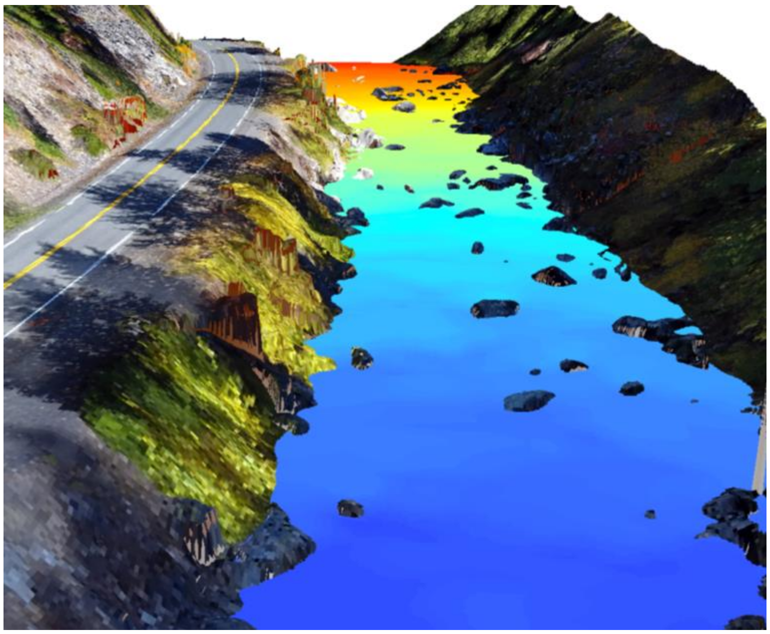
SOUTH FORK CLEARWATER RIVER

MP 28 Hypothesized Velocity Barrier – Phase II

Heuristic Modeling Exercise Addendum Technical Memo



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EXECUTIVE SUMMARY

In summer 2016, Nez Perce Tribe (NPT) contracted with Cramer Fish Sciences (CFS) for surveying, modeling, and analyzing a reach of the South Fork (SF) Clearwater River (Idaho), to determine if one of more velocity barriers exist during spring flows that prevent adult steelhead (*Oncorhynchus mykiss*) migration to upstream spawning habitat. CFS collaborated with Northwest Hydraulic Consultants (NHC) to model flows through the reach at a range of seasonally relevant discharges. Hydraulic modeling output data were then queried in a series of spatial analyses to quantify the emergence of potential barriers to passage for a 90 cm steelhead under hydrologically and biologically relevant conditions.

Findings from this initial study ("Phase I," CFS & NHC 2017) indicated that numerous potential velocity barriers emerge within the study reach. At discharge as low as 100 cfs, certain patches may be impassable (at 20 sec burst speed) for a 90 cm steelhead. As discharge exceeds approximately 1,000 cfs within the reach, at least one very high velocity barrier emerges, which would appear to exhaust the theoretical upper limit of swimming velocity capacity (5 sec burst speed) for a 90 cm steelhead. As discharge increases above 1,000 cfs, the number and spatial extent of potential barriers within the study reach increases at an increasing rate. It is likely that these features functionally restrict upstream migration for at least a subset of the steelhead population attempting to migrate through the study reach.

It may be possible to mitigate some of the barriers and impediments present in this high velocity reach, e.g., using techniques that include targeted rock removal and/or placement. As a first step in evaluating the likelihood that mitigation efforts would meaningfully improve passage, the present study was undertaken. Here, we leverage modeling results from Phase I to quantify the extent of potential fish barriers under two conceptual mitigation scenarios. Alternative 1 includes targeted rock removal (i.e., precision blasting), and Alternative 2 includes both rock removal and placement.

Findings from the current analysis include the following:

- At moderate flows (≤400 cfs), Alternatives 1 and 2 both are predicted to provide substantial (40-60%) reductions in the reachwide spatial extent of all barriers.
- As flows increase above 600 cfs (and, particularly at and above 1,000 cfs), the predicted reachwide reduction in spatial extent of all barriers provided by both Alternatives diminishes, approaching zero.
- However, both Alternatives are predicted to continue to provide benefits for fish passage in terms of reductions in very high velocity (5 sec burst) barriers, even as flows approach bankfull (~1,500 cfs).
- Evidence from the current modeling exercises indicates that either of the Alternatives considered here has substantial potential to mitigate for the emergence of very high velocity patches that currently impede upstream migrations of adult steelhead through the study reach.

All deliverables (reports, animations) associated with this project are housed here[1].

[1] *This and all links in this document expire on March 1, 2018; please make a local copy of all files contained therein before March 1, 2018.*

Acknowledgement of Funding Agency:

Funding for the investigation into the barrier by NPT, CFS, and NHC is provided by Bonneville Power Administration Project #2010-003-00, Lower South Fork Clearwater/Slate Creek Watershed Restoration and by funding made available by the Snake River Basin Adjudication (SRBA).

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INTRODUCTION

Purpose and Need

In summer 2016, Nez Perce Tribe (NPT), contracted Cramer Fish Sciences (CFS) and Northwest Hydraulic Consultants (NHC) to evaluate a potential hydraulic barrier to steelhead (*Oncorhynchus mykiss*) migration near river mile 44 (RKM 71) in the South Fork (SF) Clearwater River. During late September 2016, CFS and NHC conducted a field survey of the channel in the study reach, which provided data for a series of modeling exercises with the goal of estimating in-stream velocities at a range of biologically relevant discharges, and subsequently to infer whether, when, and how much a barrier to upstream migrating adult steelhead emerges.

This initial suite of analyses (referred to hereafter as "Phase I") indicated that it was likely that numerous potential barriers to fish passage emerge at increasing discharge. As flows within the study reach exceed approximately 1,000 cfs, small patches of very high velocity water emerge, which could create barriers to a 90 cm adult steelhead migrating upstream at a 5 sec burst swimming speed.

In response to this, NPT expressed an interest in leveraging the series of models that were developed during Phase I to evaluate potential mitigation scenarios targeting improved fish passage, which was the impetus for the current evaluation (Phase II). The goal of the current study was thus to evaluate how hydraulic conditions that are predicted to occur under two potential mitigation scenarios could influence steelhead passage within the study reach. The current effort focused on comparing water velocity under baseline conditions and those predicted to occur under each of two Alternatives, and to compare the spatial extent of potential barriers under each scenario.

Study Area: South Fork Clearwater River

To reach the project area (Figure 1) on their migration to the SF Clearwater River from the North Pacific Ocean, steelhead traverse nearly 1,000 river kilometers and eight mainstem dams. Historic steelhead escapement above what is now Lower Granite Dam approached 115,000 fish on an annual basis (USFWS 2012). More recent estimates by the Idaho Department of Fish and Game (IDFG) for the years of 1994-2003 indicate total steelhead escapement to the Snake River ranging from 273 to 6,895 with a mean of approximately 2,000 fish per year (USFWS 2012). Current mandates require at least 14,000 adult steelhead to reach the area upstream of the Lower Granite Dam (USFWS 2012), meaning that escapement is well below the target of resource management agencies.

