

SApril 27, 2026

To: Glen Canyon Leadership Team for Implementation of Experiments under the Long Term Experimental and Management Plan (LTEMP)

From: Glen Canyon Dam Planning and Implementation Technical Team

Re: Recommendation Regarding a Smallmouth Bass Flow Experiment at Glen Canyon Dam, Summer 2026

I. Recommendation Summary

Based on the 2016 LTEMP Record of Decision (ROD; DOI 2016b) and 2024 LTEMP Supplemental Environmental Impact Statement (SEIS) ROD (DOI 2024b), the Glen Canyon Dam Planning and Implementation (PI) Technical Team has worked over the past several weeks to evaluate existing information and data in determining this recommendation regarding a Smallmouth Bass Flow experiment at Glen Canyon Dam (GCD). The PI Technical Team's recommendation regarding implementation of a Summer 2026 Smallmouth Bass Flow Experiment is based on a careful assessment of resources and best available science.

By majority recommendation, The Planning and Implementation (PI) Technical Team recommends the PI Leadership Team consider the following Long-Term Experimental and Management Plan (LTEMP) Supplemental Environmental Impact Statement Alternative Flow for implementation in the summer/fall of 2026:

- **Flow Option = Cool Mix**
- **River Mile Target and On-ramp = When average daily temperature at River Mile 15 exceeds 15.5°C for three consecutive days.**
- **Off-ramp Date = October 20th, 2026**

Key discussion topics of the Planning and Implementation Technical Team summarized by Reclamation:

The PI Technical Team understands that Cool Mix Flows comes at a substantial cost to hydropower production and the Basin Fund. Cool Mix Flows were created and originally recommended as a Mid-Term action to address spawning of already entrained fish. Cool Mix Flows have been effective at disadvantaging smallmouth bass in 2024 and 2025, however, **without a limitation on entrainment, Cool Mix Flow efforts in the long-term may be unsustainable as management tool.**

The PI Technical Team emphasizes the need for adequate monitoring in the Lees Ferry reach to determine the level of entrainment given this year's projected low reservoir elevations. **Alternative tools that address both entrainment at Glen Canyon Dam and expansion of nonnative fish species downstream are needed** to protect all the resources of the Glen Canyon Dam Adaptive Management Program. Finally, the PI Technical Team would like to see progress on long-term management tools for nonnative species and protection of the Colorado River below Glen Canyon Dam.

Background and Purpose of the Recommendation

The purpose of this memorandum is for the PI Technical Team to transmit a recommendation to the PI Leadership Team. Once the PI Leadership Team has provided a recommendation, this memo will be forwarded to the Department of the Interior (Department) in accordance with the LTEMP ROD (DOI 2016a). The PI Technical Team includes technical representatives from the National Park Service (NPS), U.S. Fish and Wildlife Service (FWS), Bureau of Indian Affairs (BIA), U.S. Geological Survey (USGS) Grand Canyon Monitoring and Research Center (GCMRC), Bureau of Reclamation (Reclamation), Western Area Power Administration (WAPA), Arizona Game and Fish Department (AZGFD), seven Colorado River Basin States (Basin States), and the Upper Colorado River Commission (UCRC).

The PI Leadership team will consider the PI Technical Team's recommendation and develop a PI Leadership Team recommendation to be submitted to the Secretary of the Interior. The Secretary of the Interior or their Designee will consider the recommendation of the PI Leadership Team but retains sole discretion to decide how best to accomplish operations and experiments in any given year pursuant to the LTEMP ROD, LTEMP SEIS ROD, and other binding obligations for GCD.

Over the past several weeks the PI Technical Team reviewed a No Action, Cool Mix, and Non-bypass Smallmouth Bass Flow experiment for the Summer of 2026. After discussions during the opening meeting, the PI team determined that evaluation of a cold shock alternative and cool-mix scenarios beyond what was considered in 2025 was not necessary. The LTEMP SEIS (DOI 2024a) determined that these flows would likely not perform as well in reducing smallmouth bass recruitment as a Cool-Mix Flow. Furthermore, current data reflects success of the Cool-Mix Flows in 2024 and 2025, providing a baseline for the implementation of Cool Mix flows. Cool Mix options were prioritized by Technical Team members for analysis and further consideration, while including one Non-bypass Flow option and the No Action alternative for comparison. The LTEMP SEIS ROD modeling found that Cool Mix Flow maximized the goal of reducing smallmouth bass recruitment and Non-bypass Flow had the least impact to hydropower costs, but was unlikely to prevent spawning. The timing of the Cool Mix Flow and Non-bypass Flow experiment options were based on water temperatures reaching $> 15.5^{\circ}\text{C}$. The PI Technical Team's recommendation to implement a Cool Mix Flow with a River Mile Target of 15 and off-ramp on October 20th, 2026, was reached by a majority vote (Table 1).

Table 1. Technical position of PI Technical Team members for consideration of a Summer of 2026 Smallmouth Bass Flow experiment.

Entity	Recommendation/Position
DOI-BOR	Support
DOI-NPS	Support
DOI-FWS	Support
DOI-USGS	Abstain
DOI-BIA	No Vote
DOE-WAPA	Oppose

Arizona	Support
California	Support
Colorado	Support
Nevada	Abstain
New Mexico	Abstain
Utah	Support
Wyoming	Oppose
AZGFD	Support
UCRC	Support

II. Screening Tool, Temperature Model, and Suggested Parameters of Cool Mix and Non-Bypass Flow, Experimental Design

Screening Tool

Overview

This analysis evaluates the ecological and hydropower impacts associated with temperature-triggered experimental flow alternatives at Glen Canyon Dam intended to reduce the risk of smallmouth bass (*Micropterus dolomieu*, hereafter SMB) establishment downstream. We integrated hydrology, water temperature, population dynamics, and habitat disturbance models to assess the timing, cost, and biological efficacy of experimental flows under a variety of hydrological and operational scenarios. These analyses followed the experimental flow framework in the LTEMP Supplemental Environmental Impact Statement (U.S. Department of Interior, 2023) and followed the general modeling framework detailed in Yackulic et al. 2024, incorporating model improvements to individual modelling components that have occurred.

Methods

We began by using the 30 hydrologic traces from the March 15, 2026, run of the Colorado River Mid-term Modeling System (CRMMS), which represent a wide range of hydrologic conditions derived from 1991–2020 inflow sequences (U.S. Bureau of Reclamation, 2020). For each trace, a “no-action” hydrograph was generated using monthly release volumes and elevations projected by CRMMS for Glen Canyon Dam. These monthly releases were disaggregated into hourly values assuming load-following operations consistent with Western Area Power Administration (WAPA) scheduling objectives and operational constraints at Glen Canyon Dam as specified by the Glen Canyon Dam Long-Term Experimental and Management Plan (LTEMP) Final Environmental Impact Statement (U.S. Department of Interior, 2016). These base hydrographs served as the reference scenario for comparison of two experimental flow types: Cool Mix and Non Bypass alternatives with the No Action Alternative.

