Operational alternatives to address warmwater invasives

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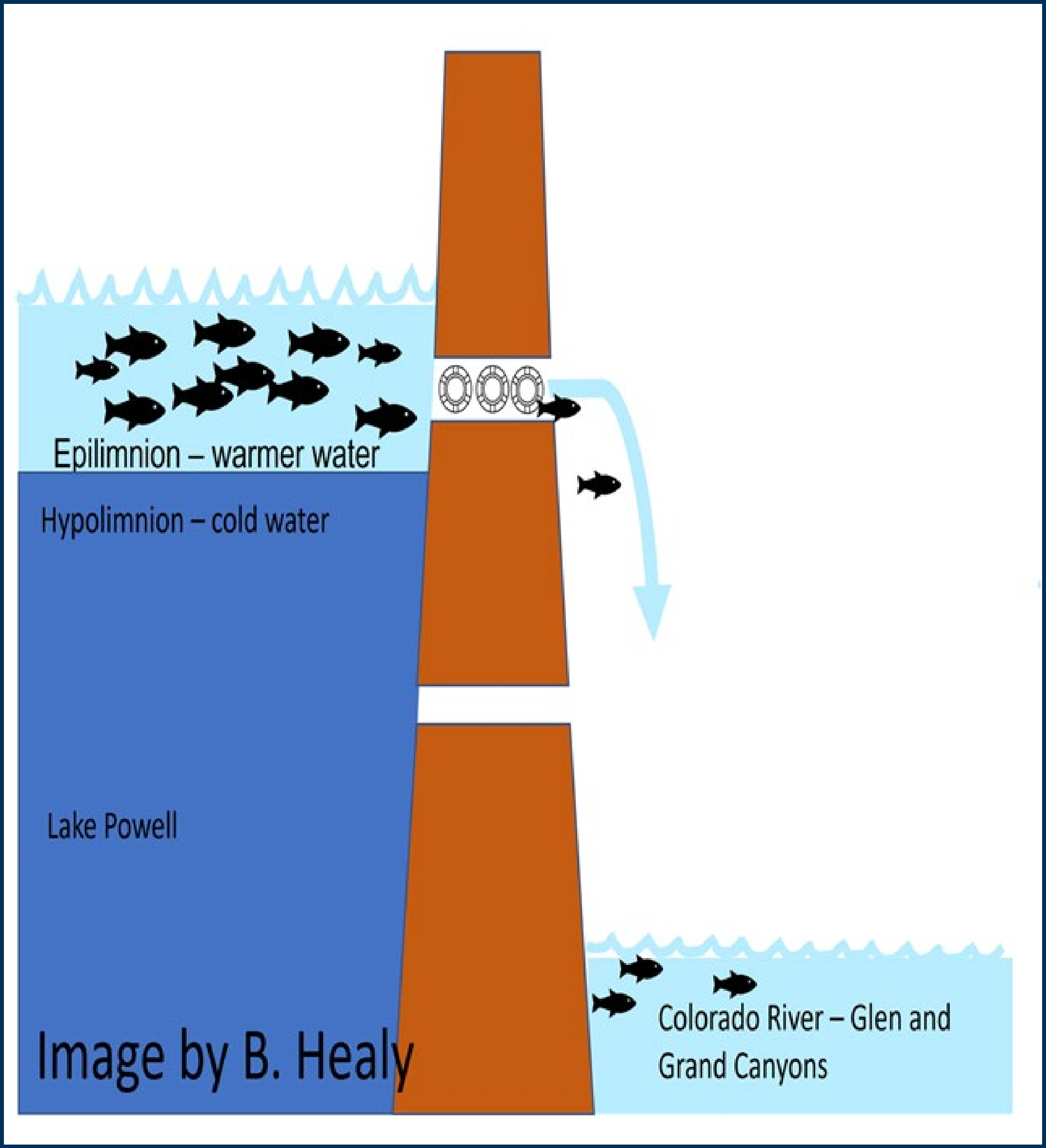
with lots of help.



Charge

- Develop 2-4 operational alternatives that could help prevent warmwater invasive fish establishment, while minimizing potential adverse effects to other resources.

- Operational alternatives that are not within the scope of the Long-Term Experimental and Management Plan Record of Decision may be proposed, but would require additional National Environmental Policy Act, Endangered Species Act, and National Historic Preservation Act compliance.

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Background: the threat

- Where smallmouth bass (SMB: *Micropterus dolomieu*) have invaded in the Colorado River basin, they are considered the biggest threat to native fish species.
  - The humpback chub population located in and around Echo Park (confluence of Green and Yampa rivers) declined by ~90% within 3 years of SMB establishment.
  - The Echo park population of humpback chub is now considered functionally extinct.

Background: why now?

- SMB have been rarely observed in our system in past years, however reproduction was not observed until 2022.
- Entrainment and water temperatures are increasing with lower lake elevations.

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Background: why operational changes?

- Actions that do not involve operational changes may delay establishment and are likely to be useful in synergy with operational changes, HOWEVER,
- There is no example, to our knowledge, in which establishment of warmwater nonnatives in a large river system like the Colorado River in the Grand Canyon segment has been prevented or reversed while environmental conditions remained suitable.

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Background: Timing

- Goal is to prevent establishment during a transition period to more long-term solutions (e.g., infrastructure to minimize fish passage and/or changes to much deeper withdrawal depths).

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Charge

- …alternatives that could help prevent warmwater invasive fish establishment, while minimizing potential adverse effects to other resources.

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Outline

- Alternative description
- Evaluation of expected effectiveness
- Tradeoffs with other resources

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Note on hydrographs

- All hydrographs that are presented begin on Wednesday and move equal weekly water volumes (based on actual hydrograph from the week of June 9, 2021).
- Assumed for graphics that jet tube releases are 11°C and penstock releases are 18°C.
- Details of hydrograph change when monthly volumes, release temperatures or seasonal conditions (e.g., solar insolation) differ.