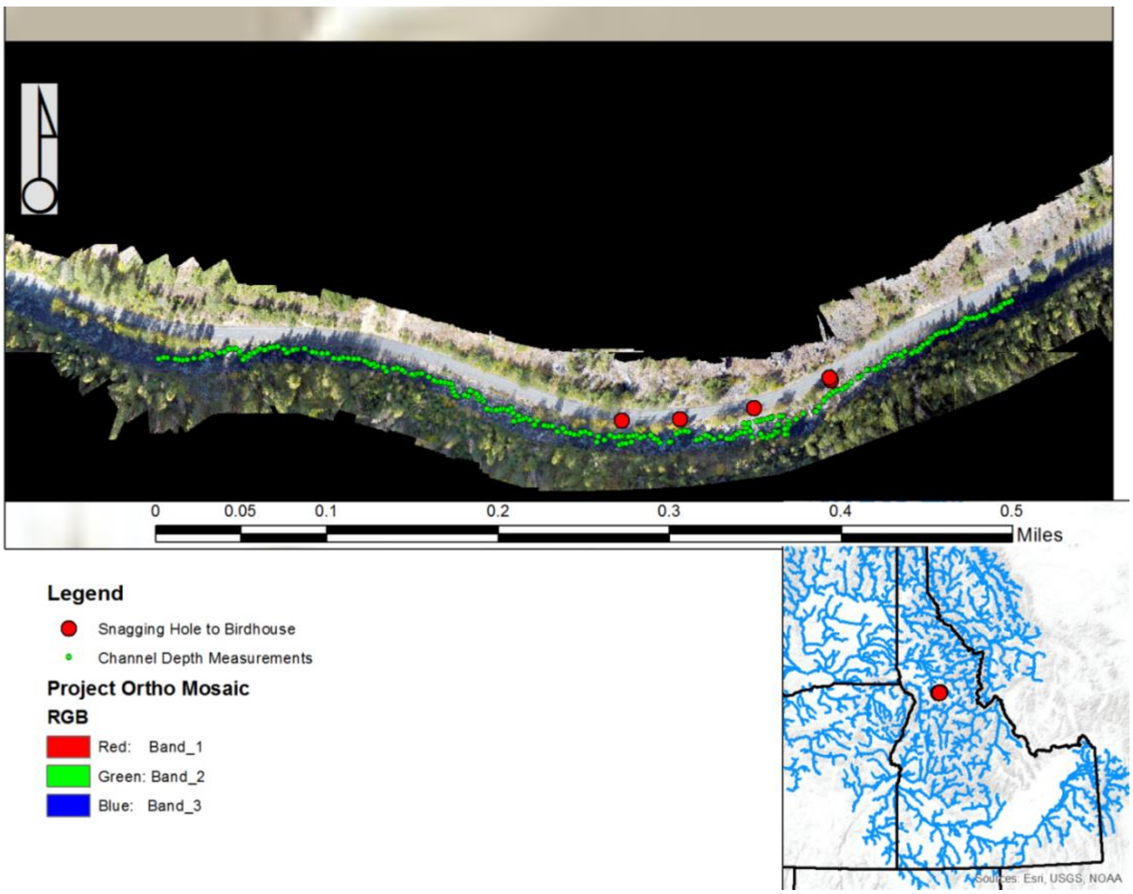

Figure 1. Orthogonalized aerial photos of the project area on the SF Clearwater River. Green dots represent channel bed surface elevation measurements. Red dots represent the study target area from "birdhouse" to "snagging hole."

Approach

For a detailed description of the mitigation alternatives considered, see NHC 2018 memo by Brown et al. that accompanies this report. Briefly, Alternative 1 amounted to selectively removing rocks within the channel, while Alternative 2 included both removal and placement of rocks within the channel.

To evaluate potential hydraulic barriers to upstream migrating adult steelhead under Alternatives 1 and 2, we applied our Phase I methodology (CFS & NHC 2017), to hydraulic modeling output provided by NHC.

Briefly, we quantified, analyzed, and summarized the predicted emergence and spatial extent of patches of water with sufficient velocity and size to create a barrier to upstream migrating adult steelhead, over a range of biologically and hydrologically relevant discharge. For our analyses, we focused on three burst swimming speeds: the pace that a 90 cm adult steelhead could sustain for 20 sec, 10 sec and 5 sec. A 20 sec barrier would thus represent a relatively long but only moderately swift patch of water, while a 5 sec barrier would represent a relatively short but intensely swift patch of water; a 10 sec barrier would be intermediate in length and velocity.

METHODS

Hydraulic Modeling

See CFS & NHC 2017, and the NHC 2018 memo by Brown et al. that accompanies this report.

Fish Contextualization

See CFS & NHC 2017.

RESULTS

All deliverables (reports, animations) for the current project can be found here. Note that this link expires March 1, 2018. Readers are encouraged to make local copies of all files before that date. In the event that this link expires, or if this document is being reviewed after March 1, 2018, electronic copies of files will be available from CFS upon request.

Hydraulic Modeling

See NHC 2018 memo by Brown et al. that accompanies this report.

Fish Contextualization

Modeling Fish Burst Swimming Performance

As previously reported in our Phase I findings (CFS & NHC 2017), under current (baseline) conditions, a large number of potential velocity barriers emerge as a result of hydraulic features that are generated as discharge increases from 100-1,500 cfs (**Figure 2**, "baseline_animation").

