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TO: Dr. Rod Wittler, Senior Scientist, Trinity River Restoration Program

SUBJECT: Spring Flow Recommendations for the Foothill Yellow-legged Frog – Trinity River Flow Schedule Sub-group Meeting

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Spring Flow Recommendation for the Foothill Yellow-legged Frog

Introduction

The foothill yellow-legged frog (*Rana boylii*) is a stream-breeding species adapted to life in a dynamic natural river system, which includes a natural snow-melt hydrograph with peak flows in April and May, tapering off in late May and June. In the mainstem of the Trinity River this species has been negatively impacted by manipulation of flows and various managed hydrographs over the last four decades, which in most situations deviate significantly from a natural flow pattern. The nature of this negative impact includes:

- Elimination of critical habitat resulting from encroachment of riparian vegetation;
- Disruption of the timing needed for nesting, breeding, and development of eggs;
- Disruption of the process of metamorphosis of tadpoles into juvenile frogs; and
- Disruption of the rearing time need for juvenile frogs to mature into adults.

Proposed mechanical and hydraulic management actions at selected rehabilitation sites by the Trinity River Restoration Program (TRRP) are aimed at restoring both physical habitat and natural fluvial processes important to survival and production of juvenile salmonids, foothill yellow-legged frogs, and other species of native riparian-dependent wildlife along the mainstem of the Trinity River.

However, although restoration actions are underway, it is critically important that proper management of the current flow regime be implemented, when the opportunity arises, to accommodate the timing and success of various reproductive, developmental, and maturation processes associated with key life-history characteristics of the foothill yellow-legged frog, as well as other species in the Trinity River system.

Life-History Attributes

Once eggs hatch into tadpoles (June – early July) the tadpoles become mobile and are capable of reacting to natural changes in the hydrograph or to most manipulations of the flow regime; however, in some situations tadpoles are susceptible to stranding in topographic depressions along the margin of the river basin. Tadpoles remain in the river for a couple for months until their metamorphosis into juvenile frogs is complete.

Although the process of metamorphosis is generally complete by August, it may vary from late July through September depending upon natural environmental cues and inherent genetic variability within the population of frogs. By late spring frog eggs have largely hatched out and tadpoles have processed through metamorphosis such that mortality is reduced as a result of any high flow event; Table 1 provides a brief summary of critical flow events during spring.

Table 1. Summary of Critical Spring Flow Events.
• **<u>April</u>** – River bars and gravel cobble margins – early breeding, nesting and nest construction, egg laying and attachment, and development
• **<u>May</u>** – River bars, gravel cobble margins, and shallow pools – mid-season breeding, egg laying and attachment, tadpoles maturation and metamorphosis, development into juvenile frogs
• **<u>June</u>** – River bars, gravel cobble margins, and shallow pools – late egg laying and attachment, final tadpole maturation and metamorphosis, development into juvenile frogs

Threats to Populations of the Foothill Yellow-legged Frog

Yellow-legged frogs lay their eggs near the end of the descending limb of the natural hydrograph (i.e., May or June) and eggs require a few weeks of stable flows to develop into tadpoles. Therefore, the primary threats to populations of this species in the mainstem of the Trinity River are:

- Insuring that any managed flow or high flow event is early enough in the reproductive life-cycle of the frog such that egg masses and tadpoles are not flushed down the river and out of the system, and that early-season tadpoles can seek shelter as juveniles or as adult frogs in gravel/cobble bar edge-water habits.

- Preventing a delay in the natural schedule of the timing of oviposition (i.e., deposition of egg masses); a delay in oviposition is known to:

  (1) Retard maturation of eggs into tadpoles and tadpoles into juvenile frogs;
  (2) Cause smaller body size at time of metamorphosis;
  (3) Increase overall vulnerability of eggs and tadpoles to desiccation and predation; and
  (4) Lower over-winter survival rates for first year juvenile frogs.

2003 Flow Assessment

Data collected in spring of 2003 shows that the drop in flows resulted in some egg mass and tadpole mortality. Several eggs masses were left high and dry, and subsequently desiccated. Additionally, in several other areas tadpoles that were in the early stages of development were stranded and desiccated before completing metamorphosis into juvenile frogs.