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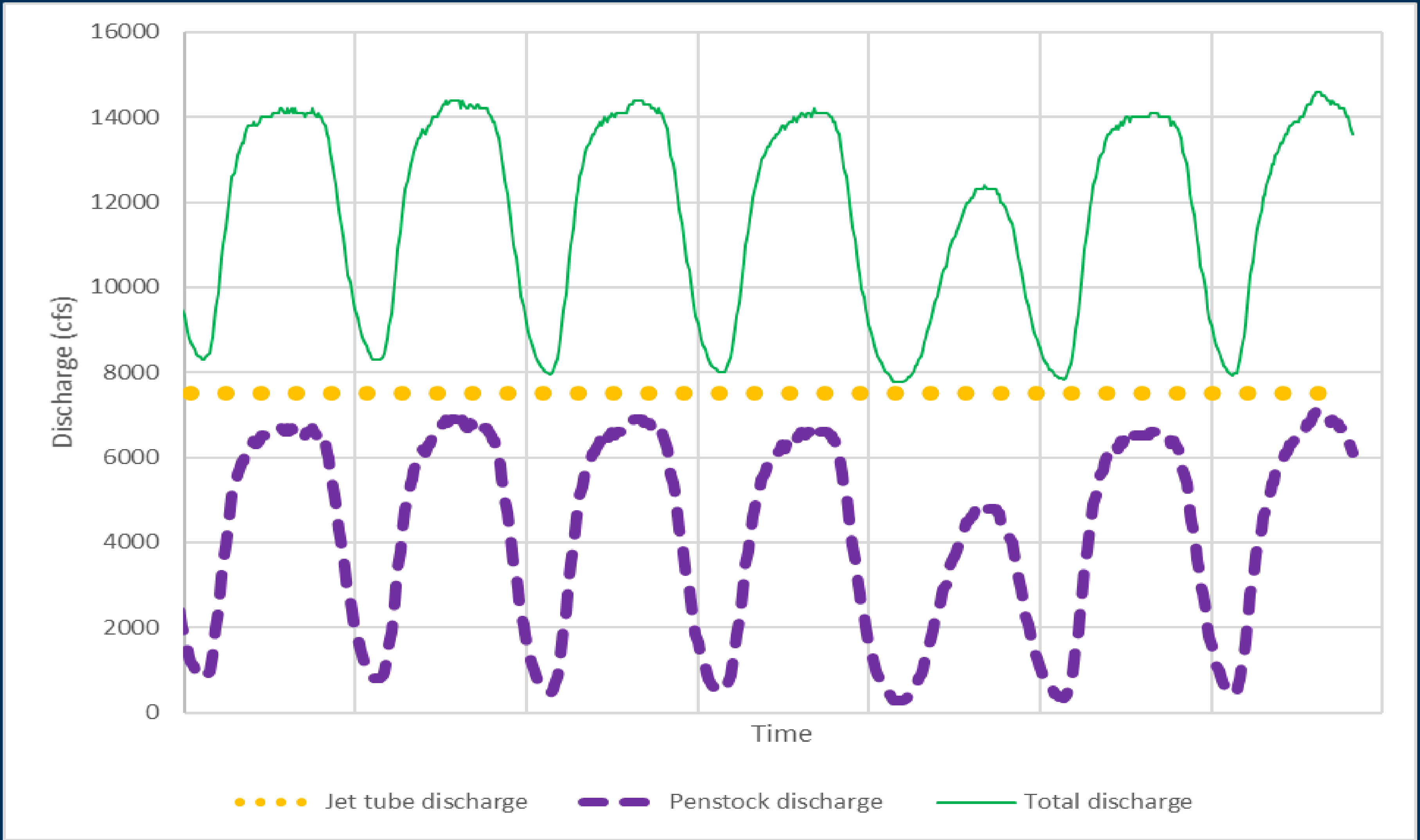
Alternative 1

- **Description: Mix water releases between penstocks and bypass tubes to maintain a daily average water temperature below 16°C at the Little Colorado River (LCR) confluence.**

- **Duration: As required.**

- **Rationale: Temperatures of 16°C or greater are required for smallmouth bass (and many other nonnatives) to initiate spawning.**

Alternative 1



(Preliminary, do not cite)

Alternative 2

- Description: Once a week, lower flows to 2000 cfs and increase to 25000 cfs – the maximum range without any bypass.

- Duration: 12 weeks starting when daily water temperatures at the LCR confluence approach 16°C.

- Rationale: Males choose nest sites with flows < 0.1 m/s. They will abandon nest sites if areas are de-watered or velocities are increased above 0.3 m/s (but often will choose new sites).

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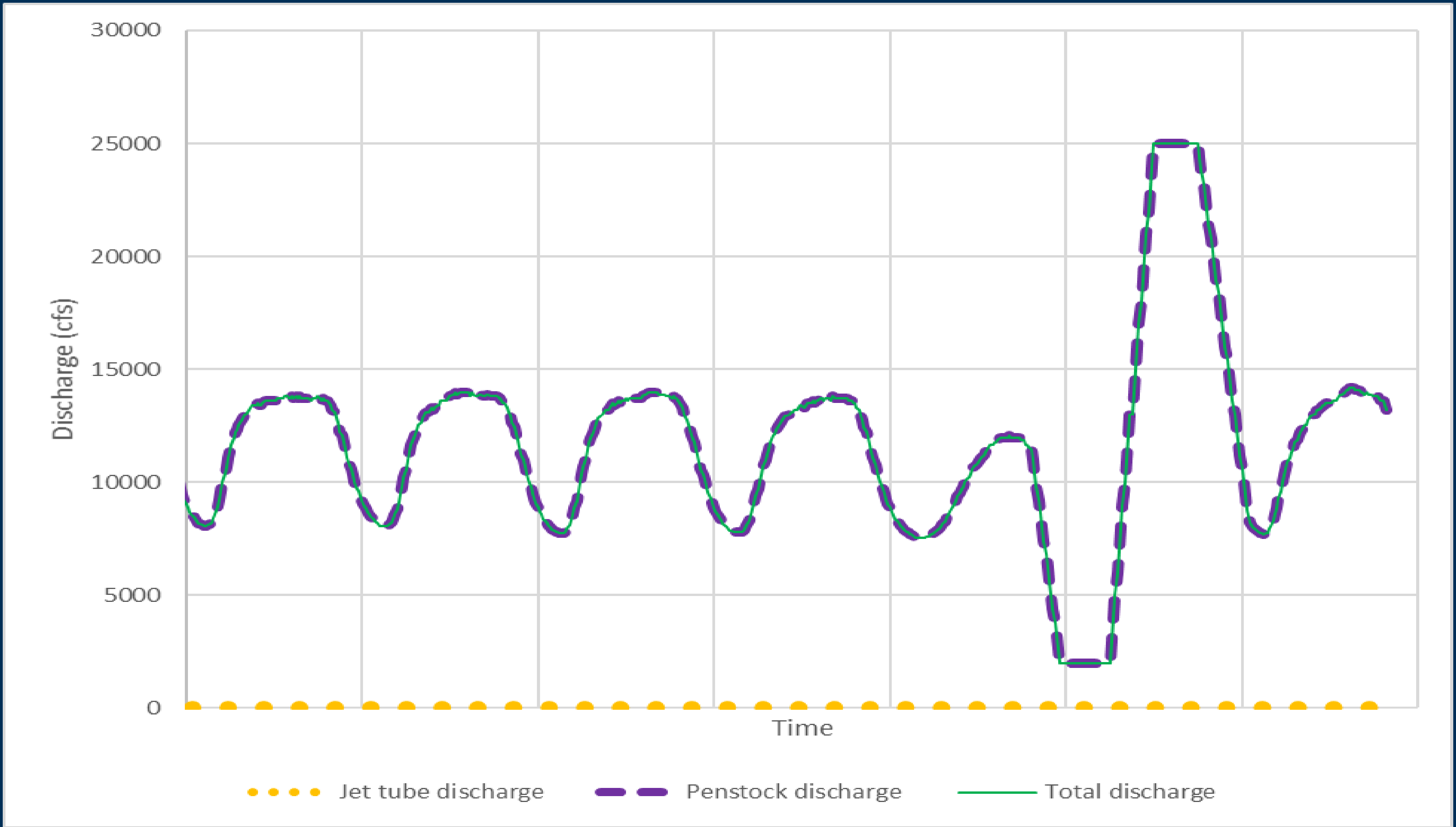
Alternative 2



(Preliminary, do not cite)

Alternative 3

- **Description: Once a week, switch fully to jet tubes for at least 48 hours.**
- **Duration: 12 weeks starting when daily water temperatures near the LCR approach 16°C.**
- **Rationale: Cold shocks are likely to disrupt SMB spawning behavior if they involve a significant drop in water temperature and occur over a sufficient time span. Temperatures below 12°C are most likely to be effective.**