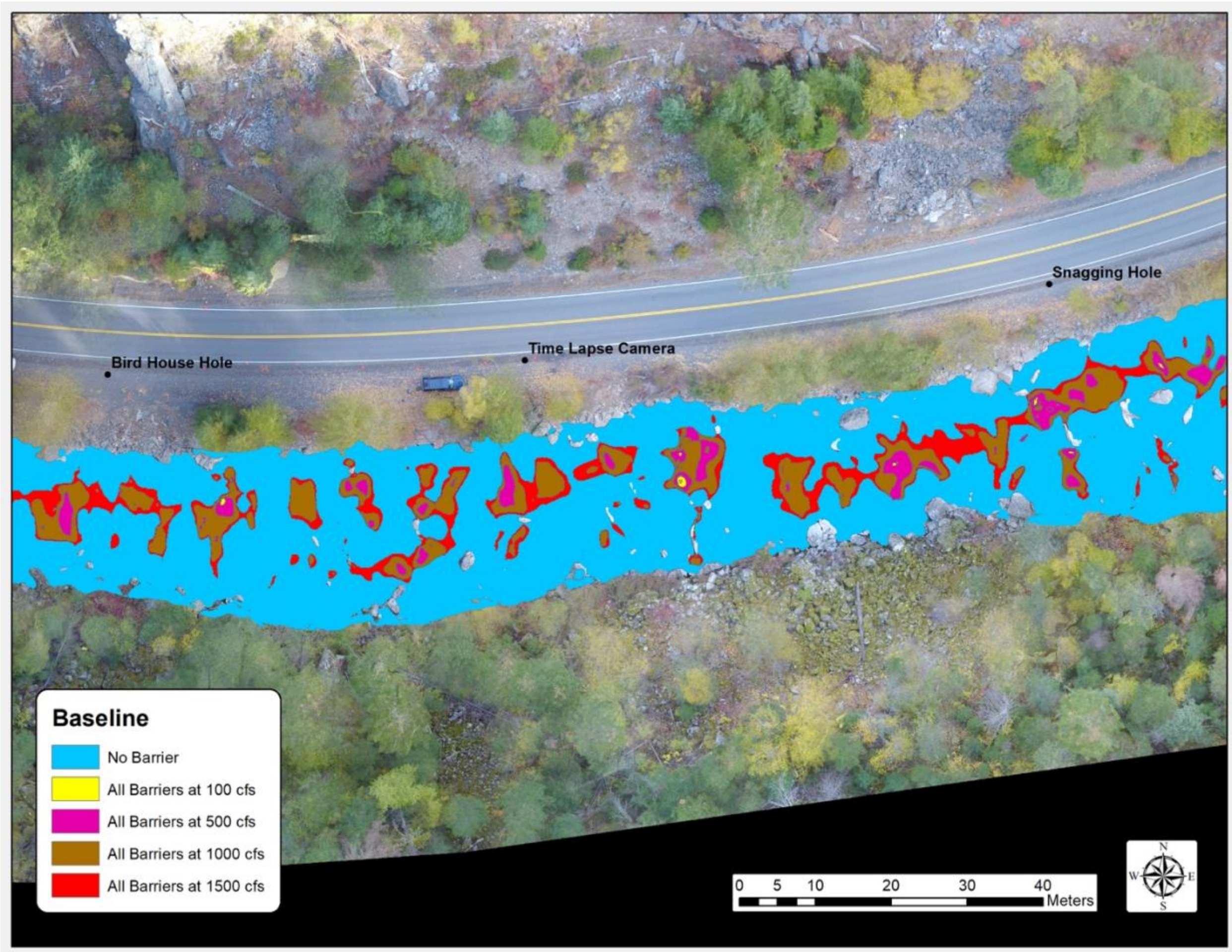

Figure 2. Spatial extent of all potential hydraulic barriers in one area of concern at four different flows ranging from 100 cfs to 1500 cfs, under current (baseline) conditions. As flows increase, the size and connectivity of hydraulic barriers increases.

A similar relationship between increasing discharge and increasing spatial extent of all potential hydraulic barriers is predicted to occur under Alternatives 1 (**Figure 3**, "alt1_Animation") and 2 (**Figure 4**, "alt2_Animation").

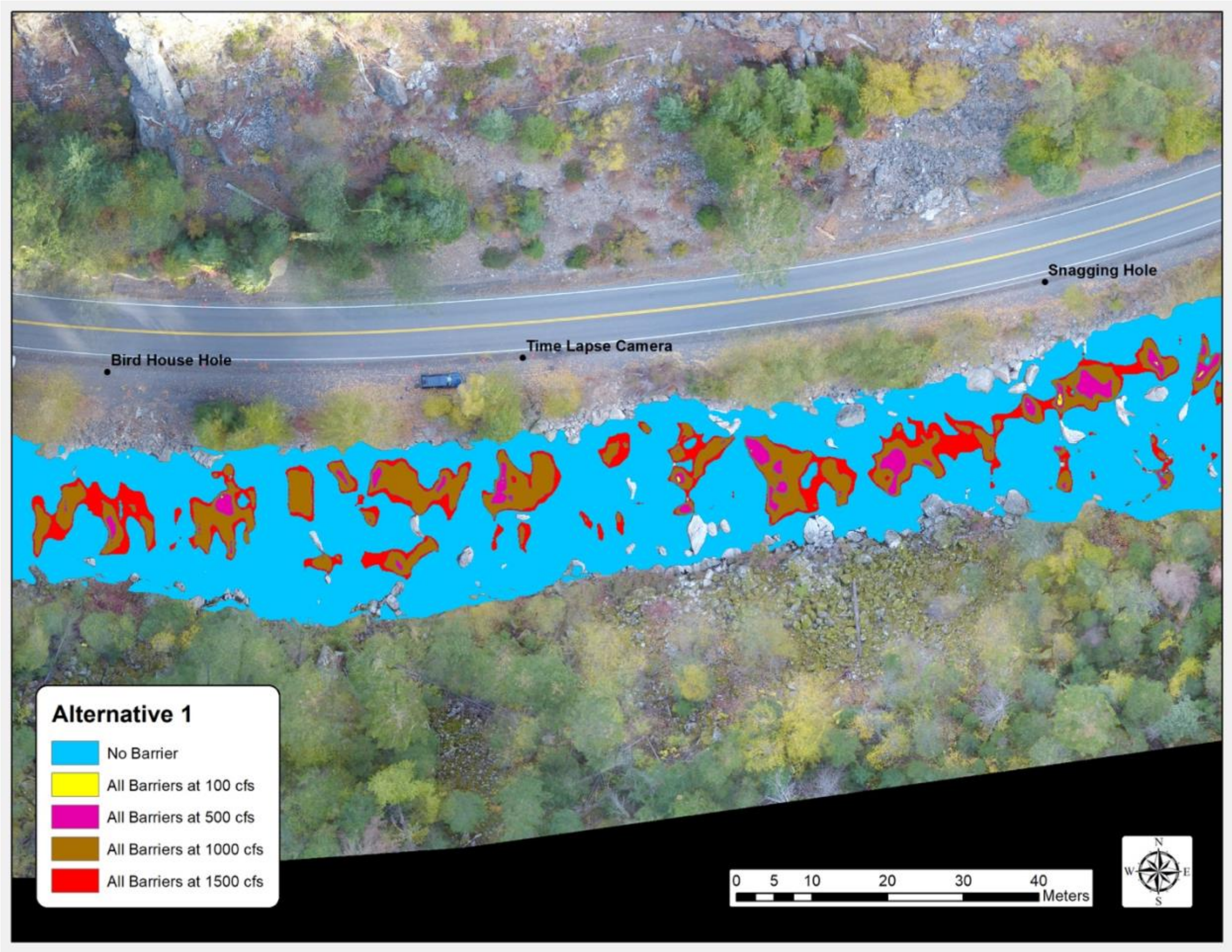

Figure 3. Spatial extent of all potential hydraulic barriers in one area of concern at four different flows ranging from 100 cfs to 1500 cfs, under the modeled "Alternative 1."