When the flow was ramped down to the steady flow plateau through June into July (i.e., 2000 cfs), many gravel/cobble bars that had the potential to offer ideal foothill yellow-legged frog oviposition sites were still inundated (i.e., deep); thus they could not support egg masses and flows were still too high for oviposition. As a result, oviposition was delayed by as much as three weeks because flows in 2003 were kept fairly high during the breeding season. Most of the egg masses that were deposited had sufficient time to develop and hatch into tadpoles before flows dropped in mid-July.

However, if the flow plateau would have been held at a lower level (i.e., 1,500 - 1,750 cfs) a larger area of suitable habitat would have been available for oviposition. Additionally, tadpoles were detected in two tributaries (Oregon Gulch and Canyon Creek) before any eggs were located in the mainstem, suggesting that oviposition was delayed because of elevated flows in the river rather than seasonal changes in weather-related environmental factors.

Making the limited habitat currently present in this riparian encroached system available to frogs, juvenile salmonids, and other riparian-dependent species through proper management of flows should be a priority of the TRRP if managing the Trinity River system is truly an objective of the Record of Decision (ROD).

FY05 Summary of Flow Recommendations for Foothill Yellow-legged Frog

The foothill yellow-legged frog would benefit from a flow regime that more closely mimics a rescaled version of the natural hydrograph of the pre-dam condition, recognizing that some years will be better than others. More natural managed flows combined with physical habitat restoration designed to create and maintain gravel or cobble bar habitats used for breeding and development should produce a measurable and positive population-level response within three years.

Recent data and monitoring of this species suggests that slight increases in reproductive output of the mainstem population in the Trinity River over the last couple of years has taken place as a result of improved approaches to managing flow and temperature regimes, but this approach will not significantly increase the: (1) population of frogs in the mainstem, or (2) total area of critical habitat for the species, because armored riparian berms and riparian vegetation that is ≥ 3 years old can not be scoured out of the system solely by the use of ROD flows.

Therefore, construction and chaining together numerous adjacent rehabilitation sites in association with ROD flows are needed to create habitat for yellow-legged frogs, as well as juvenile salmonids in order to get an increased population response by these groups of organisms.

Further, small sample size continues to be problematic and currently does not allow conclusive or defendable scientific evidence that population size and adult survival are improving without additional monitoring. Environmental cues trigging reproductive behavior are under investigation, but flow velocity, inundation level, temperature, and weather are all part of the equation that must be understood to achieve the management goal of increasing long term viability of populations of foothill yellow-legged frog.

Management Implications and Recommendations

It should be clearly evident that population size of the foothill yellow-legged frog and the overall mainstem-wide area of quality habitat for this species will not improve in a quantitative way until a significant number of rehabilitation sites are implemented in association with ROD flows. Additionally, the presence and accessibility of gravel and cobble bar edge-water habitats, associated sparse riparian vegetation (< 3 years old), increased temperatures within these edge-water habitats, and relative stability of these conditions throughout the period of egg development and metamorphosis of tadpoles into juvenile frogs constitutes the same set of quality environmental conditions that favor development, growth, and overall production of salmonid fry, as well as other riparian-dependent species.

Therefore, management recommendations designed for specific live-history stages, critical habitat needs, and long term viability of populations of the foothill yellow-legged frog likely will also benefit populations of juvenile salmonids. The reason for this lies in the fact that populations of these organisms have evolved and adapted to the same set of pre-dam environmental conditions that the Trinity River Restoration Program is attempting to re-initiate with rehabilitation efforts in association with ROD flows, but at a scaled-down version of the original river system.

Preferred Flow Schedule for Foothill Yellow-legged Frog

Although, flow schedules for a normal water year and a wet water year do a reasonably good job of following this pattern, peak flows historically recede too late in the reproductive season. This may not be a problem as long as summer flows are kept steady long enough to prevent desiccation of egg masses and stranding of tadpoles.