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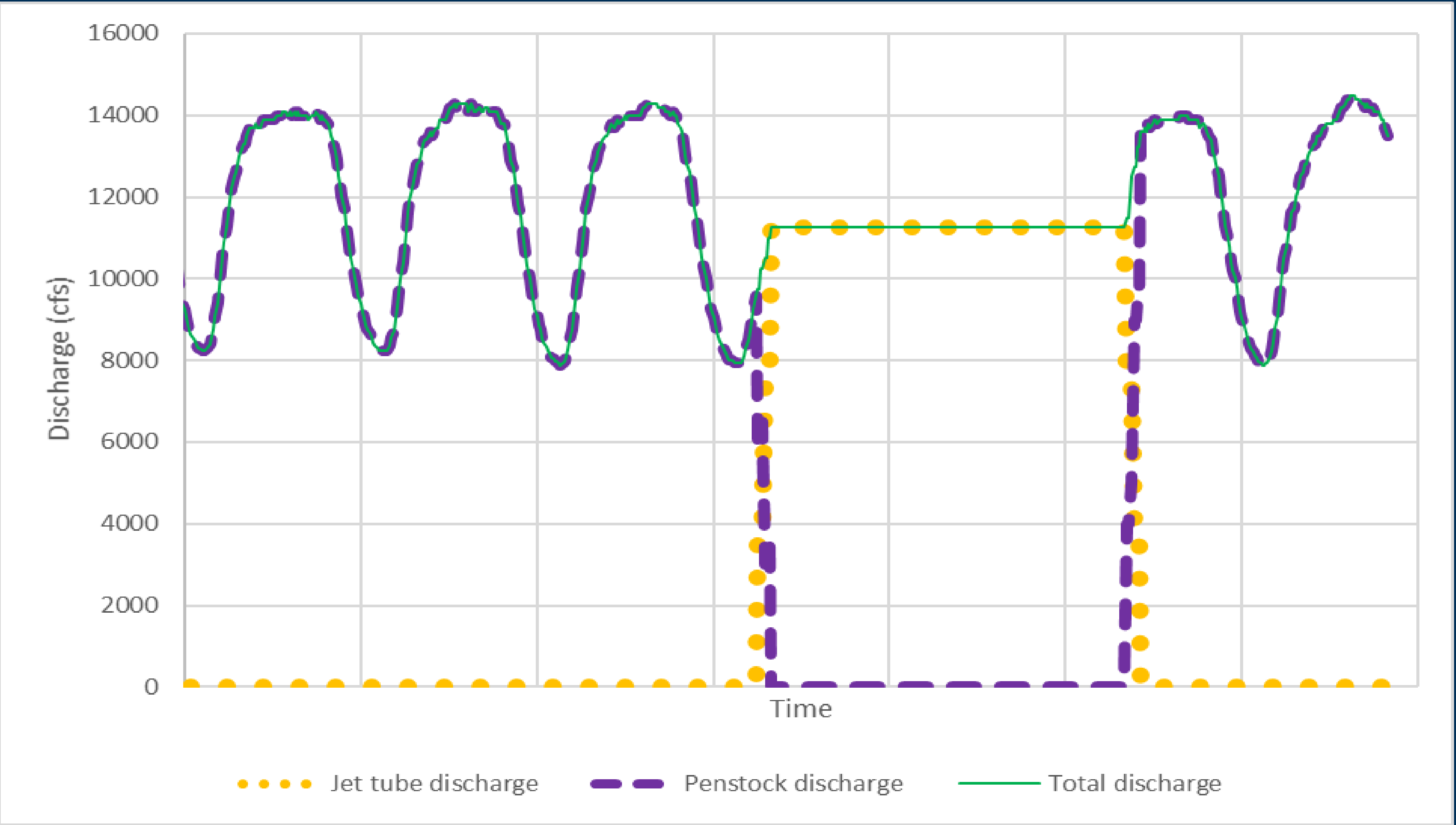
Alternative 3



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(Preliminary, do not cite)

Alternative 4

- **Description: Once a week, switch fully to jet tubes for at least 48 hours and then follow with a short flow spike.**

- **Duration: 12 weeks starting when daily water temperatures near the LCR approach 16°C.**

- **Rationale: Cold shocks are likely to disrupt SMB spawning behavior. The flow spike would be expected to disrupt spawning in some margin habitats.**

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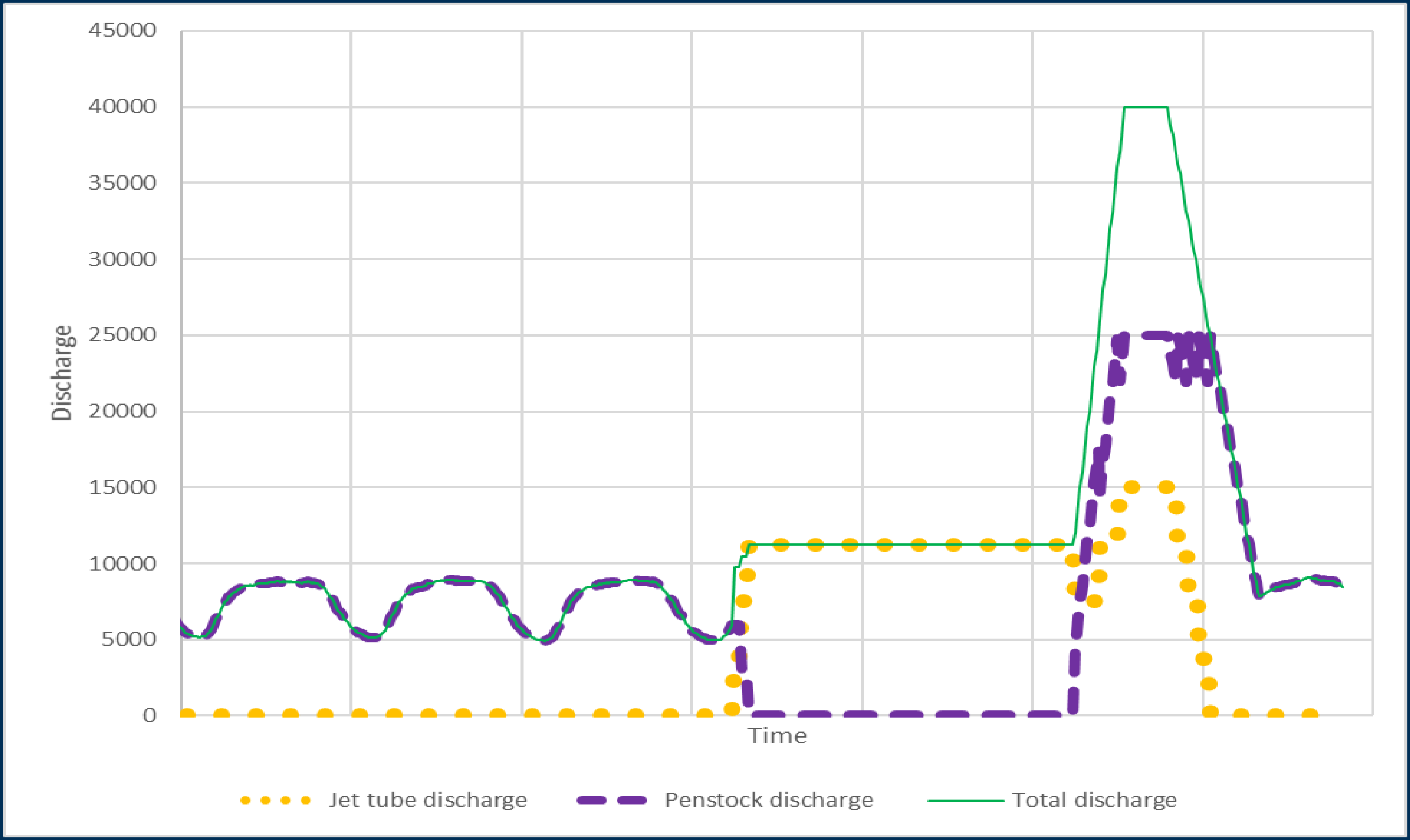
Alternative 4



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Evaluation

- Lambda
  - < 1 – declining population
  - 1 – stable population
  - > 1 – increasing population (e.g., 2 indicates population is doubling ever year)
- Bypass
  - Proportion of annual discharge moved through jet tubes based on alternative.