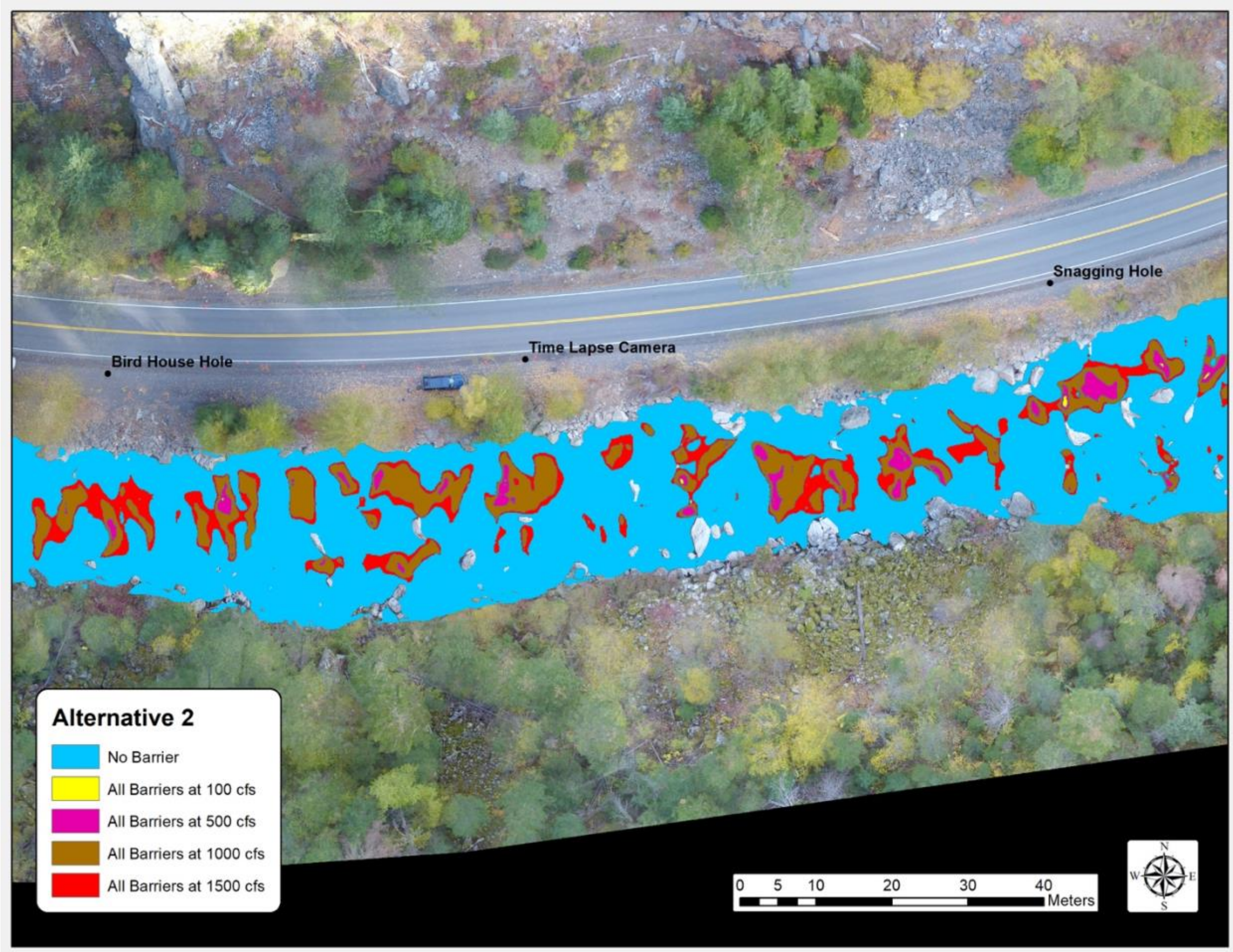

Figure 4. Spatial extent of all potential hydraulic barriers in one area of concern at four different flows ranging from 100 cfs to 1500 cfs, under the modeled "Alternative 2."

Under Alternatives 1 and 2, the spatial extent of barriers present at biologically and hydrologically relevant flows (i.e., up to the approximately annual spring freshet flow of 1,000 cfs) is predicted to decrease, compared to baseline conditions (**Figure 5**, "combined_Animation2").