To determine when flows should be triggered, we estimated daily average water temperatures along the Colorado River using a two-part model. The first part estimated Glen Canyon Dam release temperatures (both penstock and bypass) based on spring inflow volume (April–July), day of year, and release depth, using a model calibrated to 225 historical temperature profiles collected between 2000 and 2021 (Andrews & Deemer, 2022; Eppehimer et al., 2025). Inputs for

each CRMMS trace included projected elevation, inflow, and outflow values. Because the release temperature model functions on a calendar-year basis, historical inflow, elevation, and outflow data from January and February 2026 were added to inputs. The second part of the temperature model, based on Dibble et al. (2021), estimated downstream warming using daily values for solar insolation (based on day-of-year and latitude), air temperature from the Page, Arizona weather station, and discharge from Glen Canyon Dam (see Eppehimer et al. 2025). These combined models yielded daily average water temperatures at river mile (RM) 0, 15, 30, and 61. RM 0 corresponds to Lee Ferry, and RM 61 corresponds to the Little Colorado River confluence. Temperature predictions represent mainstem conditions and do not account for warmer or cooler temperatures in adjacent backwaters.

Alternatives were triggered for a given scenario when the three-day rolling mean of estimated temperature at the selected target RM exceeded 15.5°C. Flows were discontinued when the three-day mean dropped below 15.5°C, and when temperatures were expected to remain below 15.5°C thereafter. In addition to this dynamic, temperature derived “offramp,” two fixed offramp dates (October 1 and October 20) were evaluated to examine sensitivity to different termination points. The 15.5°C threshold was chosen to ensure a high likelihood of keeping temperatures below the 16°C estimated spawning threshold for SMB (U.S. Department of Interior, 2023), accounting for variation in warming rates and forecast uncertainty (Eppehimer et al., 2025). The combination of river mile thresholds and offramp dates, both temperature-driven and fixed, define the set of possible scenarios for each experimental alternative.

We assessed the biological efficacy of each experimental flow alternative by estimating the SMB population growth rate, or lambda (λ), using a matrix population model developed by Eppehimer et al. (2025). This model estimates lambda based on thermal suitability. Each simulation covers a 16-month window starting in January and includes temperature-dependent estimates of spawning initiation (triggered when daily average temperature exceeds 16°C and does not drop below 13.9°C within the following week), age-0 growth, and survival. For each scenario and hydrologic trace, we generated 100 lambda values by drawing randomly from the posterior distributions of model parameters, capturing uncertainty in population predictions as well as uncertainty in temperature predictions from the 30 CRMMS traces that trigger temperature management. The lambda estimates assume reproductive adult SMB are present at the target location. **Lambda estimates do not include estimates of either entrained juvenile or adult SMB.** Adult SMB entrainment rates are largely governed by Lake Powell elevation (Eppehimer et al., 2025). Under most hydrologic traces, forecasted elevations for 2026 are lower than anything observed since Dam filling. Therefore, we expect adult entrainment to be greater than observed in 2022 (the lowest year on record), but within the range predicted by the published adult entrainment model (Eppehimer et al., 2025). The extent of juvenile entrainment that will occur is uncertain as the adult entrainment model was designed to estimate adult entrainment. Evidence of juvenile entrainment has not been identified in the last two years or in other moderately low elevation years. **It is possible that juvenile entrainment contributed to the number of juvenile SMB in 2022, the year with the lowest elevations in the late summer when juvenile entrainment would be expected to be greatest, however local reproduction below Glen Canyon Dam was observed in 2022 confounding estimates of the extent of juvenile entrainment.**

The Non Bypass alternative is defined in the LTEMP Supplemental Environmental Impact Statement (U.S. Department of Interior, 2023) and consists of a weekly, short-duration flow experiment. The Non-Bypass alternative evaluated is temperature driven at RM 0. The experiment begins on Sunday at 9:00 PM with a reduction in discharge to 2,640 cfs, followed by a ramp-up to 26,900 cfs (or the maximum available penstock capacity depending on maintenance constraints) by 7:00 AM on Monday. This peak flow is maintained for 1 hour, after which discharges return to normal operations by Monday afternoon. All ramp rate constraints are adhered to during the implementation of this alternative. For Non Bypass scenario, we estimated the effect of fluctuating discharges on SMB spawning habitat using a discharge-velocity model of the Lees Ferry reach at 5x5 meter resolution (Kaplinski et al., 2022a; 2022b; Nelson et al., 2016). We identified potential SMB nesting habitat as areas with baseflow velocities ≤ 0.1 m/s and assumed nests would fail if velocities exceeded 0.3 m/s or if the area became dewatered. These assumptions reflect the likelihood of nest abandonment by guarding males and the high mortality of eggs and larvae under such conditions (Miller & Brewer, 2021; Knotek & Orth, 1998; Lukas & Orth, 1995). We further assumed that SMB could renest up to three times per season. The resulting model estimated the proportion of offspring remaining after one or more nest disturbances using formula based on cumulative habitat loss (see analyses in Yackulic et al. 2024 for details). This proportion was then multiplied by fecundity in the SMB population model using the estimated temperatures from penstock discharge. Habitat disturbance was calculated at weekly intervals, and an average was used to modify estimated SMB fecundity. Differences in trace in the Non Bypass alternative affect the specific discharges and water velocities used to calculate estimated disturbance rates, and we assumed that there was no habitat disturbance following an offramp date.

In addition to estimated SMB lambdas, which are derived from analysis of data from the Green and Yampa rivers (Bruckerhoff et al., 2025), we analyzed whether SMB recruitment from age-0 to age-1 would be expected using published laboratory studies that linked water temperature to the time spent in different life stages (egg, larvae, juvenile; Shuter et al., 1980) as well as growing until 20 mm TL as a juvenile (Coutant & Deangelis, 1983). As with the lambda analysis we assume that age-0 SMB recruit at some rate if they reach or surpass 20 mm TL. Since this approach is temperature derived and focuses on a binary outcome (1=some recruitment to age-1, 0=no recruitment to age-1), the Non Bypass alternative has the same metric value as the No Action alternative. All results presented are for traces in which temperatures reach the 15.5°C trigger (i.e., the subset of traces in which an action would be triggered).

To design temperature control strategies under the Cool Mix alternative, we optimized the timing and volume of bypass releases to keep daily average water temperatures below 15.5°C at the target river mile (RM), while minimizing hydropower revenue losses. This was achieved using a Mixed-Integer Linear Programming (MILP) tool that minimizes the operational costs of a hydropower dam developed by Argonne National Laboratory. The optimization was subject to both operational constraints—such as ramping rates, daily volumes, limits on daily release changes and bypass operations—and environmental constraints, including downstream temperature targets. The model enforced that the daily average temperature remains below the target, allowing hourly deviations of $\pm 2^\circ\text{C}$ as long as the daily average stayed within the limit.

The optimization prioritized bypass use during low-price hours and smoothed load-following operations to reduce turbine efficiency losses. It was applied only during the period when bypass was active (between specified start and end dates); outside of this period, standard operations were assumed. Parameters like the water-to-power conversion factor were treated as constant within each month, with monthly values derived from historical empirical data using linear fits based on elevation and hydrology. Operational limits on bypass and penstock flows incorporated scheduled outages from the Bureau of Reclamation's summer outage schedule. Input parameters—including penstock, bypass, and delta temperatures between Glen Canyon Dam and various RMs—were computed using the GCMRC temperature model and treated as fixed inputs in the optimization. The MILP optimization was run independently for each CRMMS trace and target RM scenario.