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Modelling assumptions.

- 7 maf outflow according to monthly schedule described in July 24 month study.
- Inflows and Wahweap temperature profiles based on resampling 2000 – 2021 – we did not include Drought Response Operations Act additions.
- Same equations as Colorado River Simulation System to update storage and lake elevation.
- Lambda determined based on time series of water temperatures using relationships developed from Yampa-Green river system.
- Effects of flow variation determined by mapping distribution of suitable habitat under base conditions and determining what proportion of suitable habitat was de-watered or subjected to velocities greater than 0.3 m/s.

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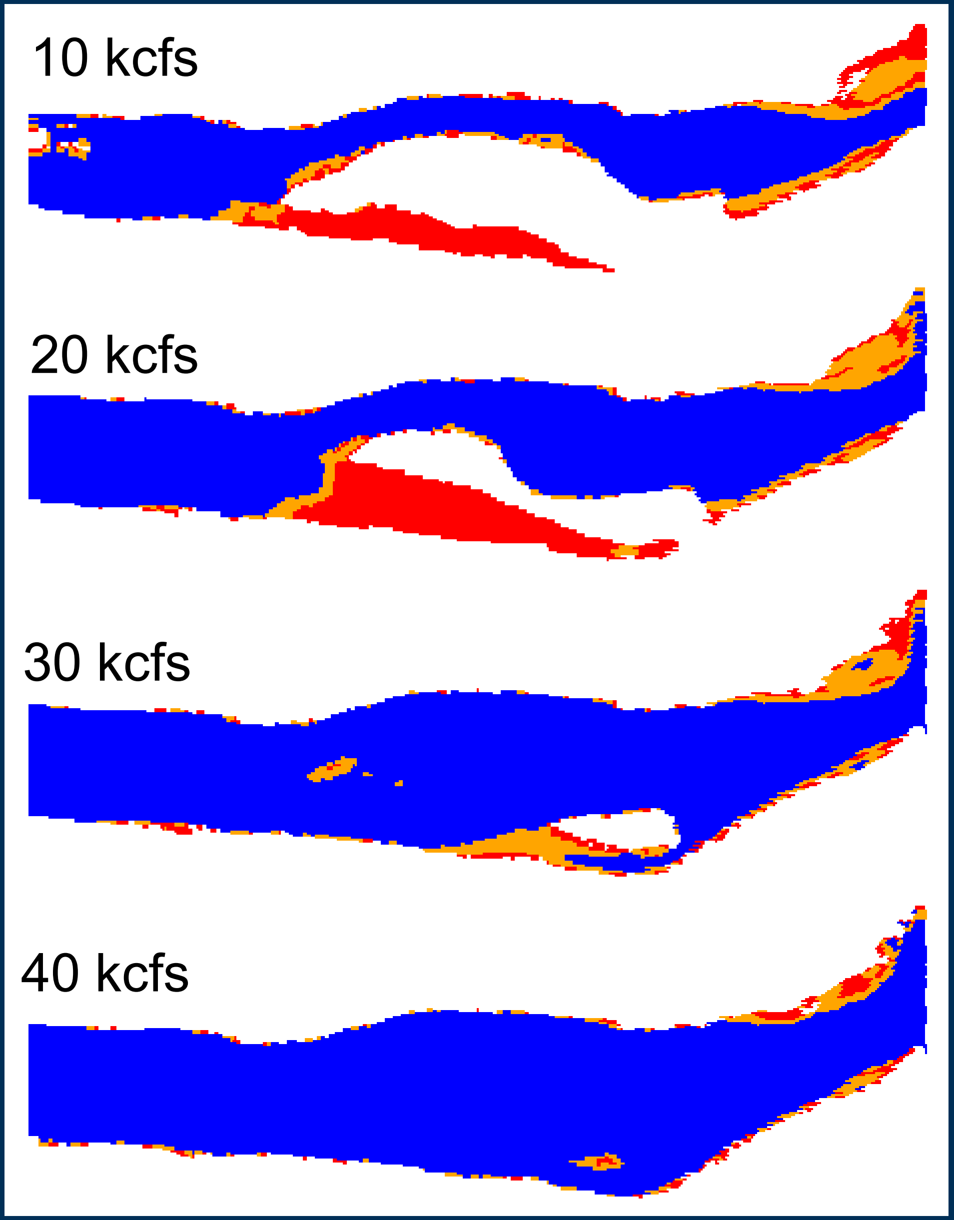
Velocity maps – the slough as an example

- **SMB potential nesting habitat in red.**
- **Areas that SMB would abandon nests in blue.**

<= 0.1 m/s
>0.1 to 0.3 m/s
>0.3



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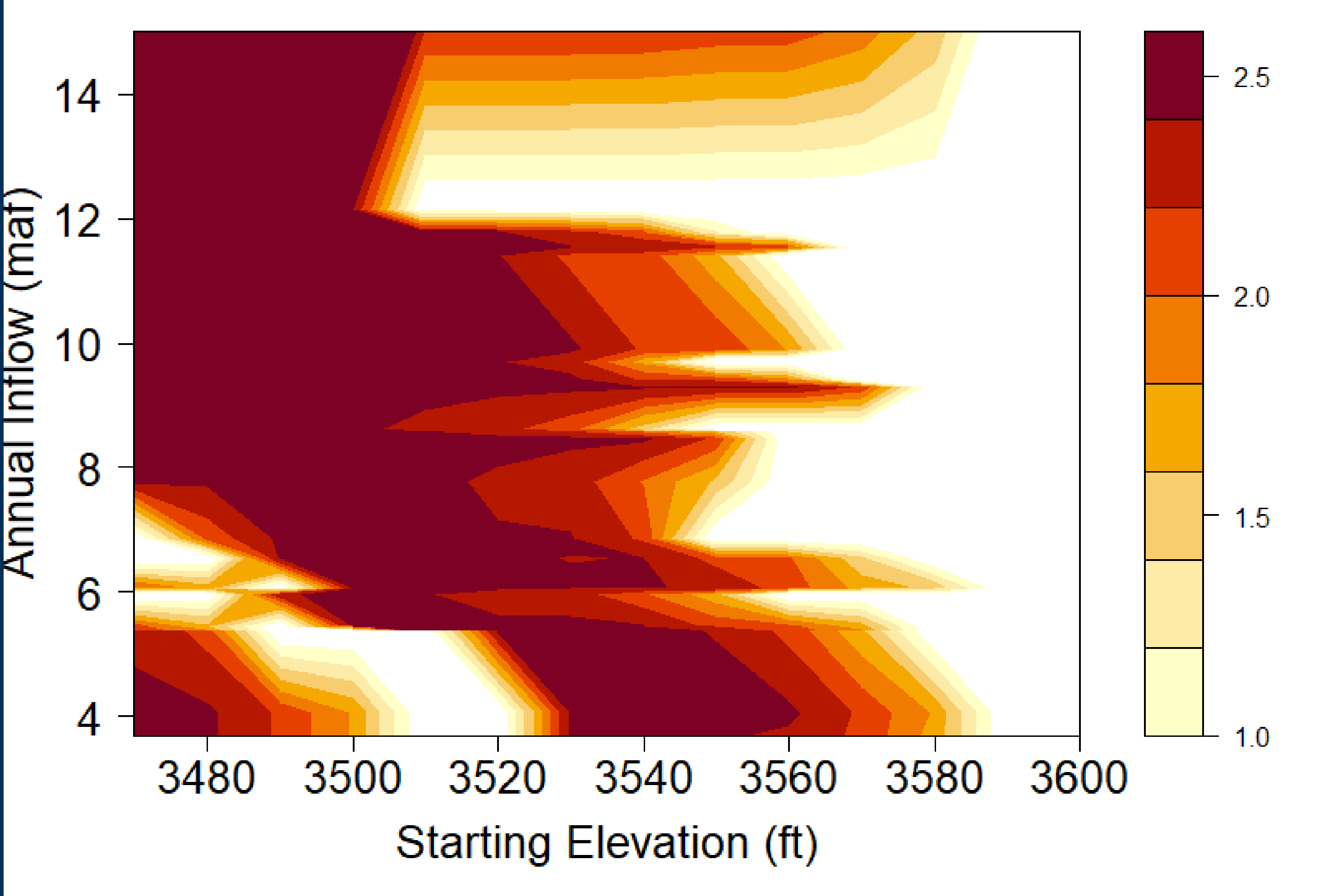
No action – SMB lambda at Little Colorado River confluence



