehabilitation, which would change the channel form to more closely mimic gravel bar alluvial features (among other features that have been incorporated into channel rehabilitation projects). Modeling using the salmonid production model SALMOD indicated that rearing habitats which are provided by gently sloping alluvial bars, was limiting production on the upper Trinity River (USFWS and HVT 1999).

To address these concerns over the spawning/rearing PHABSIM based flow recommendations and the anticipated channel form changes due to substantial channel rehabilitation efforts, alternative spawning and rearing flow recommendations were developed for Normal, Wet and Extremely Wet water years. These recommended spawning and rearing flows would, to a degree, mimic the natural system with higher and increasing flows through the spawning and rearing periods. The hypotheses for these recommendations were that increasing flows during the spawning period would distribute spawning fish in different areas as flows increased, reducing superimposition of spring- and fall- run Chinook salmon and increasing flows during rearing period would increase rearing habitat availability as gravel bars became inundated (USFWS and HVT 1999). Some preliminary modeling on changes in the location of rearing habitats was conducted but no fish distribution data validating this were available and no information was available to support the hypothesis that spawners would redistribute. These recommendations were ultimately not adopted for the TRFE following review by PHABSIM experts and Department of the Interior policy individuals. Their reasoning was that, while logical, these recommendations, especially their magnitude, were not supported by the available data, so, in essence, they were arbitrary and not acceptable. The primary concern was that these recommendations would not likely "hold up" in the anticipated lawsuit over the flow recommendations and could jeopardize the entire effort.

Moving Past ROD Flow Recommendations

The final TRFE recommendations adopted in the ROD included the 300 cfs spawning and rearing flow recommendations based on PHABSIM. But a critical component of the TRFE and ROD recommendations was the implementation of an Adaptive Environmental Assessment and Management (AEAM) program. A need for an AEAM program was identified because the river and its aquatic resources were going to experience substantial changes over time due to channel rehabilitation and an increased flow regime. There was substantial uncertainty as to how the riverine system and its dependent aquatic resources would respond. Additionally, some of the recommendations were based on limited data and it was anticipated they would be refined following additional data collection and analyses. Through the assessments conducted under the AEAM program, necessary modifications to any management action would be guided and implemented based on goals and objectives of the TRRP.

Appendix O of the TRFE (USFWS and HVT 1999) lists tasks to be implemented for "Improving Understanding of the Alluvial River Attributes and Biological Responses in the Trinity River". The TRRP has changed several components of the ROD hydrographs (magnitude and duration of peak geomorphic flows, outmigrant temperature flows) through the AEAM program, and addressing other components of the hydrograph are needed, including many of the alternative hypotheses.

Specifically concerning the 300 cfs spawning and rearing flows, Appendix O (USFWS and HVT 1999, pages O-4 through O-8) address the need to evaluate spawning and rearing flows and suggest hypotheses and alternative hypotheses for managing these flows. Modeling using the fish production model SALMOD indicated that rearing habitat under the existing channel shape was limiting juvenile Chinook Salmon production (USFWS and HVT 1999). Modeling using the contemporary Trinity River juvenile salmonid production model (S3, Perry et al. 2018) indicated increasing juvenile rearing flows while mimicking natural flow patterns could be anticipated to increase the number and size of juvenile Chinook salmon produced from the upper Trinity River.

Discussions on the need to evaluate and potentially change the rearing flows have occurred over the past 10-15 years and the TRRP implemented different rearing flows for the first time in 2023. Preliminary results presented to the Trinity Management Council (TMC) indicate that there were biological benefits by increasing winter rearing flows (Lindke 2023).

Moving Forward for Water Year 2024

A proposal for WY2024 was made to the TMC, using the same process recommended for WY2023 (Lindke 2023) but it was not approved. To help move the winter variable flow project forward for WY2024, various methods to provide increased winter rearing flows during the period of February 15 through April 28 are presented. These are just conceptual with example hydrographs for each water year type. Refinements of these recommendations, especially with setting flow thresholds that address programmatic objectives, are anticipated, and will improve the hydrographs.

One of the administrative constraints that has prevented implementation of different rearing flows in the past is timing of water year designation and the resulting instream allocation, which does not occur until early April. Additionally, concerns of "spending" too much water prior to the April B120 water year forecast were expressed in the case of a water year being categorized in a dryer category as was used to implement a winter flow. The process recommended in the Winter Flow Variability Report (TRRP 2022) address this issue by using conservative water year forecasts for February and March (B120 90% exceedance) and the B120 50% exceedance for the April forecast.

The overarching objectives of these methods as proposed in this document were to mimic aspects of natural flows during winter rearing period such as increasing flows throughout this period and to increase volumes of water released during the winter rearing period as ROD volumes increase from Critically Dry to Extremely Wet water years. In addition to these overarching objectives, shifted volumes of water to meet winter rearing flows were constrained so other flow-related objectives may be met. The summer spring-run Chinook Salmon holding/water temperature flows of 450 cfs were maintained in all scenarios and all water year types. The spawning flows (450/300 cfs) were also maintained for all scenarios and all water year types.