The cost of replacement power for the Non Bypass and Cool Mix alternatives were estimated by calculating the hourly value of energy produced differences between the experimental alternatives and the no-action hydrograph. Using ARGUS forward curves for the Palo Verde trading hub, we generated 1,000 simulated hourly price trajectories for May through November 2025 accounting for the fact that the forward curves include a risk premium that our modeling removes. For each hydrograph, we converted discharge and elevation to hourly generation in MWh and multiplied this by hourly price to obtain the value of energy generated. The cost of each experimental alternative was defined as the difference in expected economic value relative to the No Action alternative for each hydrological trace.

Results

Estimated flow trigger dates (indicating reaching a 3-day rolling average of 15.5C) ranged from late May to mid-July depending on the trace and target location (Figure 1) and flows were triggered at all locations in all hydrologic traces. The earliest trigger dates were at RM 61 due to downriver warming.

Under no action, 97.8% of the posterior distribution for lambda is greater than 1 when considering both hydrologic uncertainty and uncertainty in SMB demographic rates. For 29 of 30 traces, 100% of the lambda posterior distribution for no action is greater than 1. Under the non-bypass option, 94.3% of the posterior distribution for lambda is greater than 1 when considering both hydrologic uncertainty and uncertainty in SMB demographic rates. For 15 of 30 traces, 100% of the lambda posterior distribution for the non-bypass option is greater than 1. Under all Cool Mix alternatives considered, 0% of the posterior distribution is greater than 1. The SMB lambda model assumes reproductive adults are present and **does consider the contribution of entrainment to population growth** (see discussion in Methods above).

Since 2022, the farthest downstream a juvenile SMB was physically capture was at RM 16.38. Since 2022, adult SMB have only been physically captured in the Lees Ferry tailwater. Given that overall capture probabilities are low and there has been less sampling effort below Badger Rapids, zero SMB detections below RM 16.38 does not necessarily indicate SMB abundance of zero at those locations. For example, eDNA sampling tested positive for SMB as far downstream as RM 37.5 in 2024 and RM 39.0 in 2025. However, positive SMB detections are likely from

fish located upstream from where samples are collected and the distance eDNA can drift downriver and still be at detectable levels depends on biological (e.g., the body size and number of SMB shedding DNA) and physical factors (temperature and velocity of water).

Relative to No Action, experimental flows reduced estimated SMB lambdas (Figure 2). The Non Bypass alternatives exhibited the weakest decrease in estimated lambda. Most traces with estimated SMB population growth under No Action also predicted lambdas > 1 with Non Bypass; however, the estimated growth rate was slower with all Cool Mix alternatives regardless of off-ramp date.

The complimentary SMB recruitment analysis predicted age-0 to age-1 recruitment in all traces when No Action is taken and when Cool Mix with an off-ramp of October 1st (regardless of the target location; Figure 3) is implemented. When the off-ramp date was Oct. 20 or temperature triggered, the predicted age-0 to age-1 recruitment was zero under all traces and at all target locations. Since the non-bypass option does not address temperature and the SMB recruitment analysis is based on temperature, we predict age-0 to age-1 recruitment in all traces under the non-bypass scenario.

Costs to hydropower when temperature targets are met are driven by RM and off-ramp dates. Typically, higher RM (i.e., further downriver) and later off-ramp dates increase costs, across alternatives. For the Cool Mix alternative costs range from a mean value of \$17.22 million (using a RM 0 and October 1st off-ramp) to a mean value of \$25.74 million (using a Temperature driven off-ramp and a target of RM 61) (Figure 5, Table 2). Maximum estimated costs of the Cool Mix alternative range from \$35.21 to \$50.20 million. The mean cost for the Non Bypass alternative is \$1.03 million and range from a minimum of \$0.97 to a maximum of \$3.68 million (Figure 5, Table 1).

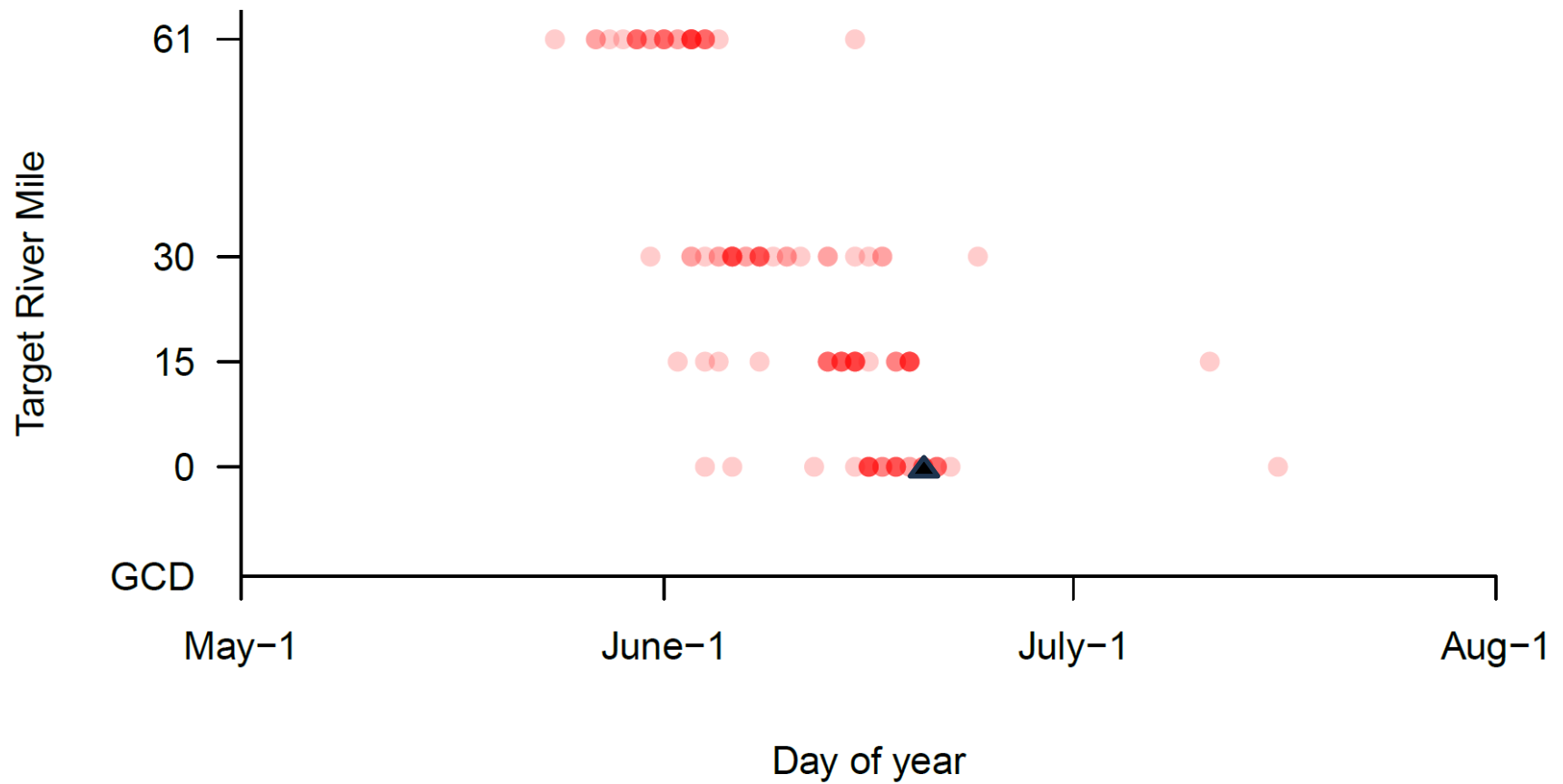


Figure 1. Estimated start dates of experimental flows from the 30 CRMMS traces based off a 3-day rolling average of 15.5C at RM 0, RM 15, RM 30, and RM 61. Dark triangle is the estimated date that River Mile 0 will be above 15.5°C.