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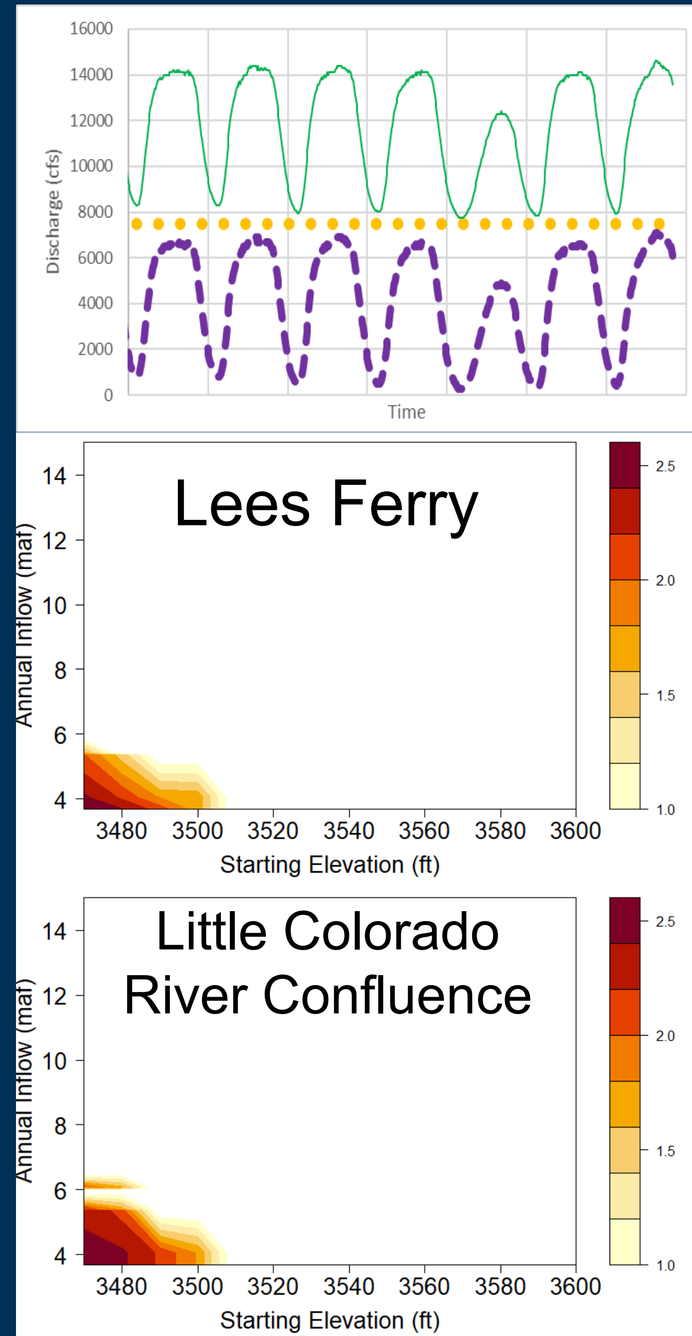
Alternative 1

- High certainty of prevention under most conditions.
- Caveats – SMB spawning in warmer margin habitats not modelled.



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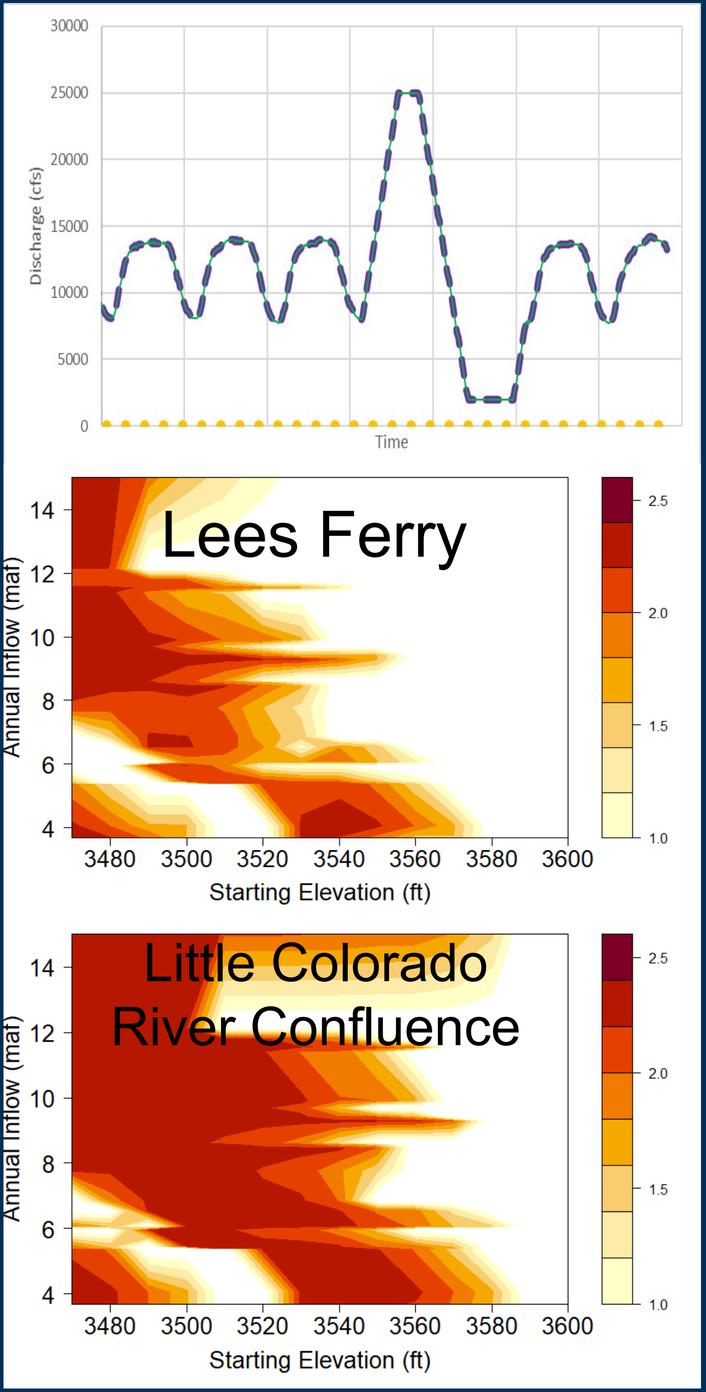
Alternative 2