The presented hydrographs focus on managing flows to increase rearing habitat availability by managing flows for the February 15 through April 28 period. This does not mean other aspects of managing flows in the Trinity River (piggybacking during winter storms or variable summer flows to manage riparian recruitment) are not important in achieving programmatic goals of the TRRP (TRFE 1999, Appendix O). Rearing habitat availability is believed to be the limiting factor on fish production, based on fish production modeling, and this should be the initial focus of modifying flows prior to the April B120 50% exceedance forecast. The effectiveness of implementing these or other proposed hydrographs needs to be thoroughly evaluated through the TRRP's Decision Support System.

Development of Example Hydrographs to Evaluate Winter Rearing Flows for WY2024

Five methods, really two with four variations of the second method, were investigated to develop annual hydrographs for each water year type that address increasing winter rearing flows, covering the period from February 15 through April 28. February 15 was selected because this is most likely the earliest date flows could be changed after the February 1st water year forecast. April 28 was selected because this is when many water year hydrographs transition into the spring snow-melt component of the hydrograph. For all methods, the flow from October 1 through February 15 followed ROD recommendations (450 or 300 cfs). From April 29 through September 30, the ROD hydrographs were iteratively scaled until approximate annual water year volumes were met except a minimum flow of 450 cfs was used to protect summer/fall temperature objectives. These scaled components of the hydrographs **are not** recommendations as they do not address spring hydrograph objectives of the TRRP. It is anticipated that these components of the hydrographs will be modified to meet the needs identified for WY2024. The volume of water shifted into the winter rearing period was estimated by subtracting the volume in acre-feet (AF) of water for each alternative by water year type in the winter rearing period by the estimated volume of water released from February 15 through April 28 for each alternative methodology.

Mechanistic Hydrographs

For the first method, hydrographs were developed that increased flows by a set amount every three weeks, leading to gradually increasing flows throughout the winter rearing. This is similar to what was considered during the development of the TRFE recommendations. The three-week period was arbitrarily selected to simplify development of these example hydrographs. These three-week benches could facilitate some of the monitoring such as habitat availability assessments and invertebrate production. Target flows for the end of the winter rearing period were increased for each water year, ranging from 750 cfs for a Critically Dry water year to 1,750 cfs for an Extremely Wet water year, in increments of 250 cfs between water year types. To determine the increases of flow for each three-week period (1 week for the end of the period), the average weekly change in flow for the 10-week winter rearing period (i.e.: for a Critically Dry water year: (750-300)/10=45) was multiplied by 3. This tripling of flows for the following period was arbitrarily selected so that increases were substantial enough so that monitoring efforts would have a better chance of identifying differences while not reaching the designated peak flow too quickly. Additionally, on the second day of each flow increase, a peak freshet flow was incorporated by doubling the flow for a day to influence invertebrate scour and redistribution and promote washing of leaf litter into the river for detritivores. The doubling of flows was also arbitrary.

The hydrographs developed using this methodology are unnatural except that base flows increase during the winter rearing period and increasing volumes of water are released across water years, increasing as water year allocation volume increases (Figure 1). There is no daily