In a river system that is highly encroached by riparian vegetation typical of the Trinity River, and where habitat is limiting for egg mass and tadpole survival, and development and metamorphosis of tadpoles into juvenile frogs, an ideal flow schedule for the foothill yellow-legged frog should have the following characteristics:

- Start with a normal flow year schedule;
- Move the high peak to earlier in the Spring;
- Recede to a moderate flow by mid- to late-May;
- Hold flows steady for at least six (6) weeks so that eggs can develop and hatch, and tadpoles become mobile enough to find refuge in cobble and gravel habitats to avoid stranding when the river level drops.

Extended Spring Flow Bench Hydrograph

Description

- Compared to the ROD Normal Water Year Hydrograph, flow releases for the proposed Extended Spring Flow Bench Hydrograph (Fig. 1) would begin on April 15th (1 week earlier than the ROD Normal Year hydrograph) and the ascending limb would have bench flows at 2,500 cfs, 3,000 cfs, and 4,000 cfs.
- A six day, 6,000 cfs peak flow would begin on April 28th (9 days earlier than a ROD Normal Year release).
- The descending limb would follow the same ramping down rate as the ROD Normal water year but would drop to 1,500 cfs (as opposed to 2,000 cfs).
- The 1,500 cfs bench flow would start on June 2nd (9 days prior to the 2,000 cfs bench under the ROD Normal Year schedule) and last for 38 days.
- Duration of the ramp down from 1,500 cfs to the summer baseflow of 450 cfs would be extended from 11 days under a ROD Normal Water Year schedule to 28 days.
- Total annual water volume = 646,400 acre-feet.

Objectives

- Make sure that flows are early enough in the reproductive life-cycle of the foothill yellow-legged frog such that egg masses and tadpoles are not flushed down river and out of the system before they can hatch (eggs) or seek shelter (early tadpoles) in gravel/cobble bar edge habits.

- Prevent a delay in timing of the natural schedule of oviposition (i.e., deposition of egg masses), which:
    - ➢ Retards maturation of eggs into tadpoles and tadpoles into juvenile frogs;
    - ➢ Causes smaller body size at time of metamorphosis relative to normal oviposition schedule;
    - ➢ Increases overall vulnerability of eggs/tadpoles to desiccation/predation; and
    - ➢ Lowers over-winter survival rates for first year juvenile frogs.

Strategy

- Increase availability of foothill yellow-legged frog spawning habitat under the existing bermed channel conditions by dropping bench flows from 2,000 cfs to 1,500 cfs.
- Begin the 1,500 cfs bench 10 days early to reduce the potential for desiccation of egg masses associated with spawning before the bench flows.
- Extend ramp down from 1,500 cfs to 450 cfs to:
    - ➢ Increase availability of warm coble/gravel edge and backwater habitats for tadpoles; and
    - ➢ Insure enough time for tadpoles to complete metamorphosis into juvenile frogs.

Temperature Consideration for Hydrographs

Average weekly temperature profiles for six (6) different hydrographs were modeled for the period extending from 1 April to 23 September 2005 in an attempt to determine what relationships exist between the seasonal temperature regime predicted by the ROD Normal Year Hydrograph under 2005 conditions, relative to those seasonal temperature regimes predicted for various other proposed hydrographs under the same set of environmental conditions (Table 2).

Figure 2 shows the relative degree of association among the six hydrographs based on these data. The most significant correlation ($r_c = 0.995$, $P < 0.0001$, $n = 26$) was between the proposed Extended Spring Bench Hydrograph and the ROD Normal Year Hydrograph. A t-test for paired two-sample means and a Kruskal-Wallis nonparametric ANOVA on ranked data both failed to show any significant difference between the modeled seasonal temperature regimes for these two hydrographs ($P > 0.10$, d.f. = 25, $n = 26$).

Additionally, a cluster analysis of the predicted 2005 weekly temperature averages (Table 2) for all hydrographs showed that the Extended Spring Bench Hydrograph and the ROD Normal Year Hydrograph have seasonal temperature regimes that are more similar to each other than either is to any of the other hydrographs modeled under 2005 environmental conditions (Fig. 3).