- **Lowers lambda but doesn't prevent establishment.**
- **Caveats – velocity data only available for Lees Ferry reach.**



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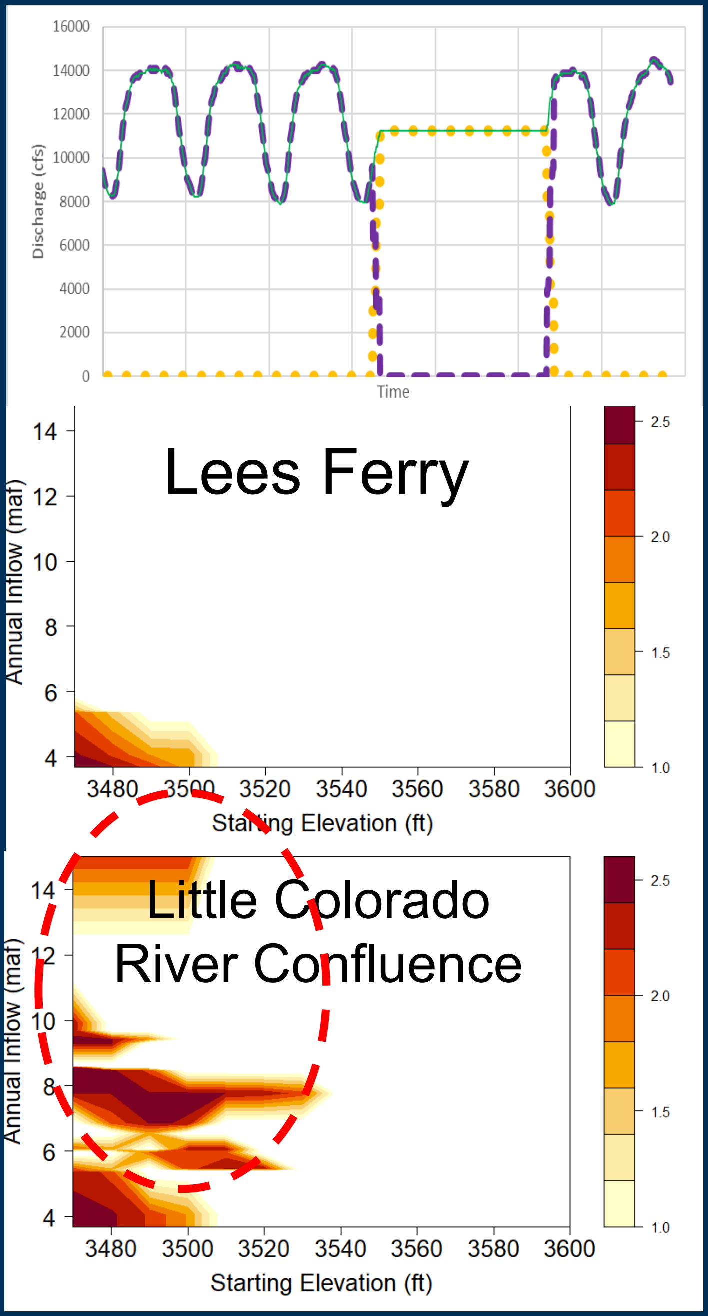
Alternative 3

- Less certainty than Alt. 1, but good chance of prevention under most conditions.
- Caveats –SMB spawning in warmer margin habitats not modelled.



(Preliminary, do not cite)

Alternative 4

- Less certainty than Alt. 1, but good chance of prevention under most conditions.
- Lower lambdas than Alt 3.
- Would address slough and similar habitats if flow spike reaches 40 kcfs.

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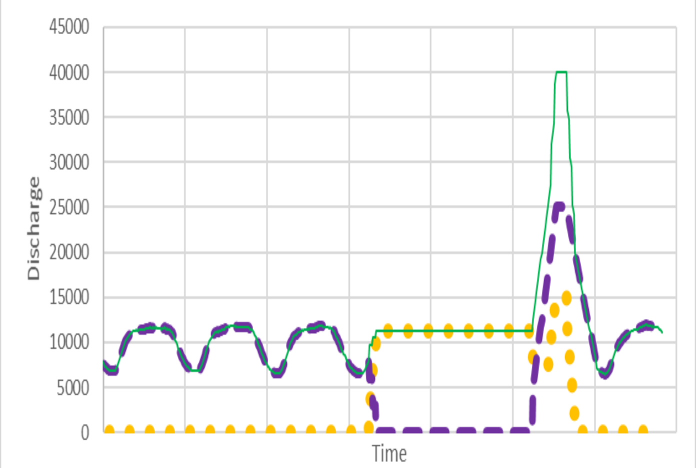