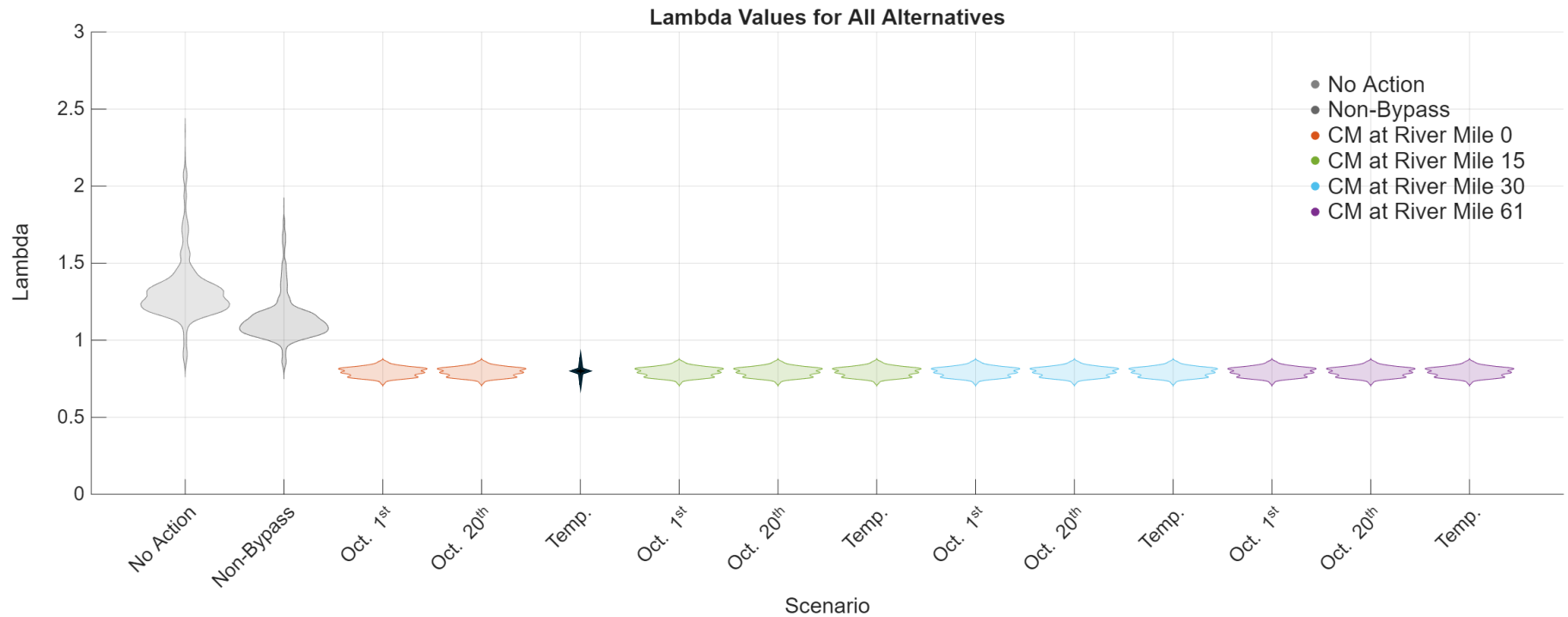


Figure 2. Smallmouth bass (SMB) population growth rate (λ) estimates under the No Action and experimental alternatives. Violin plots summarize lambda (λ) values from 100 stochastic simulations across CRMMS hydrologic traces that trigger temperature management. Scenarios are grouped by river mile (RM) target (0, 15, 30, and 61) and scenario specifying No Action and off-ramp dates (Oct. 1, Oct. 20, or temperature-driven (Temp)). Lower λ values reflect greater suppression of SMB recruitment; values >1 indicate potential population growth. Temperature driven lambda at RM 0 was not evaluated. The lambda estimates shown here assume reproductive adult SMB are present at the target location. Lambda estimates do not include estimates of either entrained juvenile or adult SMB.

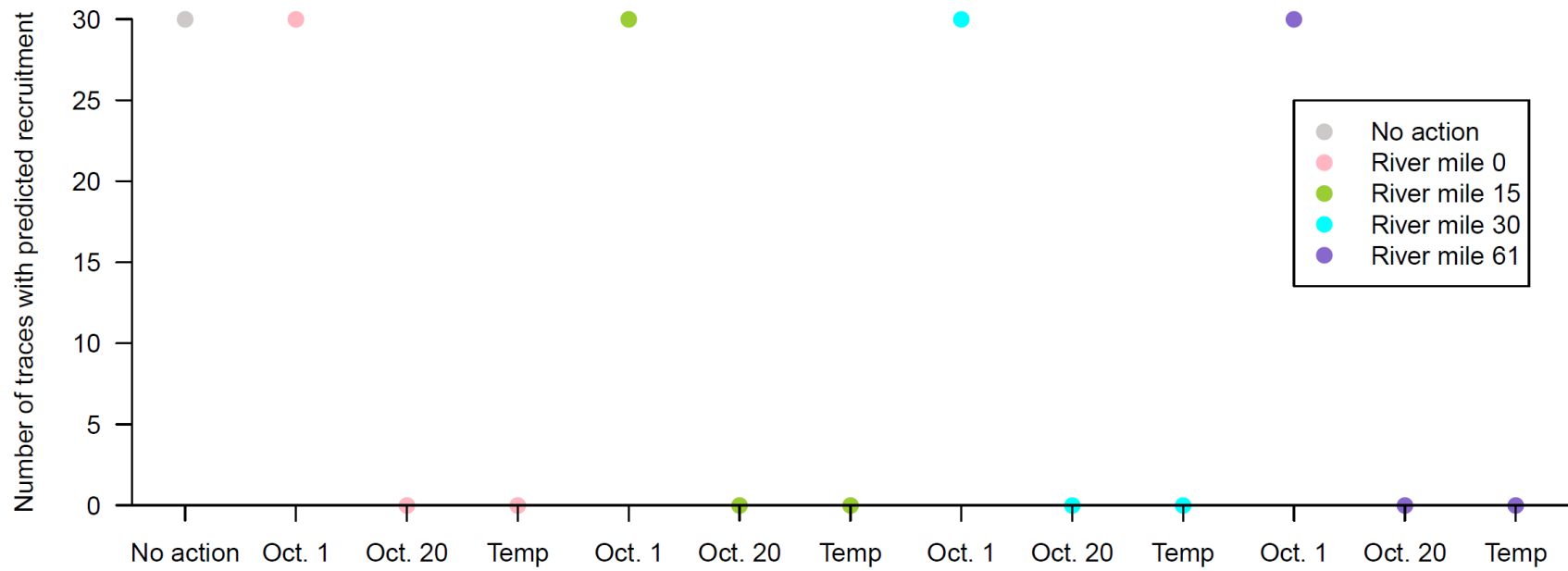


Figure 3. Number of traces (out of 30 total) in which SMB recruitment from age-0 to age-1 is predicted under No Action (NA), Cool Mix full temperature trigger (Temp), Cool Mix early off ramp date October 20 (Oct20), and Cool Mix early off ramp date October 1 (Oct1) at different river mile locations.