Finally, for the period extending from 3 June to 29 July, which encompasses the 2,000 cfs bench of the ROD Normal Year Hydrograph and the 1,500 cfs bench of the Extended Spring Bench Hydrograph (Fig. 1), the average temperature predicted for the ROD Normal Year flow was 13.54 degrees C, whereas the average temperature predicted for the proposed Extended Spring Bench was 13.81degrees C. The extent of correlation between the bench-sections of the

ROD Normal Year Hydrograph and the Extended Spring Flow Bench also was highly correlated (r_c = 0.998 (P < 0.001).

Therefore, seasonal temperature data derived from modeling 2005 environmental conditions under various proposed hydrographic scenarios do not indicate any significant difference in the overall water temperature regime between the ROD Normal Year Hydrograph and the proposed Extended Spring Bench Hydrograph. Additionally, there does not appear to be any significant difference between modeled seasonal temperature regimes for the bench-sections of these two hydrographs for the period extending from 3 June to 29 July 2005.

Recommendations

Therefore, there does not appear to be any valid biological reason not to implement the proposed Extended Spring Flow Bench Hydrograph. This conclusion is based on the following logic and information presented herein, including:

- The need for maximizing survival, reproduction, and habitat availability for populations of the foothill yellow-legged frog in the mainstem Trinity River;
- The similarity in overall shape (i.e., timing) of the proposed Extended Spring Flow Bench Hydrograph relative to the ROD Normal Year Hydrograph;
- The overall high correlation of 2005 modeled temperature regimes between the Extended Spring Flow Bench and ROD Normal Year hydrographs;
- Ability to modify the Extended Spring Flow Bench Hydrograph to accommodate a lesser amount of water (i.e., approximately 22,000 acre feet) – if the needed; and
- The consistency of shallow water habitat needs among frog egg masses, tadpoles, and juvenile salmonids rearing habitats.

Table 2. Average, minimum, and maximum of weekly temperatures (weekly averages) for different hydrographs modeled for the period extending from 1 April to 23 September 2005.

Month	Date	Dry Original	Normal 2 Weeks Early	Normal 2 Weeks Late Flows	Extended Spring Bench	Normal Original	Normal Original Warm Dry
April	4/1/2005	11.49	9.64	9.64	9.64	9.64	12.90
	4/8/2005	12.11	9.98	9.98	9.98	9.98	13.71
	4/15/2005	12.99	10.29	10.42	10.38	10.42	14.58
	4/22/2005	13.70	10.53	10.99	10.66	10.98	15.03
	4/29/2005	12.59	10.80	11.46	10.71	11.10	14.03
May	5/6/2005	12.95	11.17	12.06	10.97	10.88	12.97
	5/13/2005	13.42	11.71	11.87	11.53	11.22	13.47
	5/20/2005	14.97	12.60	11.53	12.46	12.00	14.89
	5/27/2005	16.42	13.34	12.08	13.40	12.82	16.02
June	6/3/2005	17.58	13.74	12.75	14.09	13.54	17.76
	6/10/2005	18.64	14.28	13.60	14.72	14.28	17.69
	6/17/2005	19.91	15.10	14.82	15.64	15.10	17.97
	6/24/2005	21.66	16.66	16.02	16.73	16.02	18.91
July	7/1/2005	22.45	19.05	16.45	17.26	16.45	19.16
	7/8/2005	22.93	20.56	16.78	18.11	17.62	20.55
	7/15/2005	23.62	21.71	17.36	19.76	20.80	23.66
	7/22/2005	23.99	22.51	18.77	21.46	22.51	25.85
	7/29/2005	23.86	22.72	21.62	22.47	22.72	25.14
August	8/5/2005	24.42	23.44	23.44	23.44	23.44	25.94
	8/12/2005	23.30	22.61	22.61	22.61	22.61	25.22
	8/19/2005	22.25	21.66	21.66	21.66	21.66	23.34
	8/26/2005	21.46	20.91	20.91	20.91	20.91	22.63
September	9/2/2005	20.38	19.87	19.87	19.87	19.87	22.88
	9/9/2005	20.18	19.68	19.68	19.68	19.68	21.72
	9/16/2005	18.70	18.26	18.26	18.26	18.26	20.35
	9/23/2005	17.17	16.71	16.71	16.71	16.71	19.67
	Average =	18.73	20.20	15.82	16.20	16.20	19.08
	Minimum =	11.49	12.90	9.64	9.64	9.64	12.90
	Maximum =	24.42	25.94	23.44	23.44	23.44	25.94