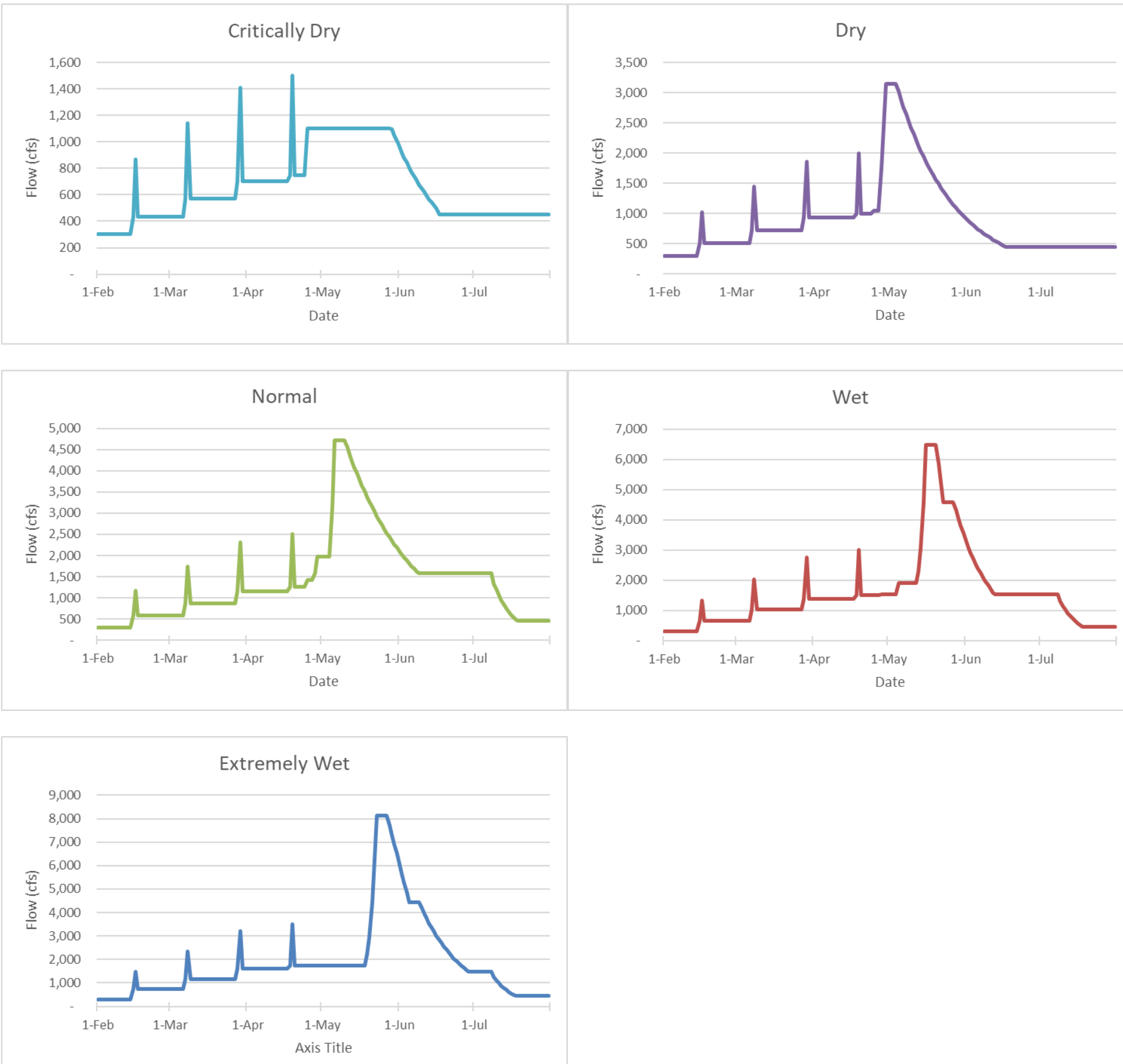

Figure 1. **Mechanistic** hydrographs for the period February 1 through July 31. *(The spring snow-melt portion of the hydrographs, following the winter rearing period (February 15-April 28), is not meant to represent a recommendation but was scaled down to maintain ROD water year volumes. It is anticipated that this component of the hydrograph would be modified to meet programmatic objectives)*.

variation in flows that is typical of natural hydrographs with the only variation, besides the gradual increases, being the peaks at the beginning of each flow increase. The additional volume of water released for this method during the winter rearing period ranged from 38,130 AF in a Critically Dry water year to 148,007 AF in an Extremely Wet water year (Table 1, Figure 2). The percentage of ROD volume reallocated to the winter rearing period ranged from 10% during a Critically Dry water year to 18% in an Extremely Wet water year.

Table 1. Volume (acre-feet) and percent of ROD volume shifted to the winter rearing period for each alternative method by water year type (EW=Extremely Wet, W=Wet, N=Normal, D=Dry, and CD=Critically Dry).

	Volume Shifted				
Alternative	EW	W	N	D	CD
Mechanistic	148,007	122,549	98,440	72,238	38,130
Average	19,621	35,403	54,770	11,810	33,096
Mimic 1	45,521	90,739	41,450	46,742	26,244
Mimic 2	107,075	90,739	70,869	46,742	26,244
Mimic 2 w peaks	111,773	98,491	77,885	50,883	28,654
	Percent of ROD Volume Shifted				
Alternative	EW	W	N	D	CD
Mechanistic	18%	17%	15%	16%	10%
Average	2%	5%	8%	3%	9%
Mimic 1	6%	13%	6%	10%	7%
Mimic 2	13%	13%	11%	10%	7%
Mimic 2 w peaks	14%	14%	12%	11%	8%

Mimicking Natural Hydrograph

The other four methods were variations mimicking natural flow patterns observed from 2001-2022. Daily data for "full natural flow" estimates for Trinity Lake (CLE) were downloaded from the California Data Exchange Center for each water year. Since these data include negative values, daily 7-day running averages were calculated for each water year.

Mimicking Natural Hydrographs - Average

The average hydrographs for each water year type were developed by averaging daily full natural flow values (7-day running average values) for the winter rearing period, February 15 through April 28. These average daily flows were scaled down so that the flows never went below 300 cfs, the current minimum flow for this period. To accomplish this, the minimum flow value of 300 cfs was divided by the minimum flow observed during the winter rearing period for each water year. This factor (300/minimum flow) for each respective water year type was applied to each daily flow estimate during the winter rearing period to develop a scaled down hydrograph that followed the pattern of the full natural flow. For example, if the minimum flow during this period was 450 cfs the scaling factor would be 0.667 (300/450). Once this factor was determined, each daily flow (using the 7-day moving average of the daily full natural flow values) was multiplied by the scaling factor to develop the scaled down hydrograph for the winter rearing period.