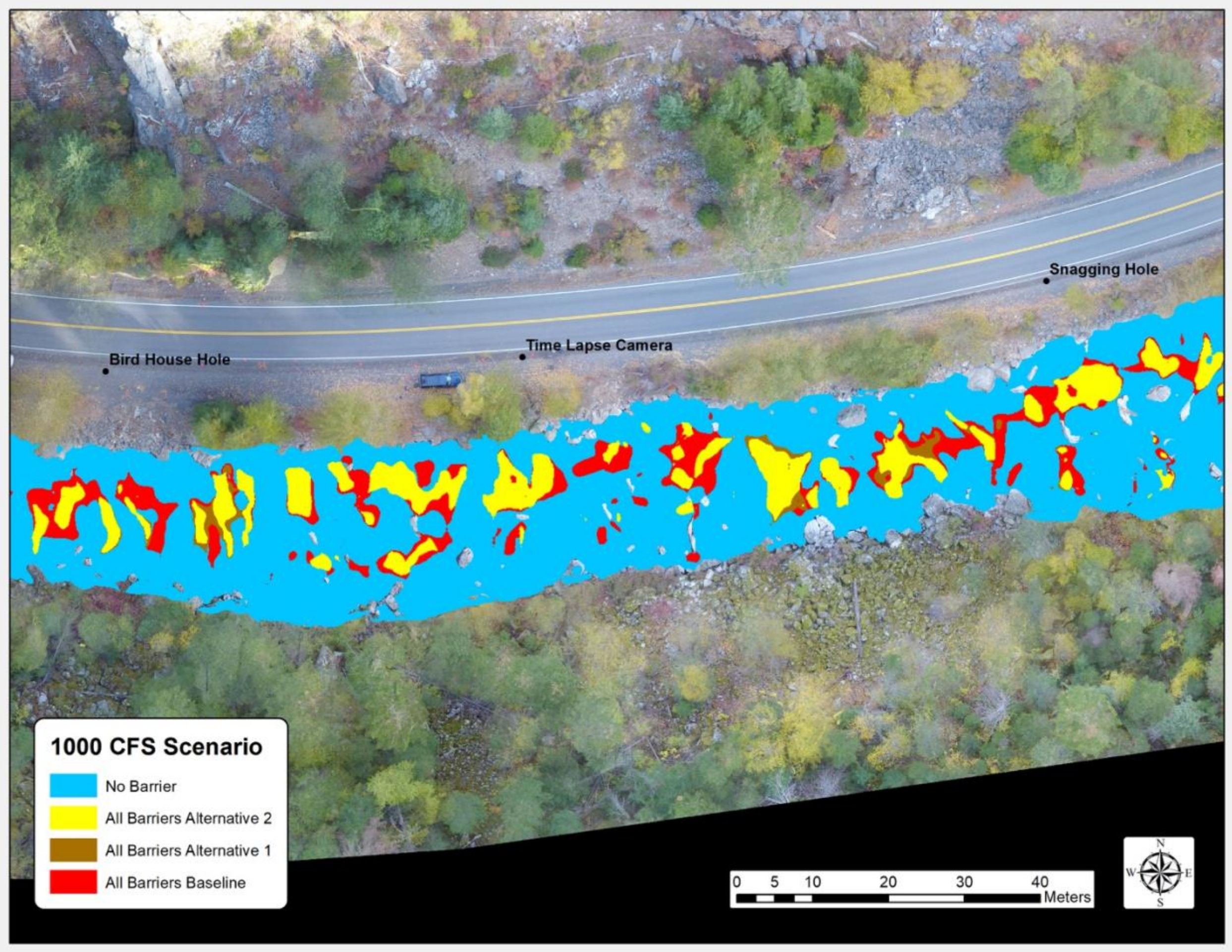

Figure 5. Spatial extent of all potential hydraulic barriers (at 5, 10, and 20 second steelhead burst speeds) in one area of concern at 1,000 cfs, under baseline (red), modeled "Alternative 1" (brown), and modeled "Alternative 2" (yellow) conditions.

However, the amount of reduction in the spatial extent of all barriers associated with conditions predicted under Alternatives 1 and 2 appears to diminish as flows within the study reach approach bankfull conditions, i.e., a ~1.5-year interval flood (**Figure 6**).

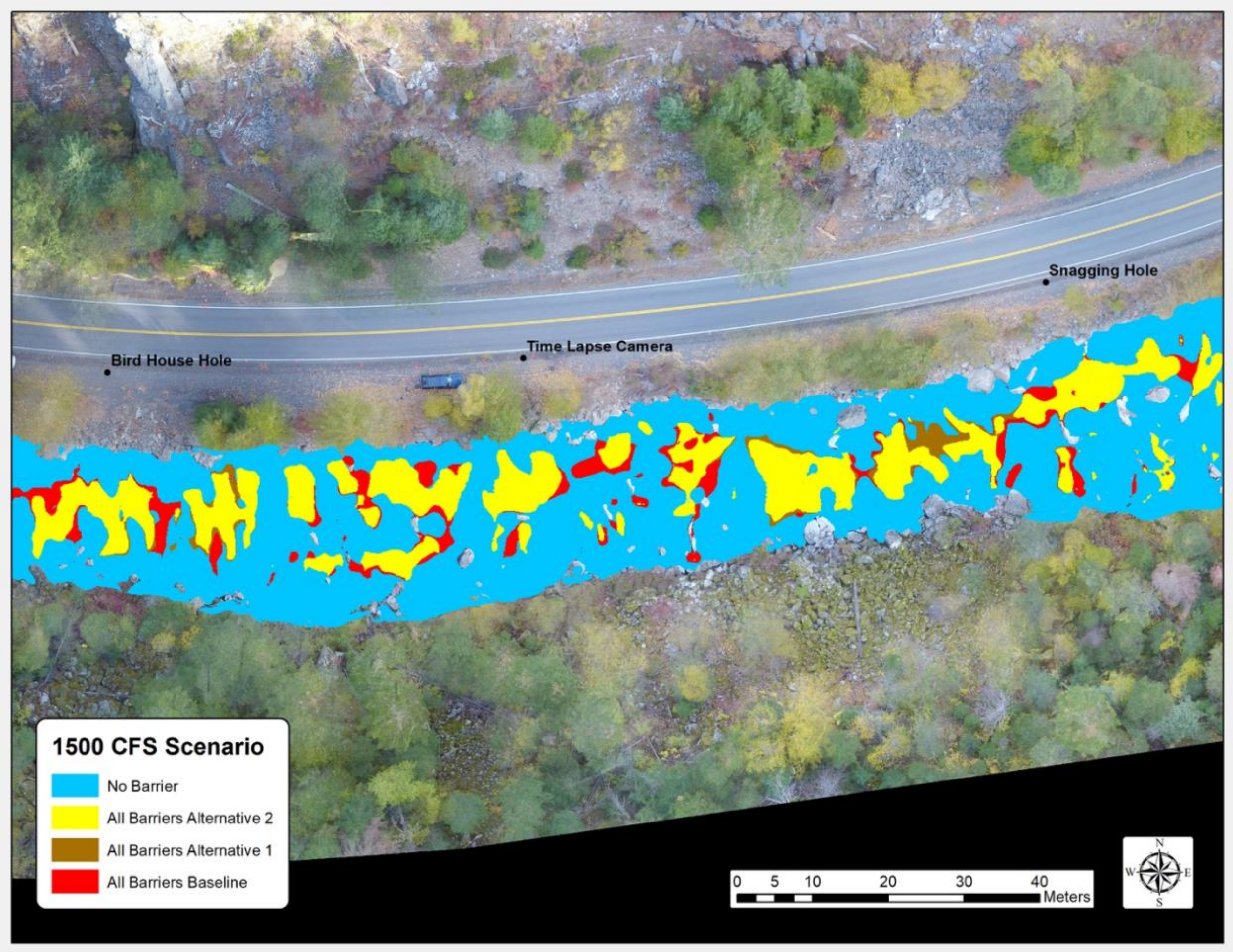

Figure 6. Spatial extent of all potential hydraulic barriers (at 5, 10, and 20 second steelhead burst speeds) in one area of concern at 1,500 cfs, under baseline (red), modeled “Alternative 1” (brown), and modeled “Alternative 2” (yellow) conditions.

The reachwide spatial extent of hydraulic barriers can be visualized quantitatively by comparing curves that describe the relationship between the aggregate size (areal extent[2]) of all emerging barriers and increasing discharge, among Baseline conditions and those predicted under Alternatives 1 and 2 (**Figure 7**). Across the range of discharge evaluated, these curves appear similar.