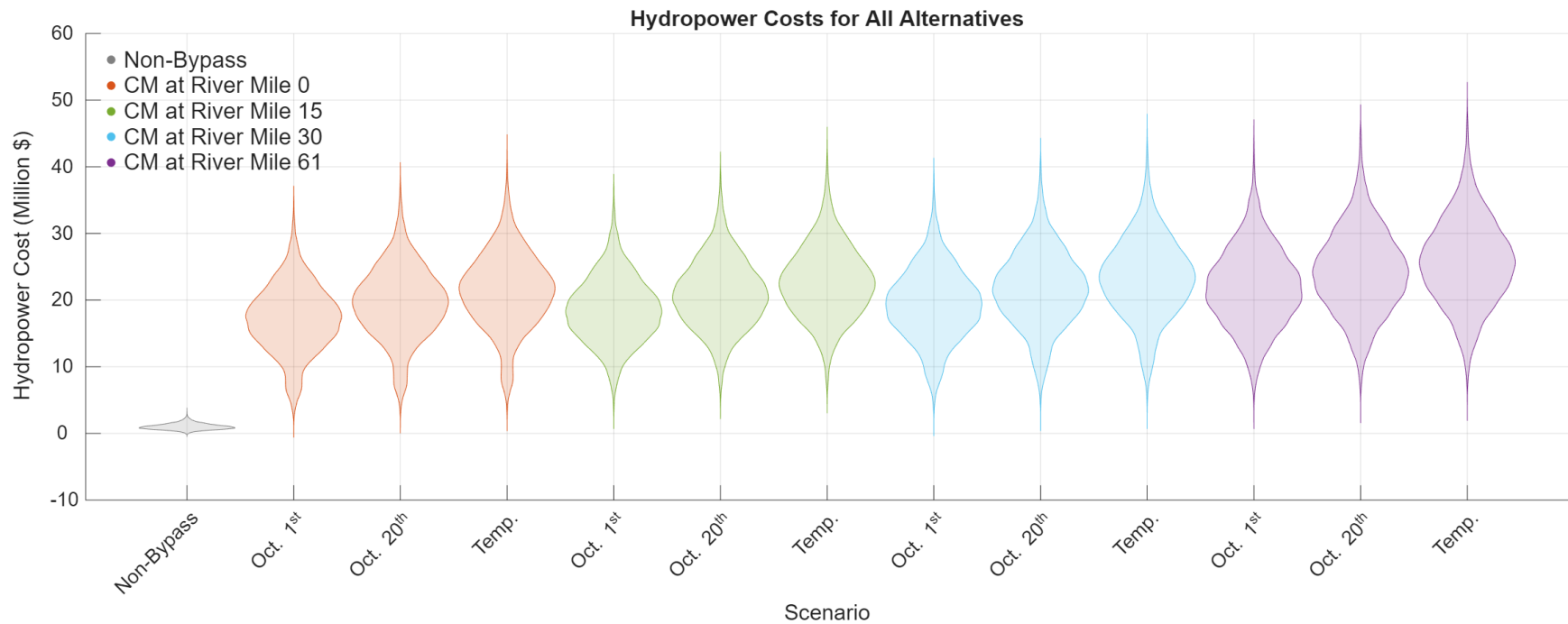


Figure 4. *Hydropower cost estimates under the alternative scenarios. Violin plots summarize costs across CRMMS hydrologic traces that trigger temperature management and 1,000 forecasts of hourly energy prices. Scenarios are grouped by river mile (RM) target (0, 15, 30, and 61) and scenario specifying off-ramp date (Oct. 1, Oct. 20, or temperature-driven (Temp)).*

Table 2. *Summary statistics (mean, median, and maximum) hydropower cost impacts for the alternative across all scenarios.*

River Mile	Non Bypass	RM0			RM15			RM30			RM61		
Off-ramp dates	Temp.	Oct. 1	Oct. 20	Temp.	Oct. 1	Oct. 20	Temp.	Oct. 1	Oct. 20	Temp.	Oct. 1	Oct. 20	Temp.
Mean Cost (Million \$)	\$1.03	\$17.22	\$19.57	\$21.35	\$18.59	\$20.96	\$22.71	\$19.37	\$21.71	\$23.35	\$21.89	\$24.23	\$25.74
Median Cost (Million \$)	\$0.97	\$17.26	\$19.63	\$21.45	\$18.41	\$20.77	\$22.56	\$19.33	\$21.67	\$23.37	\$21.75	\$24.13	\$25.64
Max Cost (Million \$)	\$3.68	\$35.21	\$38.64	\$42.72	\$37.00	\$40.22	\$43.86	\$39.27	\$42.15	\$45.67	\$44.76	\$46.91	\$50.20

To evaluate tradeoffs between experimental flow implementation and economic impact, we examined how the cost of replacement power varies with the number of experimental flow days and with associated inflow and outflow volumes across modeled traces. Rather than relying on a single summary metric, these figures illustrate how costs respond to both operational intensity (days of experimental flows) and hydrologic conditions (joint inflow–outflow volumes), while also characterizing the full distribution of outcomes under representative hydrologic traces. The results show that higher flow volumes are generally associated with increased costs, although this relationship is nonlinear and exhibits notable dispersion, including occasional high-volume, low-cost outcomes. In contrast, the relationship between cost and the number of experimental flow days is weaker, with costs spanning a similar range across much of the observed range in days. Together, these figures provide a complementary view of the cost of replacement power, highlighting both central tendencies and variability across dry, intermediate, and wet conditions.