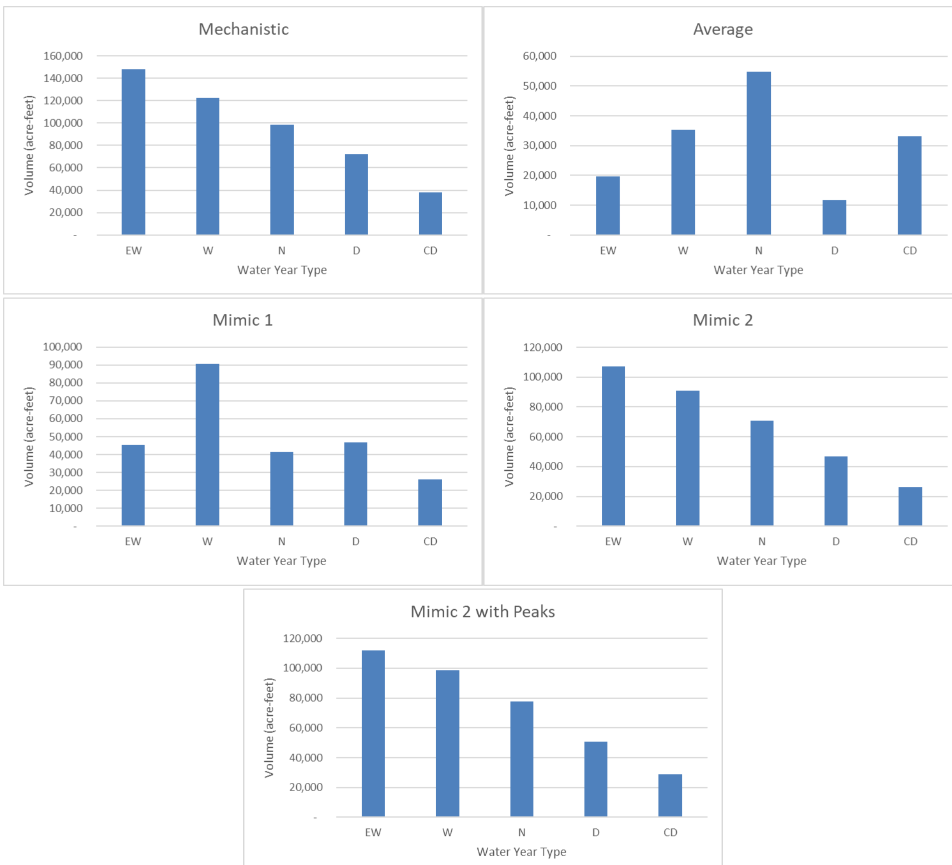

Figure 2. Volumes (acre-feet) of ROD volumes shifted into the winter rearing period (February 15-April 28) for each hydrograph development method.

The hydrographs developed using this method exhibited daily variability similar to the full natural flow hydrographs (Figure 3), although somewhat muted due to averaging, but the volumes did not increase with increasing ROD water year allocation (Table 1, Figure 2). The additional volume of water released during the winter rearing period ranged from 11,810 AF in the Dry water year to 54,770 AF in the Normal water year. The percentage of ROD volume reallocated to the winter rearing period ranged from 2% in the Extremely Wet water year to 9% in the Critically Dry water year.