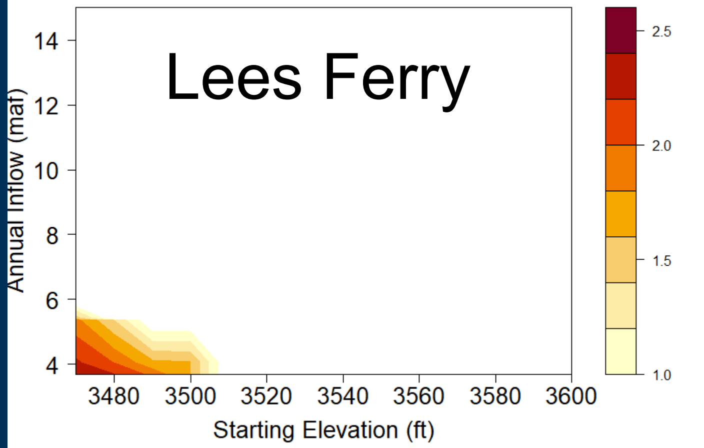

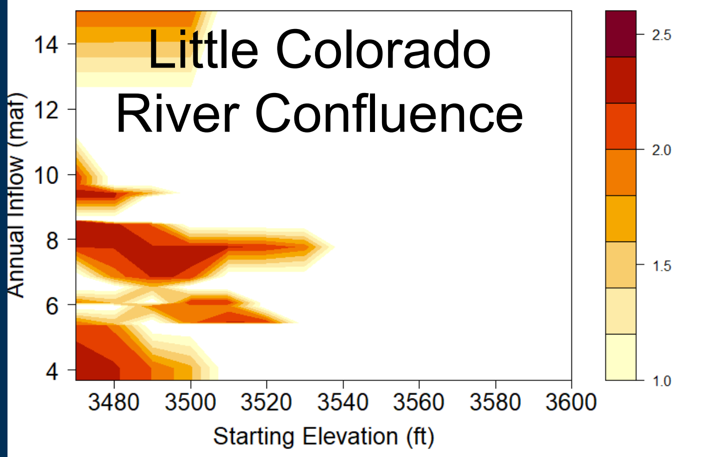

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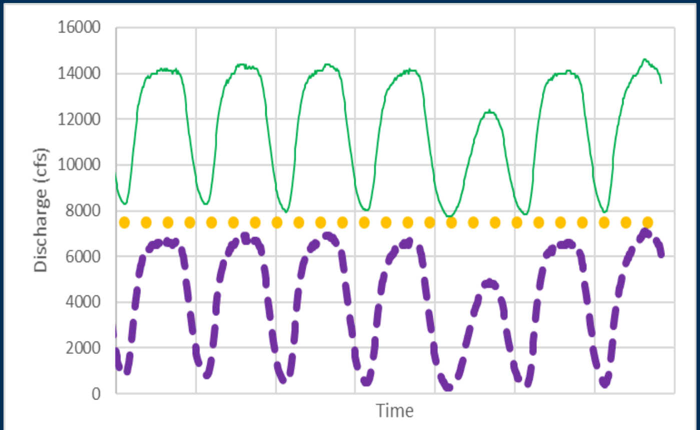
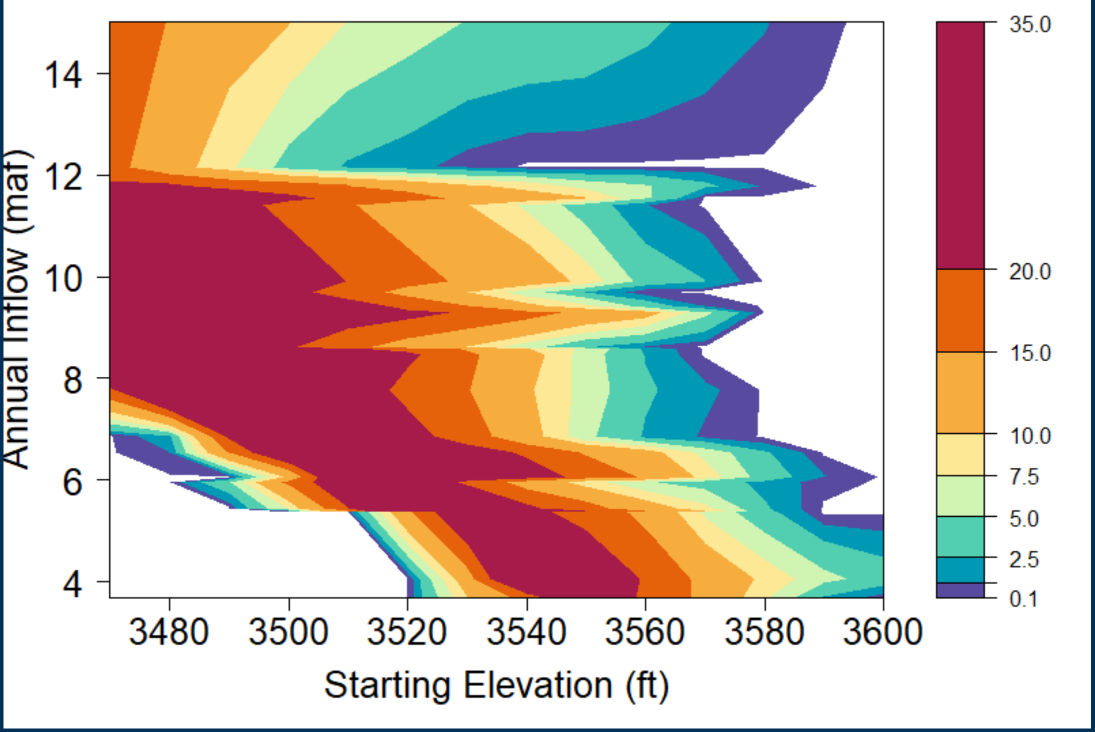
Alternative 1



- Highly effective with high certainty.
- Potential for substantial amounts of bypass.
- Could reduce bypass through changes in monthly allocation and/or by switching to full bypass in some months.



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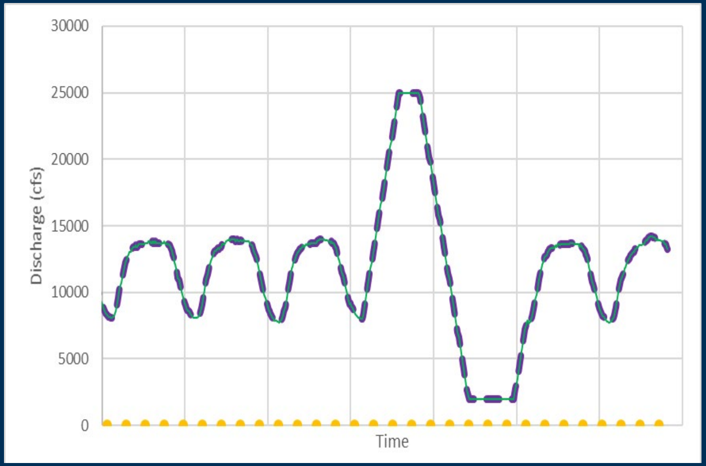
Alternative 2

- No bypass, but unlikely to prevent establishment.
- May moderately slow establishment and/or lower carrying capacity for SMB.



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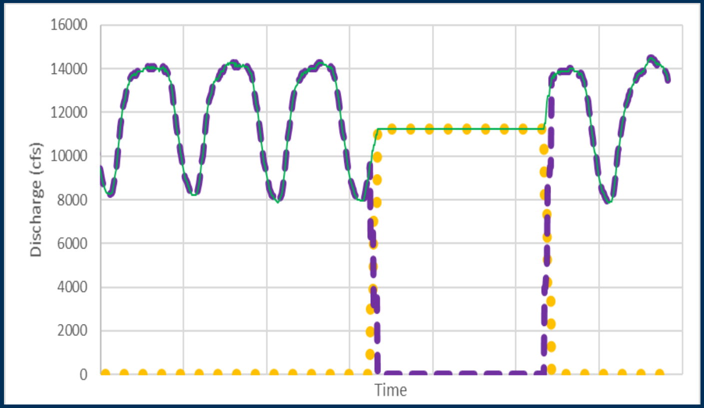
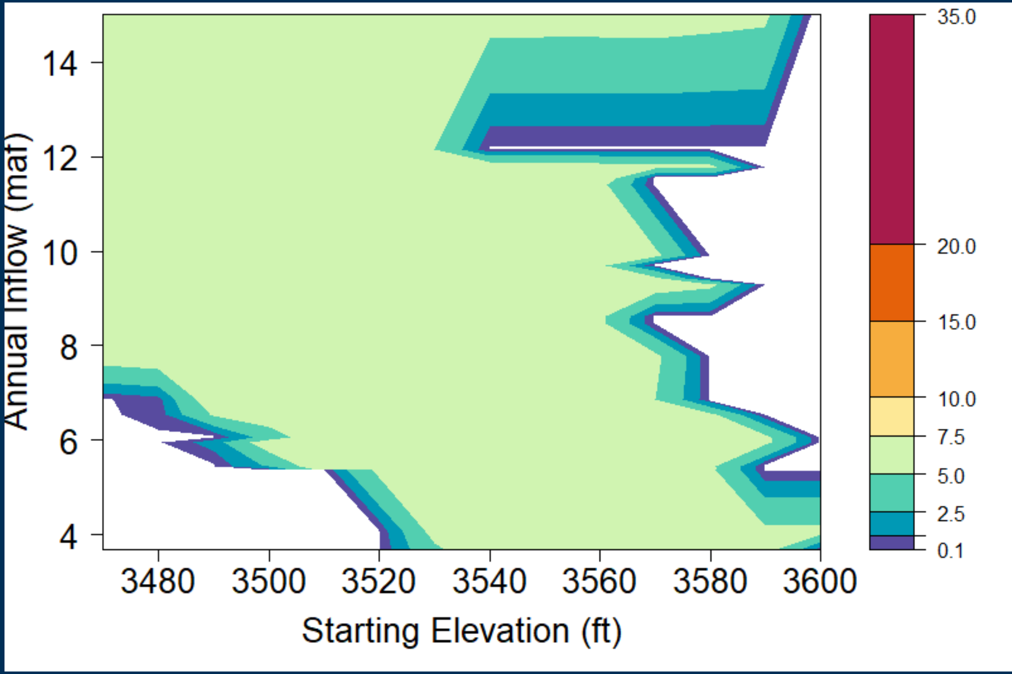
Alternative 3



- Could be effective, but more uncertainty than alt. 1.