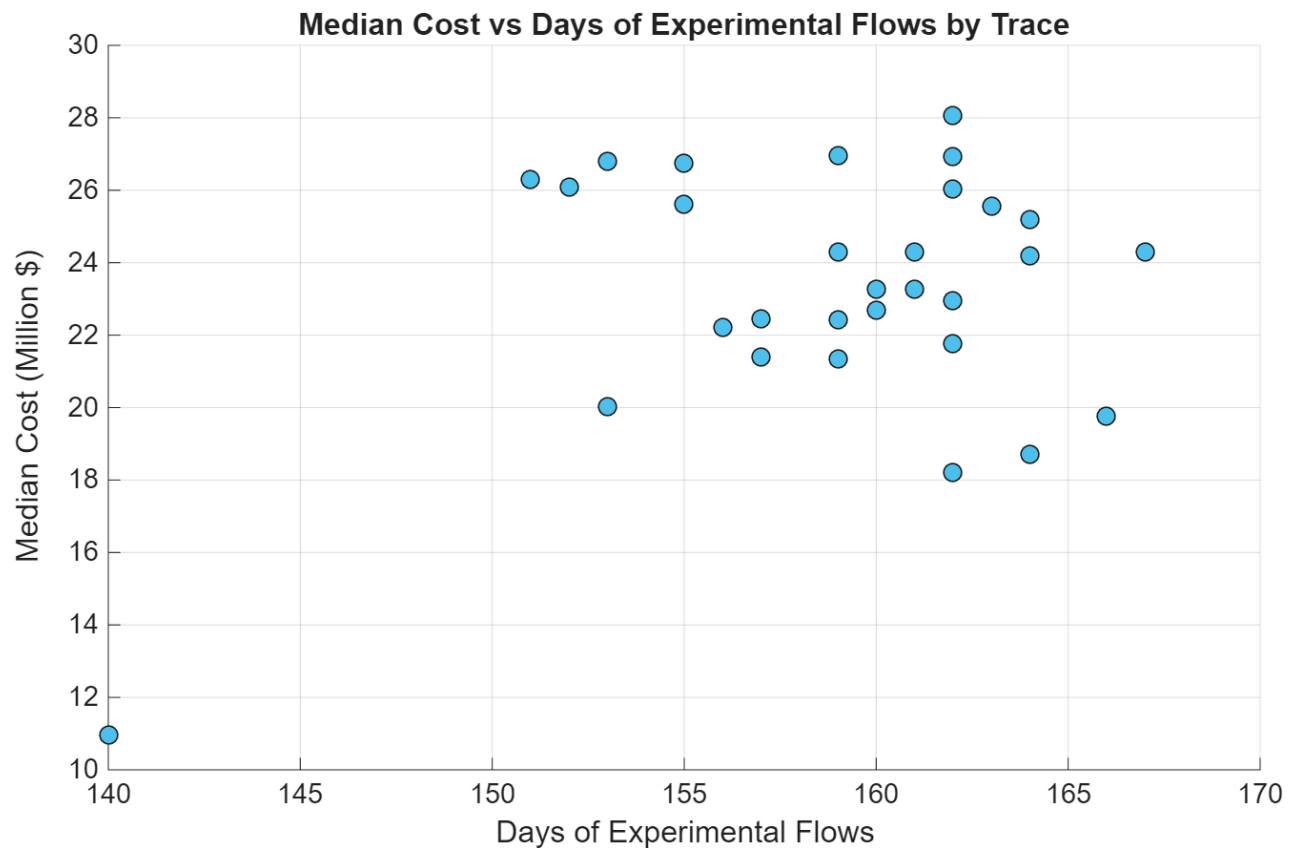


Figure 5. Relationship between the number of days with experimental flows and median hydropower cost across modeled traces. Each point represents an individual trace, with the x-axis showing total experimental flow days and the y-axis showing median cost (million \$). Costs generally cluster between ~\$21–\$27 million for 155–165 experimental flow days, with modest variability and no strong monotonic trend, though lower costs appear at both lower and higher ends of the experimental flow range.

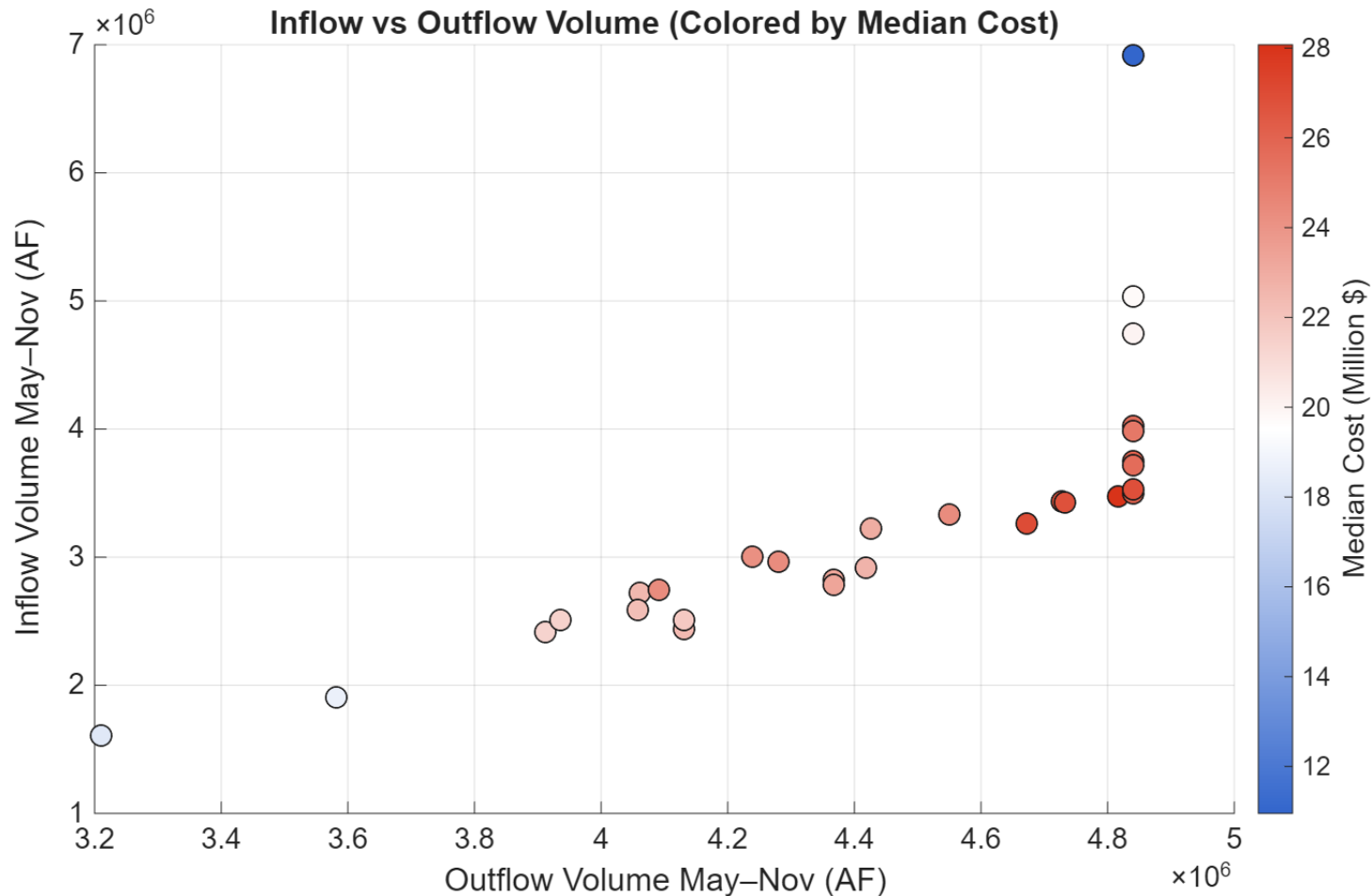


Figure 6. Relationship between May–November outflow volume (x-axis) and inflow volume (y-axis) across modeled traces under cool-mix, temperature-driven operations at River Mile 30. Each point represents a trace, with color indicating median the cost of replacement power (million \$). Inflow and outflow volumes are positively correlated, reflecting system mass balance and operational constraints. Higher-cost outcomes (warmer colors) are generally associated with higher flow volumes, particularly at the upper range of outflows (~4.5–4.9 million AF). A notable exception occurs at very high inflow (~6.9 million AF), where costs are comparatively low, indicating a high-volume, low-cost outlier. Overall, median costs tend to increase with flow magnitude, though the relationship is nonlinear and exhibits some dispersion at intermediate volumes.