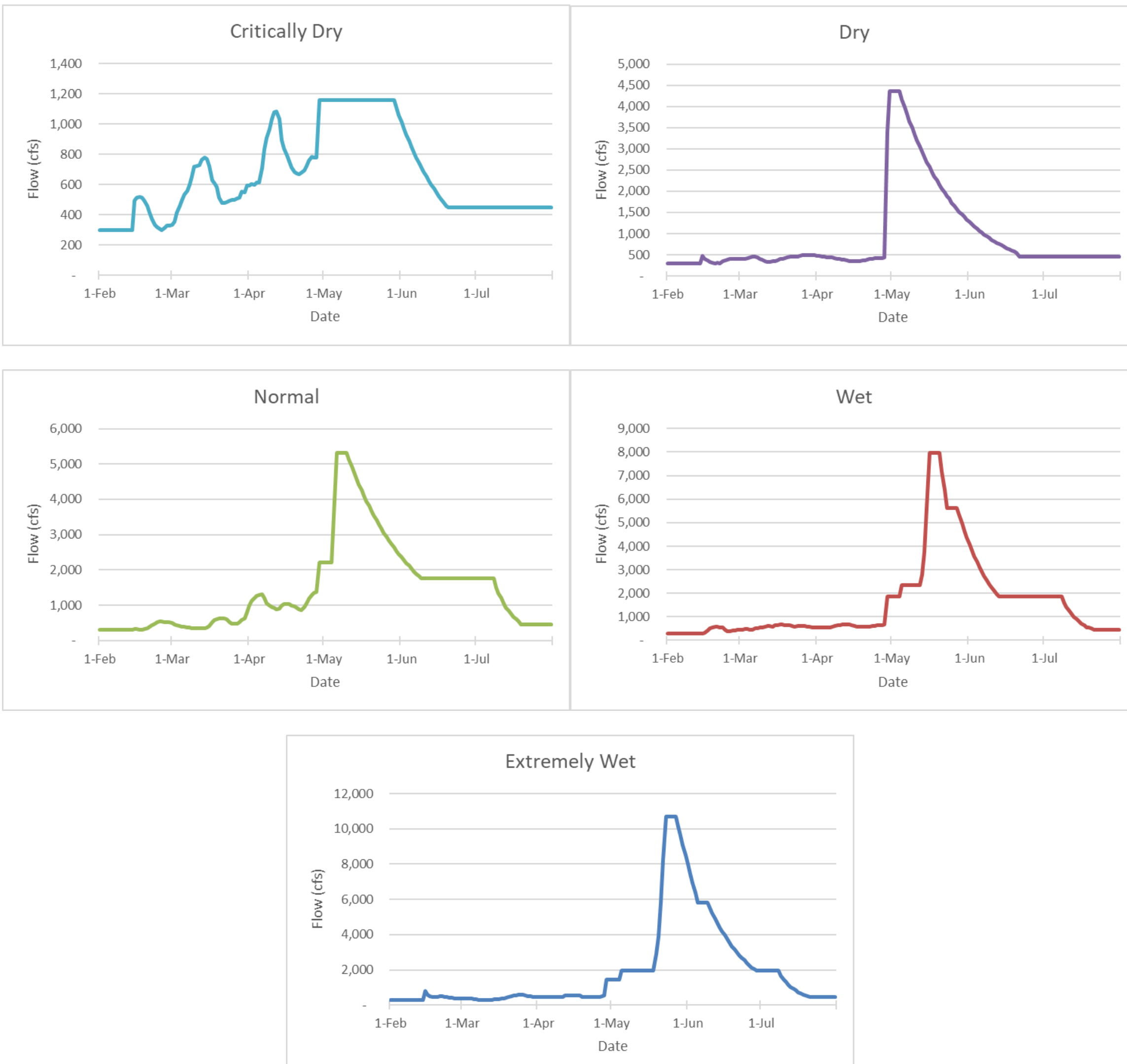

Figure 3. **Average mimic** hydrographs by water year type for the period February 1 through July 31 maintaining at least 300 cfs for all water year types during the winter rearing period. *(The spring snow-melt portion of the hydrographs, following the winter rearing period (February 15-April 28), is not meant to represent a recommendation but was scaled down to maintain ROD water year volumes. It is anticipated that this component of the hydrograph would be modified to meet programmatic objectives)*.

The initial expectation of this exercise was to use the average hydrograph for each water year type. But using the average hydrographs proved problematic due to limited representation of Normal and Extremely Wet water years and dataset used (2001-2022) did not exhibit the desired magnitude of increasing flows throughout the winter rearing period across water years (Figure 3). Only Critically Dry and, to a lesser degree, Normal water years exhibited a substantial increasing trend in flow. Additionally, increasing volumes released during the winter rearing period as water year volumes increase across water year ROD allocations was not realized in this exercise (Figure 2). Using a more extensive dataset may address these issues (See slide 15 in Lindke presentation to TMC).

Mimicking "Representative" Water Year Hydrographs

Continuing with the idea of using historical hydrograph data to guide flow recommendations for the winter rearing period, specific water years were selected to represent each water year type. The primary criteria were that flows during the rearing period exhibited a substantial increase. The water years selected were: 2021 for Critically Dry, 2013 for Dry, 2002 for Normal, 2011 for Wet, and 2006 for Extremely Wet.

Representative Mimic 1. For each representative water year, the full natural flow estimates for the winter rearing period were scaled down so that the flows never went below 300 cfs in the same manner the "Average Hydrographs" data were treated.

The hydrographs developed using this method exhibited daily variability similar to the full natural flow hydrographs (Figure 4). While the volumes released during the winter rearing period increased from Critically Dry to Dry water years, it declined in Normal and Extremely Wet water years from the previous water year type. (Table 1, Figure 2). The additional volume of water released during the winter rearing period ranged from 26,244 AF in the Critically Dry water year to 90,739 AF in the Wet water year. The percentage of ROD volume reallocated to the winter rearing period ranged from 6% in the Normal and Extremely Wet water years to 13% in the Wet water year. This did result in hydrographs that generally increased during the winter rearing season, but the volumes of water shifted to this period did not increase with increasing water year volumes. The volumes for Dry, Normal and Extremely Wet were similar (Table 1),

Representative Mimic 2. The same methodology used to develop the "Mimic 1" hydrographs was used but the scaling factor was changed for two water year types (Normal and Extremely Wet), so the volumes of water released during the winter rearing period increased across water years. The scaling factor for the Normal water year was 400 divided by the minimum full natural flow during the winter rearing period and for the Extremely Wet water year it was 500 divided by the minimum full natural flow during the winter rearing period. Doing this resulted in flows not going below 400 cfs for Normal and 500 cfs Extremely Wet water years. Once scaling factor was determined, each daily flow (using the 7-day moving average of the daily full natural flow values) was multiplied by the scaling factor to develop the scaled down hydrograph for the winter rearing period. These scaling factors were arrived at through iteratively using different values until the volume pattern was attained.