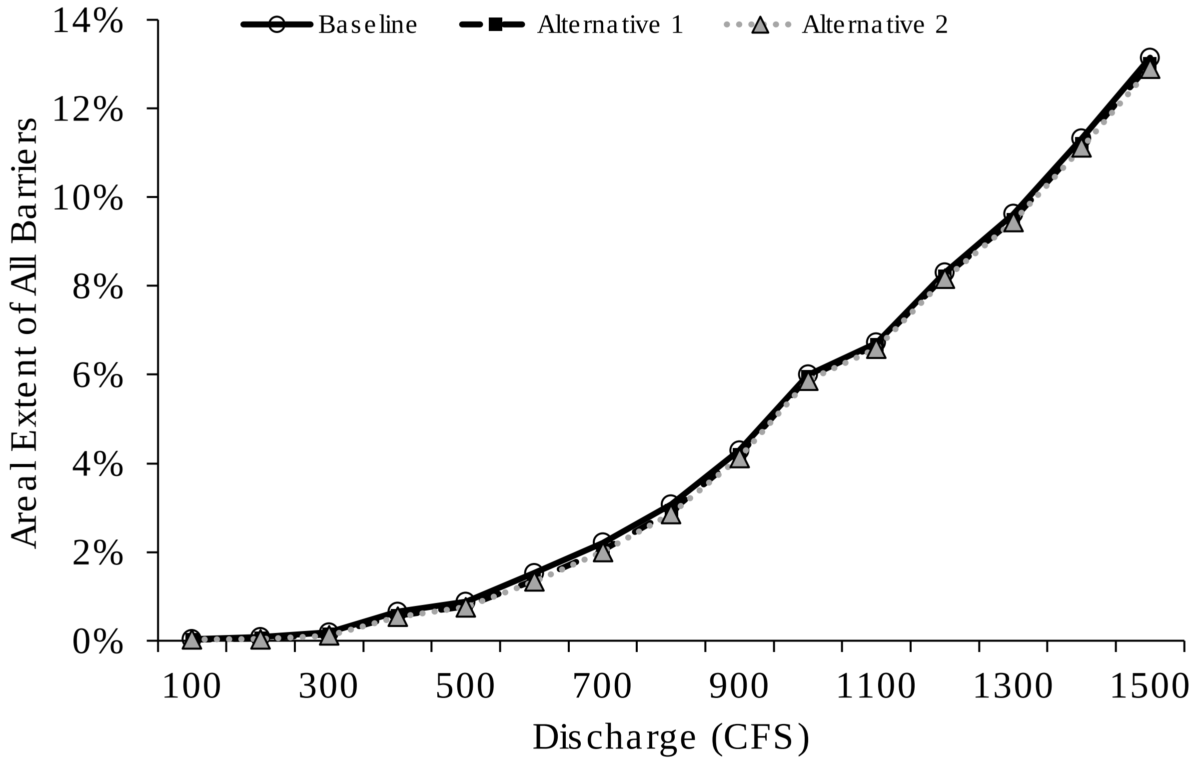

Figure 7. Emergence of reachwide areal extent (as percentage of wetted channel area) of all potential barriers as a function of increasing discharge, under baseline conditions and modeled alternatives, across the entire range of modeled flows.

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[2] *The ratio of predicted barrier patch area to total wetted channel area within the study reach.*

Focusing on effects at moderate discharge, the spatial extent of all potential velocity barriers is predicted to be less under Alternatives 1 and 2 at flows ≤400 cfs, with Alternative 2 offering a slightly greater reduction (**Figure 8**).

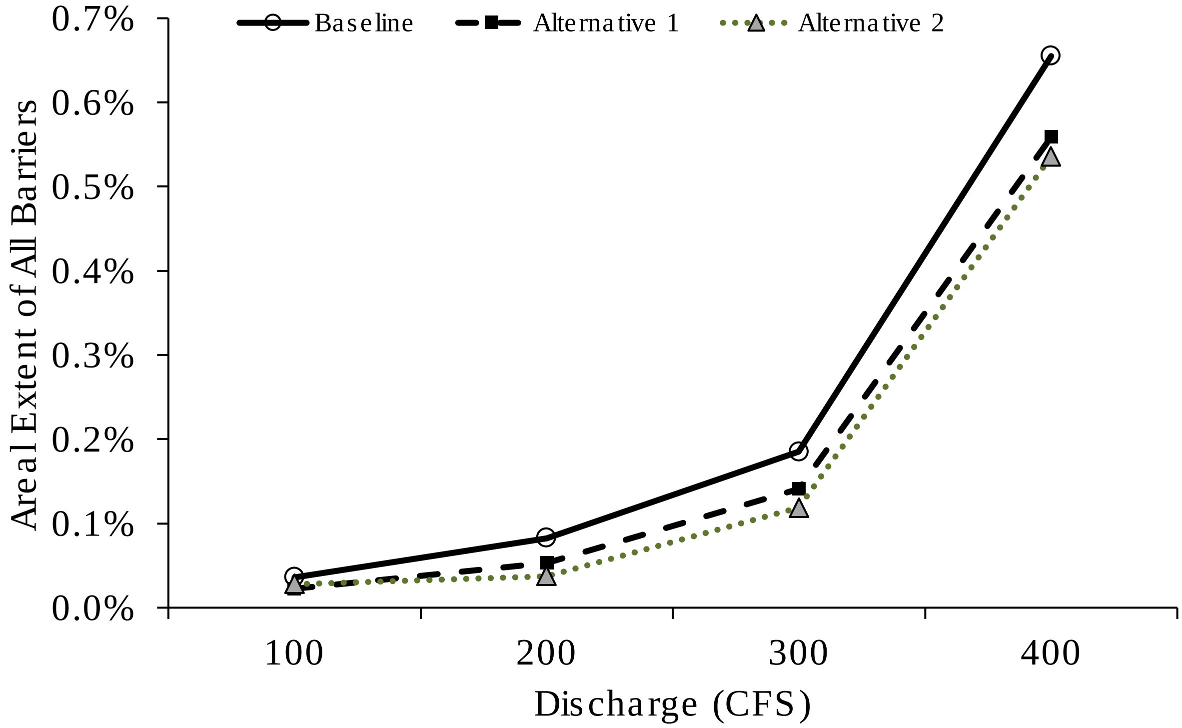

Figure 8. Emergence of reachwide areal extent (as percentage of wetted channel area) of all potential barriers as a function of increasing discharge, under baseline conditions and modeled alternatives, focusing on moderate flows only.

The benefits to fish passage associated with the evaluated Alternatives can be visualized by focusing on the reduction (compared to baseline) in spatial extent of all potential velocity barriers that is predicted to occur under Alternatives 1 and 2 (**Figure 6**). For both Alternatives, this reduction appears substantial at low to moderate discharge (≤400 cfs). Small differences in the curves for Alternative 1 and 2 at moderate discharge suggest that Alternative 2 may provide greater fish passage benefits under such flow conditions. Above 400 cfs, the benefits associated with Alternatives 1 and 2 are predicted to converge, and as discharge exceeds 600 cfs, the reduction in spatial extent of all barriers associated with both Alternatives drops below 10%. As discharge approaches 1,000 cfs (the previously determined barrier generating flow), reduction in spatial extent of all barriers associated with both Alternatives approaches zero.