- Bypass of 5 - 7.5% or less.



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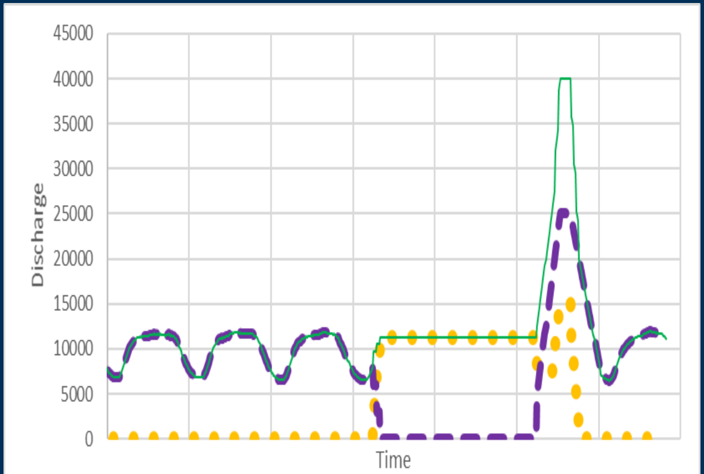
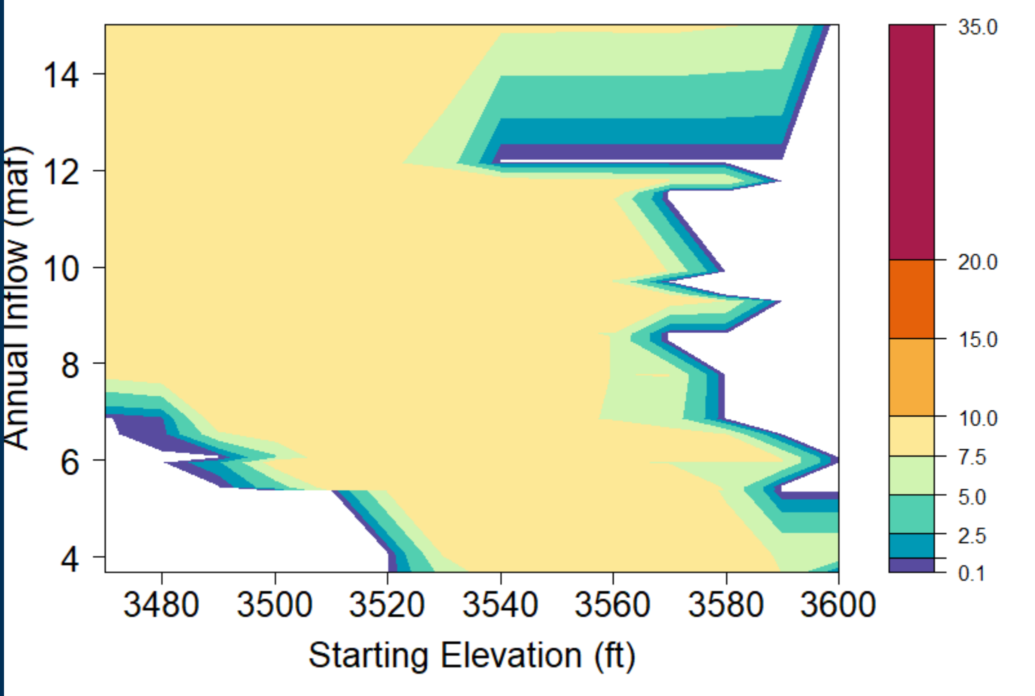
Alternative 4

- Slightly higher chance of prevention than alt. 3 because of flow spike.
- Bypass of 7.5 - 10% or less.





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Interpreting the next slide

	Alt 1	Alt 2	Alt 3	Alt 4
Resource	-	+	+ + / 0	+ + / - -

- **Attempt to distill complex responses from experts with much more nuance.**
- **<u>All signs are relative to a no action alternative.</u>**
- **Signs based on typical preferred direction for a resource (i.e., a + for warmwater nonnatives means you are decreasing them).**
- **Number of pluses or minuses indicates the relative magnitude of an effect.**
- **Dashes indicate either uncertainty or where there are multiple facets to a resource that might respond differently.**

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Expected impacts to other resources relative to baseline LTEMP operations

	Alt 1	Alt 2	Alt 3	Alt 4
Hydropower	- - -	+ / -	- -	- -
Riparian Vegetation	0	+ / -	0	- - / - - -
Archaeological and Cultural Resources	0	+ *	0	+ + / + *
Sediment	0	+ *	0	+ + / + *
Recreation	+ + + / 0	+ / - -	+ + / - -	+ + / - -
Rainbow trout	+ + +	- -	+ + / -	+ + / -
Aquatic warmwater nonnative invasive species (besides smb)	+ + +	+ + / 0	+ + / 0	+ + / 0
Humpback chub	+ + +	+ / -	+ + + / 0	+ + + / 0
Other native fish	+ + +	+ / -	+ + + / 0	+ + + / 0
* based on this year's sand enriched conditions - would differ if sand were depleted.				
Resources not evaluated here: Natural processes & Tribal Resources				

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Conclusions I

- Alternative 1 has a high certainty of success in prevention with positive or neutral tradeoffs for all evaluated resources except hydropower.

- In comparison, Alternatives 3 and 4 are less certain, less directly beneficial to rainbow trout, and likely to have less effect on other warmwater invasive fish species but involve less impacts on hydropower and in the case of Alt 4 could benefit some terrestrial resources.

- Alternative 2 is unlikely to prevent SMB establishment.

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Conclusions II

- Acting next year will increase the likelihood of success and is likely to minimize long-term costs. We are likely to see increased entrainment in the coming winter / spring.

- All alternatives will be more effective if paired with efficient and targeted non-operational actions.

- Modifications to alternatives and/or hybrid alternatives could help to minimize negative tradeoffs and/or increase positive tradeoffs, however important that perfect does not become enemy of the good.

- Taking a truly adaptive approach informed by well designed, efficient monitoring and research could lead to improved tradeoffs over time.

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Acknowledgements

- The smallmouth bass ad-hoc group, especially Laura Dye, Emily Higuera, Seth Shanahan, and Shana Rapoport provided invaluable input that helped shape alternatives and the analysis of their predicted impacts.
- Special thanks to Kevin Bestgen for providing thoughts based on many years of experience with smallmouth bass in the Green and Yampa river systems.
- Thanks to scientists at GCMRC, FWS, AZGFD, and NPS who evaluated resource tradeoffs on very short notice.
- Small mouth bass task force members contributed substantially to earlier analyses and ideas and included participants from USFWS, USBR, NPS, USGS, AZGFD, and WAPA.
- Models used to analyze effectiveness relied heavily on earlier work in collaboration with Lindsey Bruckerhoff, Kevin Bestgen, Jian Wang, Kim Dibble, Bryce Mihalevich, and Jack Schmidt.
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