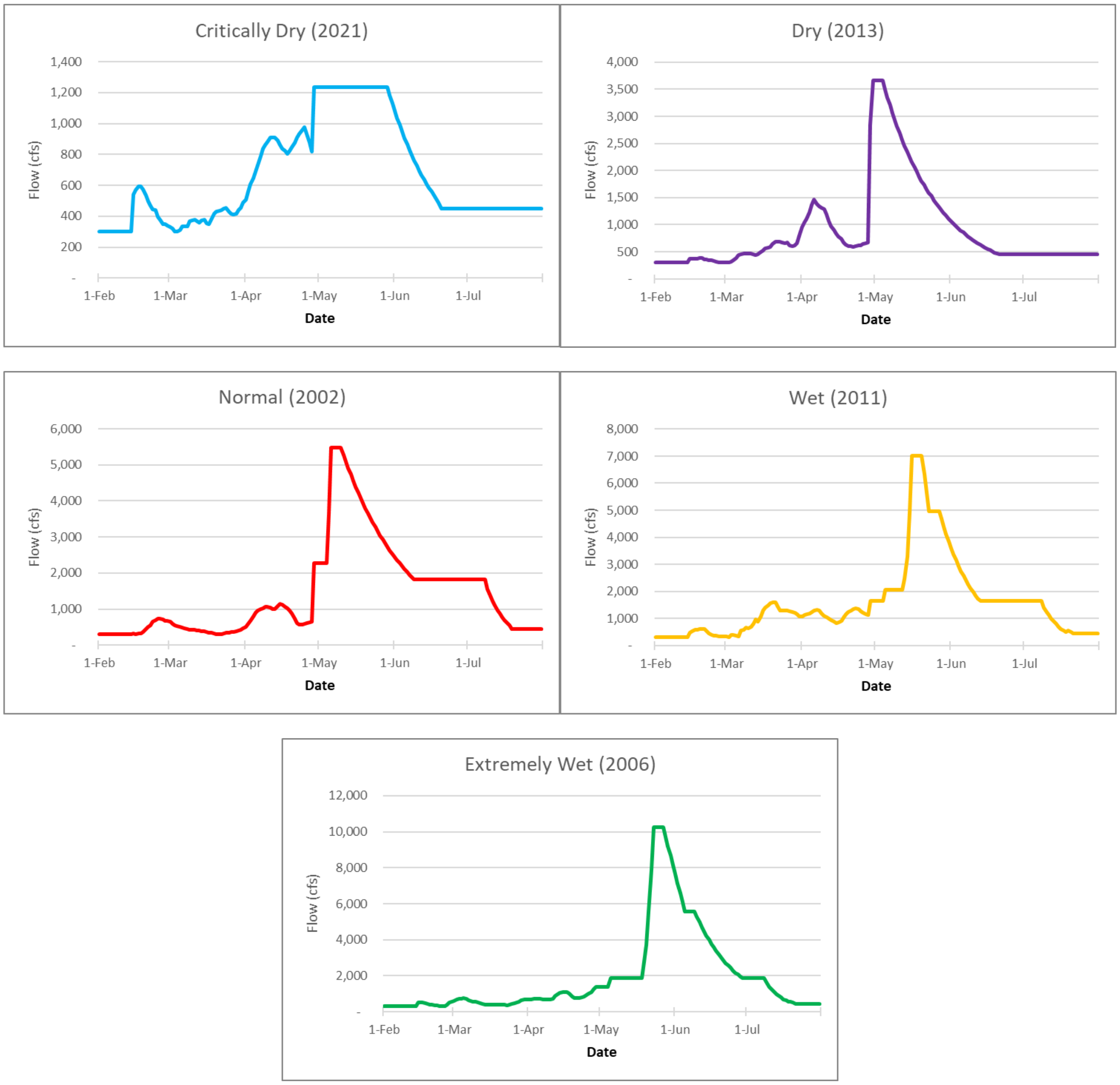

Figure 4. **Representative Mimic-1** hydrographs for the period February 1 through July 31 maintaining at least 300 cfs for all water year types. *(The spring snow-melt portion of the hydrographs, following the winter rearing period (February 15-April 28), is not meant to represent a recommendation but was scaled down to maintain ROD water year volumes. It is anticipated that this component of the hydrograph would be modified to meet programmatic objectives).*

These hydrograph adjustments exhibited daily variability similar to the full natural flow hydrographs (Figure 5) and resulted in increased volumes of water released during the winter