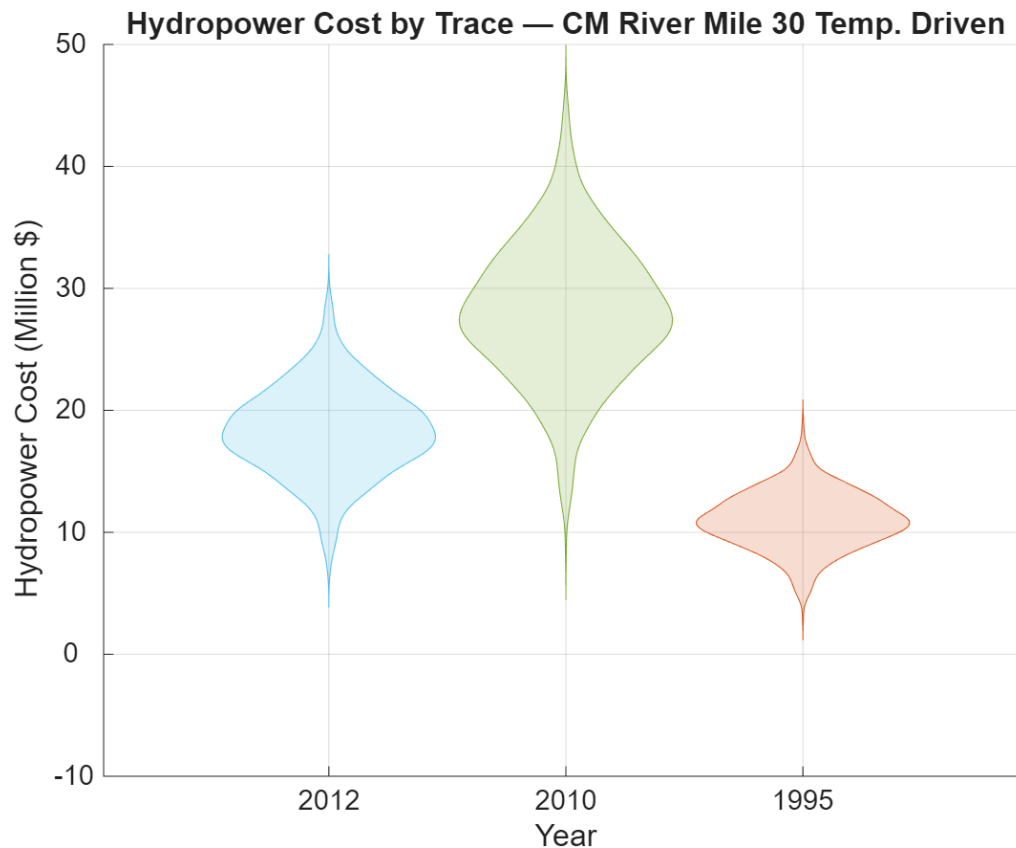


Figure 7. Distribution of costs of replacement power (million \$) under cool-mix, temperature-driven operations at River Mile 30 for three representative historical traces (1995, 2010, and 2012). Violin plots illustrate the full distribution and density of modeled costs for each trace. Costs are highest and most variable for 2010, with a broad distribution centered around ~\$25–30 million and an extended upper tail. The 2012 trace shows intermediate costs, generally centered near ~\$17–20 million with moderate variability. The 1995 trace exhibits the lowest costs and least variability, concentrated around ~\$10–12 million. The chosen traces represent a low inflow low outflow year (2012) and intermediate inflow intermediate outflow year (2010) and a high inflow and intermediate outflow year (1995)

GTMax Results

Table 3. Summary statistics (mean, median, and maximum) hydropower cost impacts for River Mile 15 at an Off-Ramp of October 20th and October 1st.

Coolmix Expense Estimates	Start Date	End Date
RM0 Target	21-Jun	20-Oct

	Mean	Median	Max
Jun	\$512,654	\$482,460	\$1,453,222
Jul	\$4,434,490	\$3,700,113	\$13,888,945
Aug	\$7,918,197	\$7,961,470	\$19,660,734
Sep	\$7,435,589	\$7,388,091	\$18,068,852
Oct	\$2,827,006	\$2,803,600	\$5,592,835
Grand Total	\$23,127,936	\$22,335,735	\$58,664,589

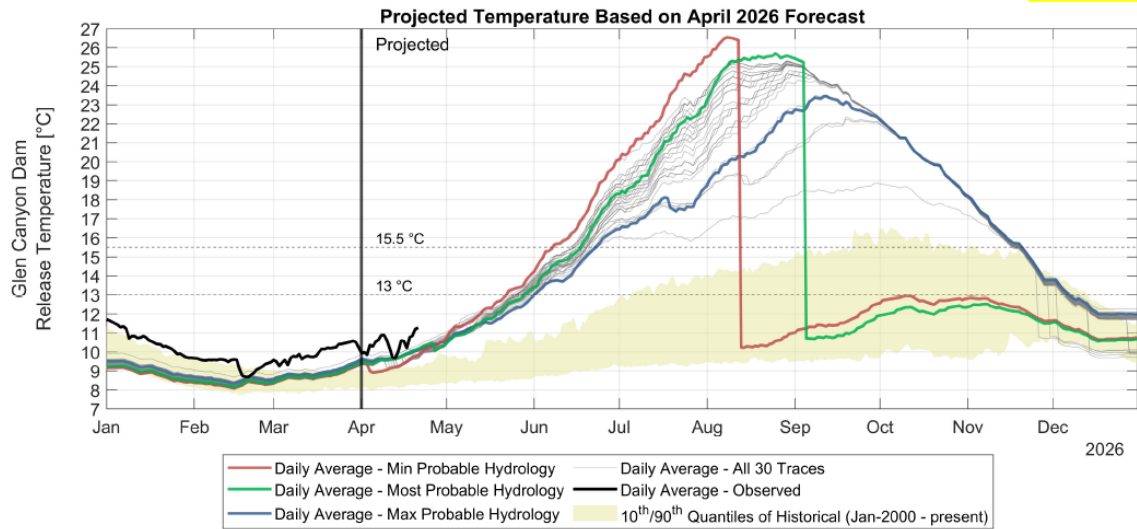
Coolmix Expense Estimates		Start Date	End Date
RM0 Target		21-Jun	1-Oct
Row Labels	Mean	Median	Max
Jun	\$512,654	\$482,460	\$1,453,222
Jul	\$4,434,490	\$3,700,113	\$13,888,945
Aug	\$7,918,197	\$7,961,470	\$19,660,734
Sep	\$7,435,589	\$7,388,091	\$18,068,852
Oct	\$164,265	\$166,729	\$327,250
Grand Total	\$20,307,265	\$19,538,150	\$53,084,625

Temperature Model

River temperatures in the Lees Ferry reach and further downstream in Marble and Grand Canyon reaches are largely driven by release temperatures from GCD but are influenced by additional factors such as local meteorology and seasonal canyon shading (Mihalevich et al. 2020). Release temperatures from GCD historically reach an annual maximum in October or November, depending on water storage conditions. However, in 2026 it is forecasted that temperatures could peak as early as September. Over the summer months (June through August) release temperatures are relatively cold with river temperatures warming as they move downstream. In general, when GCD downstream temperature transitions in October and peaks in November, river temperatures are typically cooling as they flow downstream. More detailed information can be found in the “LTEMP SEIS Cool Mix Flow Summary Report” (DOI 2025). Two models (Figures 15 and 19) were used to predict temperature at RM 61 (Personal Communication from B. Mihalevich, unpublished data presented at the Glen Canyon Monthly Coordination Presentation on April 17, 2025).