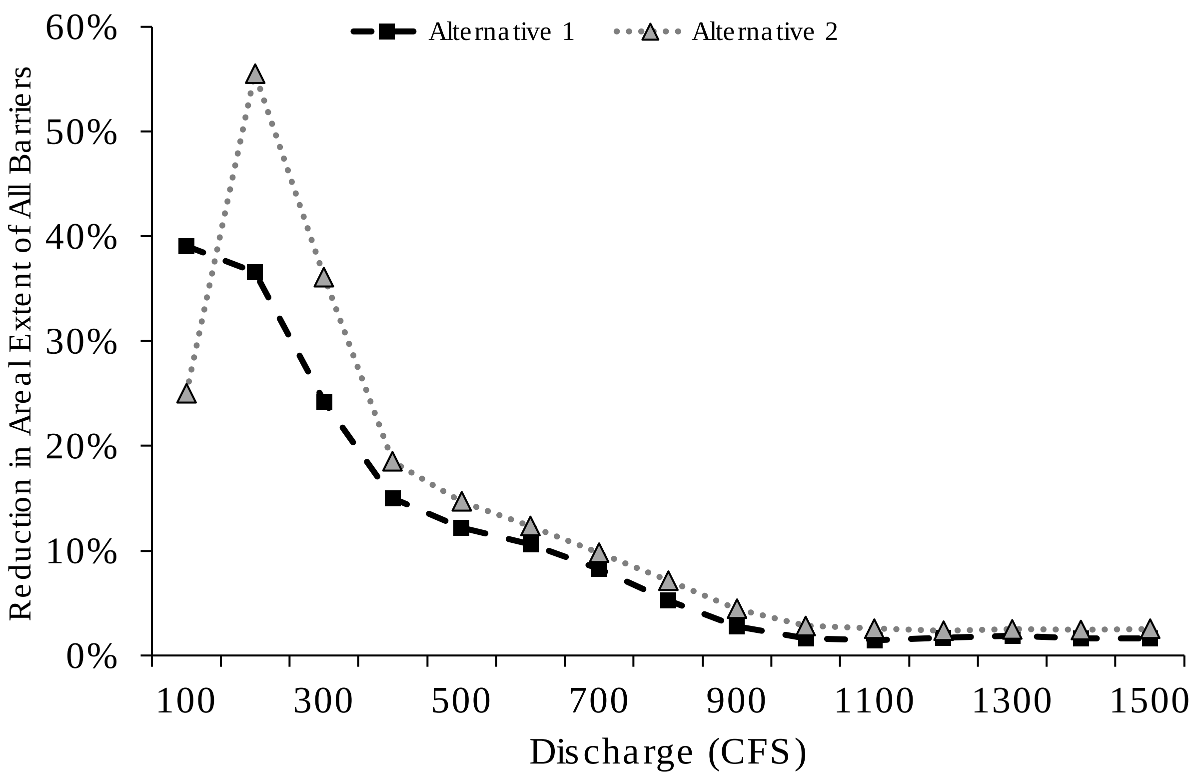

Figure 9. Percent reduction (compared to baseline conditions) in the spatial extent of all potential barriers across the study reach, under Alternatives 1 and 2, as a function of increasing discharge.

However, reduction in all potential barriers is not necessarily a biologically appropriate or logistically feasible goal. If, instead, we focus on the highest intensity velocity patches (5 sec burst speed barriers), it can be seen that conditions predicted under both Alternatives 1 and 2 would lead to a much smaller spatial extent of 5 sec burst speed barriers, which emerge under baseline conditions at discharge ≥1,000 cfs (**Figure 10**).

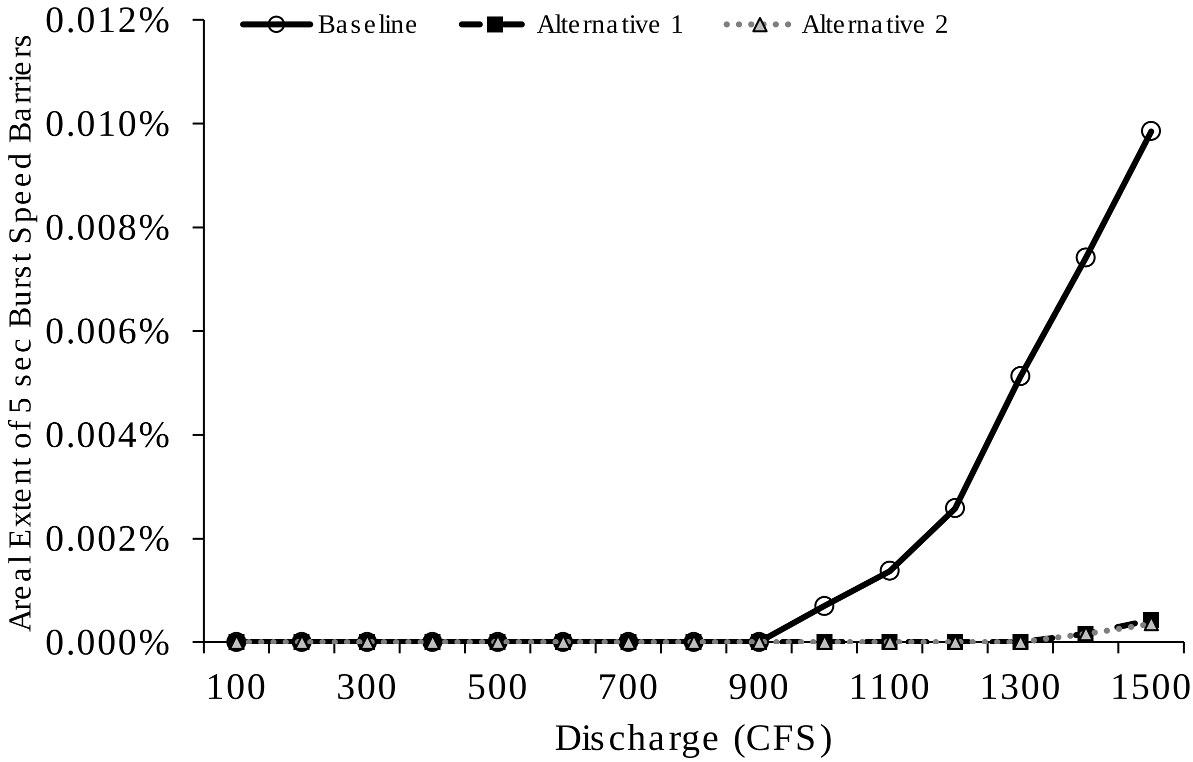

Figure 10. Emergence of reachwide areal extent (as percentage of wetted channel area) of 5 second burst speed barriers as a function of increasing discharge, under baseline conditions and modeled alternatives.