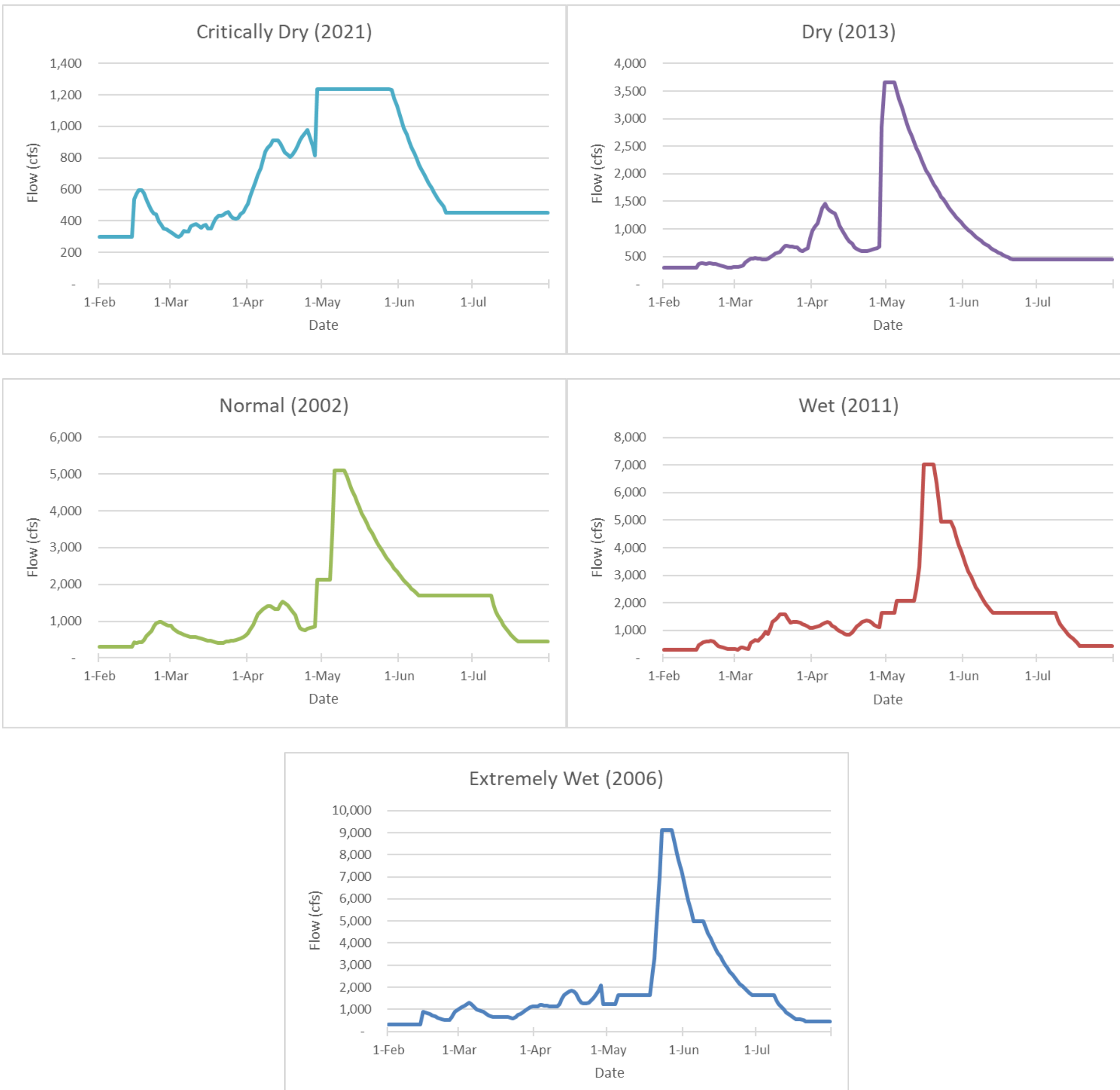

Figure 5. **Representative Mimic-2** hydrographs for the period February 1 through July 31 by water year type. Full natural flow hydrographs were scaled by 300 except for Normal (scaled by 400) and Extremely Wet (scaled by 500). *(The spring snow-melt portion of the hydrographs, following the winter rearing period (February 15-April 28), is not meant to represent a recommendation but was scaled down to maintain ROD water year volumes. It is anticipated that this component of the hydrograph would be modified to meet programmatic objectives)*.

rearing period as water year allocations increased (Table 1, Figure 2). The additional volume of water released during the winter rearing period ranged from 26,244 AF in the Critically Dry water year to 107,075 AF in the Extremely Wet water year. The percentage of ROD volume reallocated to the winter rearing period ranged from 7% in the Critically Dry water year to 13% in the Wet and Extremely Wet water years.

Representative Mimic 2 with Peaks. The hydrographs developed using the methodology for the "Mimic 2" hydrographs were modified to include peak freshet flows every two weeks. Peak flows were incorporated into the hydrographs to influence invertebrate scour and redistribution and promote washing of leaf litter into the river for detritivores, similar to the "Mechanistic Hydrographs". Every two weeks, starting from the second day of the winter rearing period a one-day flow pulse was incorporated into the hydrographs developed using the "Mimic 2" hydrographs. The magnitude of these flow pulses was 750 cfs for the Critically Dry water year, 1,000 cfs for the Dry water year, and 1,500 cfs for Normal, Wet and Extremely Wet water years. If the flow for a day in which a pulse was prescribed was greater than the pulse flow magnitude, the hydrograph was not modified, and the higher flow value used. The magnitude of these pulse flows was somewhat arbitrary but based on some of the hydrographs displayed in the TRRP variable flow report (TRRP 2022).

These hydrograph adjustments exhibited daily variability similar to the full natural flow hydrographs (Figure 6) and resulted in increased volumes of water released during the winter rearing period as water year allocations increased (Table 1, Figure 2). The additional volume of water released during the winter rearing period ranged from 28,654 AF in the Critically Dry water year to 111,773 AF in the Extremely Wet water year. Incorporating peak pulse-flows into the hydrographs resulted in minor to moderate increases over the "Mimic 2" volumes ranging from an increase in 2,409 AF in the Critically Dry water year to 7,752 AF in the Wet water year. The percentage of ROD volume reallocated to the winter rearing period ranged from 8% in the Critically Dry water year to 14% in the Extremely Wet water year.