Figure 1. 2005 ROD Normal Year Hydrograph and Extended Spring Branch Hydrograph Under a Normal Water Year Type

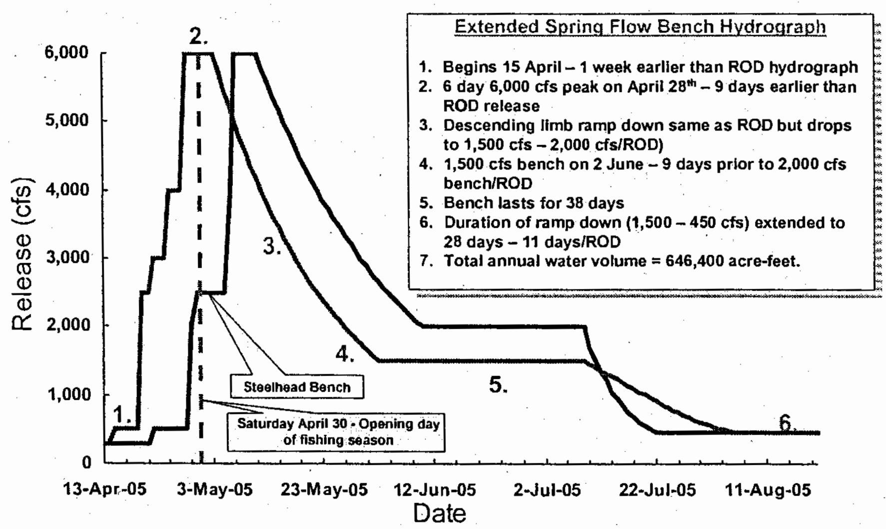

Figure 2. Scatter Plot and Pearson Correlation Matrix of Temperature Variables (n = 26) for Various Hydrographs

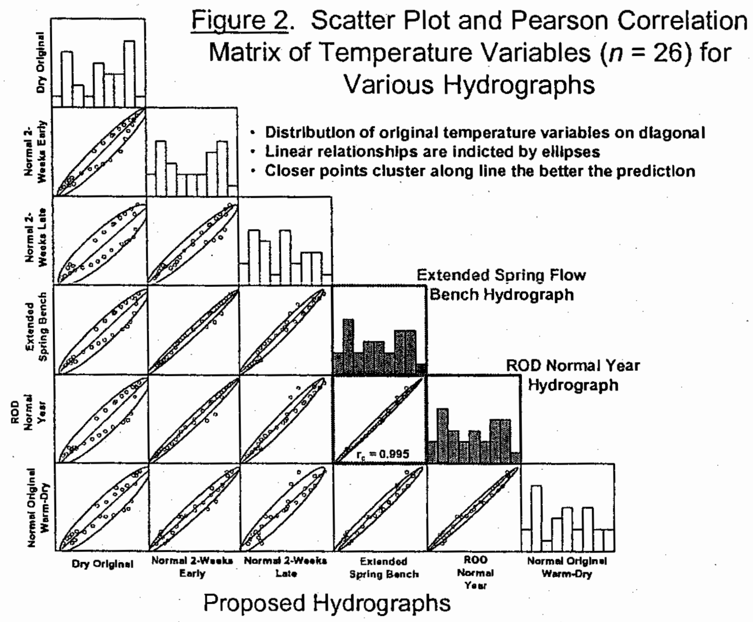

Figure 3. Cluster Analysis of Mean Weekly Temperatures Derived From Temperature Modeling for Various Hydrographs (1 April – 23 September 2005)