The predicted fish passage benefits of Alternatives 1 and 2 can be visualized more clearly by plotting the reduction in emergence of 5 sec burst speed barriers as a function of increasing discharge (**Figure 11**). Under baseline conditions, at flows <1,000 cfs none of these very high velocity barrier patches occur within the study reach; at flows ≥1,000 cfs an increasing number and spatial extent of very high velocity barrier patches emerge. At flows of approximately 1,000-1,300 cfs, Alternatives 1 and 2 are predicted to completely eliminate those very high velocity barrier patches that do emerge under baseline conditions (e.g., immediately upstream of the snagging hole). Of note, these effects are predicted to persist at high flow (1,300-1,500 cfs): the reduction in spatial extent of high velocity barrier patches predicted under Alternatives 1 and 2 is >95%, up to at least 1,500 cfs.

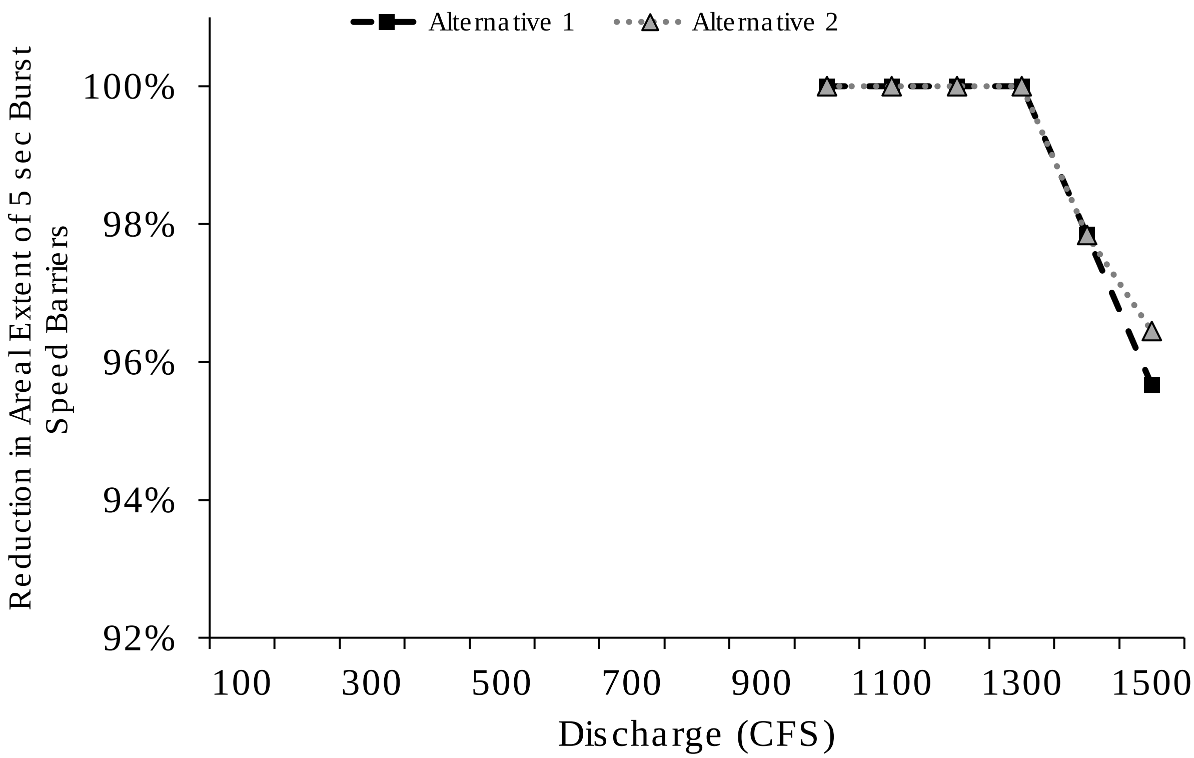

Figure 11. Percent reduction (compared to baseline conditions) in the spatial extent of 5 second burst speed barriers across the study reach, under Alternatives 1 and 2, as a function of increasing discharge. Below 1,000 cfs, no such barriers are present under baseline conditions.

Discussion

Hydraulic Model Inference

See NHC 2018 memo by Brown et al. that accompanies this report.

Fish Contextualization Inference

Is fish passage improved overall?

Under either of the Alternatives evaluated, upstream adult steelhead passage could increase. In particular, there appears to be potential for substantial reduction in the emergence of very high velocity barriers (5 sec burst barriers) under both options. Reachwide reduction in spatial extent of all potential barriers does not appear likely under either Alternative. But, this may not be biologically relevant, given that fish already pass under conditions where substantial sub-critical velocity barriers emerge.

What is the relationship between passage improvement and discharge?

Reductions in spatial extent of very high velocity (5 sec burst) barriers associated with Alternatives 1 and 2 could provide benefits to fish passage that would likely persist across the range of discharge evaluated, which includes hydrologically and biologically relevant flows (e.g., spring freshet and bankfull discharge). Reachwide reductions in all potential barriers does appear to diminish at discharge ≥1,000 cfs, indicating that these modifications may become overwhelmed at high flow. But, this reduction in effect may not be biologically relevant if high velocity patches are reduced or eliminated.

Is there reasonable evidence suggesting that mitigation work would solve, and not just redistribute or re-categorize, fish barriers?

It does appear that the mitigation options evaluated would distribute and in some instances increase the spatial extent of sub-critical velocity barriers. However, this is not the case for very high velocity (5 sec burst) barriers, which are predicted to be eliminated or reduced by ≥95% in area, up to at least 1,500 cfs (bankfull flow).

CONCLUSIONS

- Both mitigation Alternatives may reduce emergence of very high velocity barriers within the study reach that occur as discharge exceeds 1,000 cfs.
- The benefits of both Alternatives are predicted to persist at high flows, including up to bankfull flows (approximately 1,500 cfs).
- Both Alternatives are predicted to almost completely prevent the emergence very high velocity (5 sec burst) barriers at flows between 1,000 and 1,500 cfs.
- Alternative 2 may provide a slightly greater reduction in the spatial extent of all barriers at moderate flows (<400 cfs).
- Neither Alternative appears to have the potential to provide meaningful reachwide reductions in all barriers as discharge exceeds approximately 600 cfs, but this may not be biologically relevant, given previous observations that fish pass when many such barriers are present.

REFERENCES

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