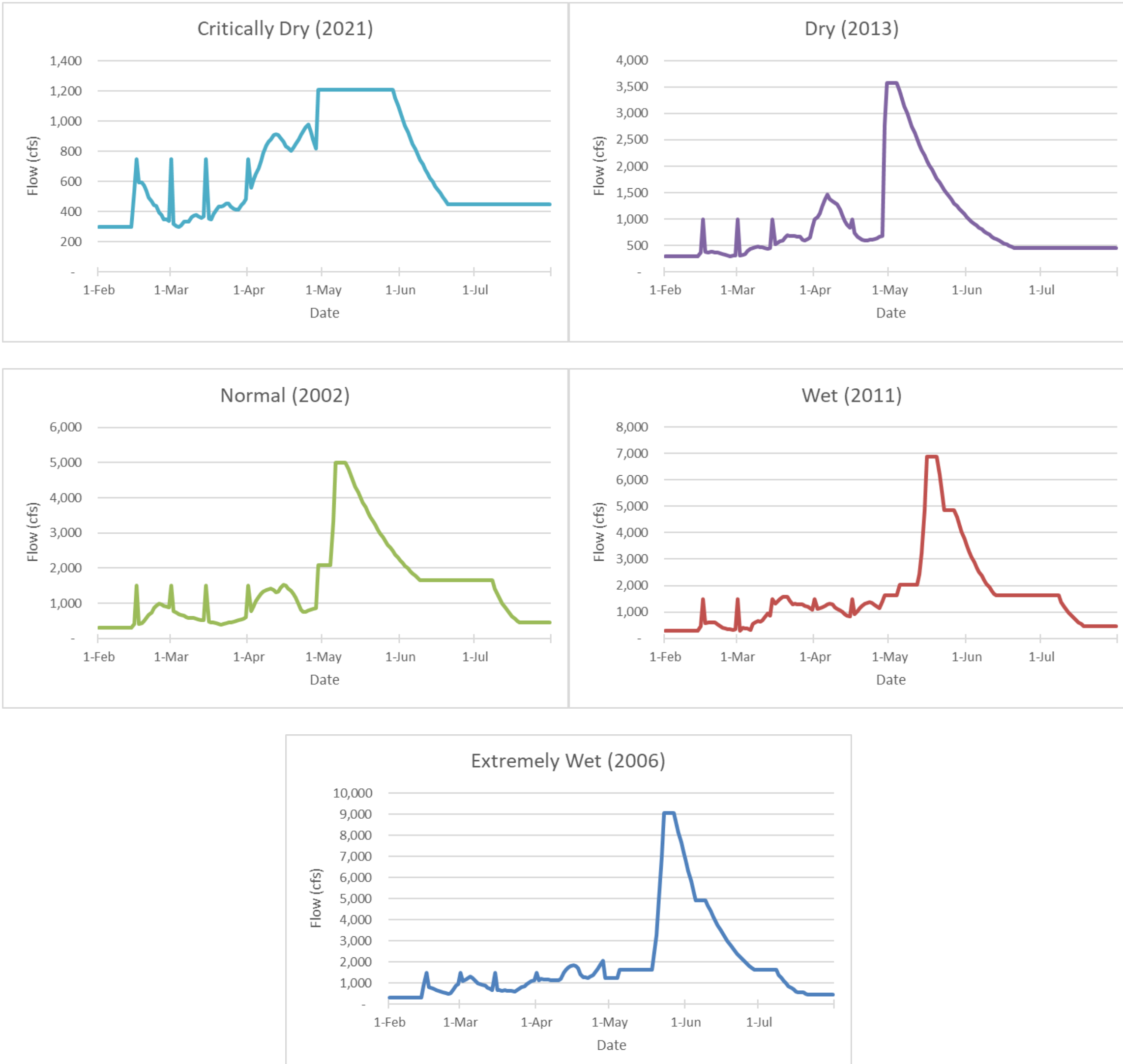

Figure 6. **Representative Mimic 2 with Peaks** hydrographs for the period February 1 through July 31 by water year type. Full natural flow hydrographs were scaled by 300 except for Normal (scaled by 400) and Extremely Wet (scaled by 500). *(The spring snow-melt portion of the hydrographs, following the winter rearing period (February 15-April 28), is not meant to represent a recommendation but was scaled down to maintain ROD water year volumes. It is anticipated that this component of the hydrograph would be modified to meet programmatic objectives).*

Summary/Recommendation

The current efforts to modify and evaluate rearing flows on the Trinity River are critical to effectively manage flows to increase fish production and are in line with the implementation of the Trinity AEAM program. It is recommended that the TRRP focus on implementing and evaluating increasing winter rearing flow in WY2024. Eventually, other components of the hydrographs (winter piggybacking releases during storm events, fall/winter spawning flows, summer adult salmonid holding flows/temperatures, etc.) also need to be evaluated for potential changes. Focusing on winter rearing flows seems to be the most urgent assessment of flow management since winter rearing habitat is believed to be limiting fish (Chinook Salmon) production based on fish production modeling.

For the methods evaluated, the "Mimic 2" variation is recommended so winter rearing flows will emulate some of the variation observed in full natural flows but not commit excessive proportions of a water year's allocation. The additional volume of water released during the winter rearing period ranged from 26,244 AF (7% of annual allocation) in the Critically Dry water year to 107,075 AF (13% of annual allocation) in the Extremely Wet water year.

The post-rearing hydrographs need to be developed so that specific TRRP objectives can be addressed during the snowmelt portion of the hydrograph.

As stated earlier, the expected effectiveness of these or other proposed hydrographs needs to be thoroughly evaluated through the TRRP's Decision Support System prior to implementation.

Other methods/modifications that should be further evaluated and possibly considered are:

- "Mimic 2 with Peaks" which may accommodate some of the redistribution/flushing of invertebrates to enter the food chain for juvenile salmonids with relatively small increases in the volume of water shifted into the juvenile rearing period.
- Using the "Average Hydrograph" methodology but with a larger database. This may result in variable hydrographs with the desired characteristic of generally increasing flows through the winter rearing period and increasing volumes relative to the specific water year type's allocation. See Slide 15 in Lindke 2023 presentation to the TMC for the pre-dam average hydrographs. Using the entire dataset (1912-2022) may be appropriate.

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