Glen Canyon Dam Release Temperature (*Eppehimer et al, 2024 model)

Does not include
DROA or 6E



* <https://doi.org/10.1101/2024.01.23.576966>



Combined Temperature Predictions April 2026 Most Probable Hydrology

Does not include
DROA or 6E

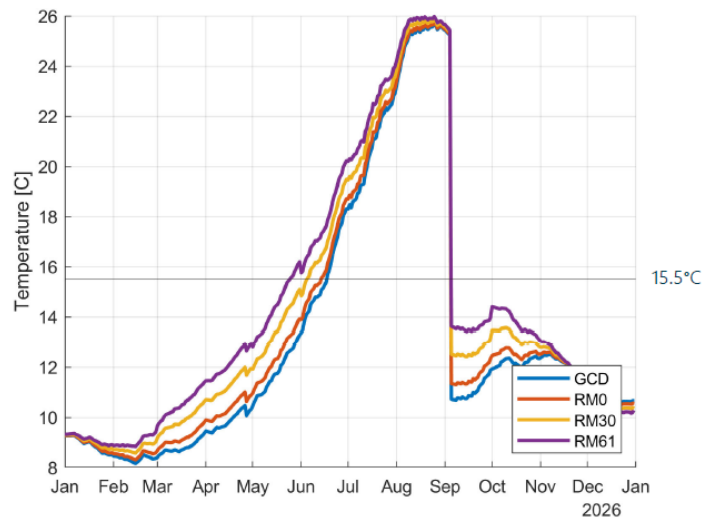


Figure 8. Glen Canyon Dam Release Temperature from the Eppehimer et al. 2024 (Top) and

combined temperature predictions at several river miles from the Dibble et al. 2020 (Bottom) model. Figure from B. Mihalevich, unpublished data presented at the Glen Canyon Dam Technical Work Group Meeting (April 2026).

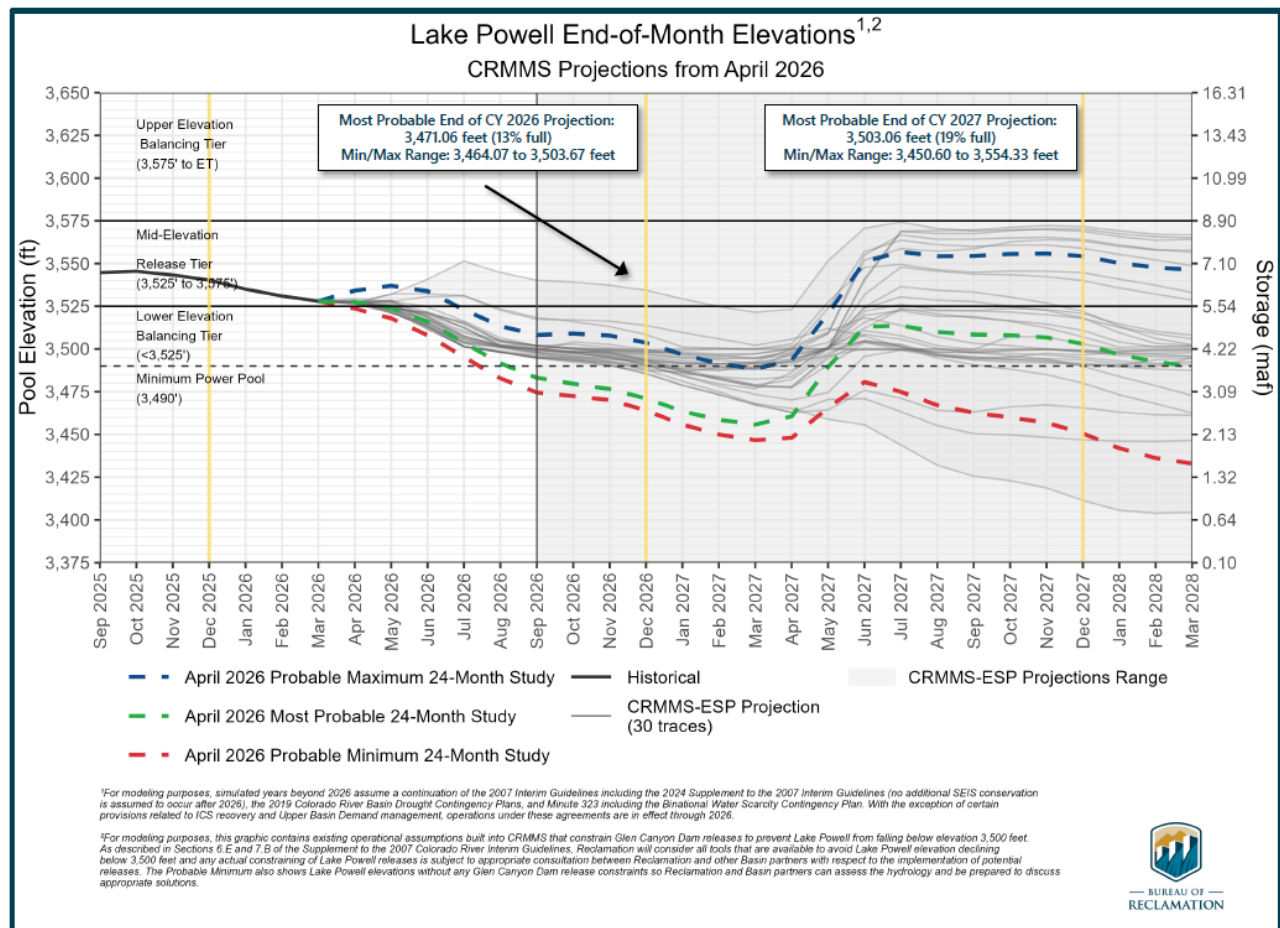


Figure 9. Lake Powell End-of-Month Elevations from the April Colorado River Modeling System (CRMMS) projection.

Cool Mix Parameters

The Cool Mix Alternative would involve using releases from both the penstock and River Outlet Works (ROW) to maintain a daily average temperature of $< 15.5^{\circ}\text{C}$ at a specific RM target within the Colorado River below GCD (DOI 2024b) to prevent smallmouth bass spawning and recruitment. To cool the river water, Reclamation proposed flows that release water through the ROW, which are four large tubes through the dam that draw water from deeper in the reservoir than the penstocks but do not power the generators. The water released through the ROW is known as bypass because it bypasses the generators and thus does not generate power. To determine what the temperature of the river immediately below the dam will be when the ROW are operating, scientists need to know the volume of the penstock (warm) and ROW (cold) water releases and how those waters mix. Furthermore, the river will warm or cool as the water flows through the

canyon downstream depending on the season. To calculate what the river’s temperature will be at a given distance from the dam, scientists must determine the dam’s release temperature (the mix of warm penstock and cold bypass water) and apply corrections to that based on how long the water is moving and how the predicted weather will change water temperature. Below are the parameters reviewed for a Cool Mix Flow:

On-ramp (initiation of experiment) and Daily Average Temperature – 15.5°C (60°F)

River Mile Target – 15

Off-Ramp (termination of experiment) –October 20, 2026

No Action

The No Action hydrograph was generated using monthly release volumes and elevations projected by CRMMS (Figure 9) for Glen Canyon Dam.

III. Monitoring Plan

Current projections for monitoring in FY2026 suggests a monitoring plan (Figure 10) similar to what was described in the LTEMP SEIS ROD will be used in 2026 to assess the effectiveness of any Smallmouth Bass Flow implementation. The following is a description of the monitoring plan to be used in 2026.

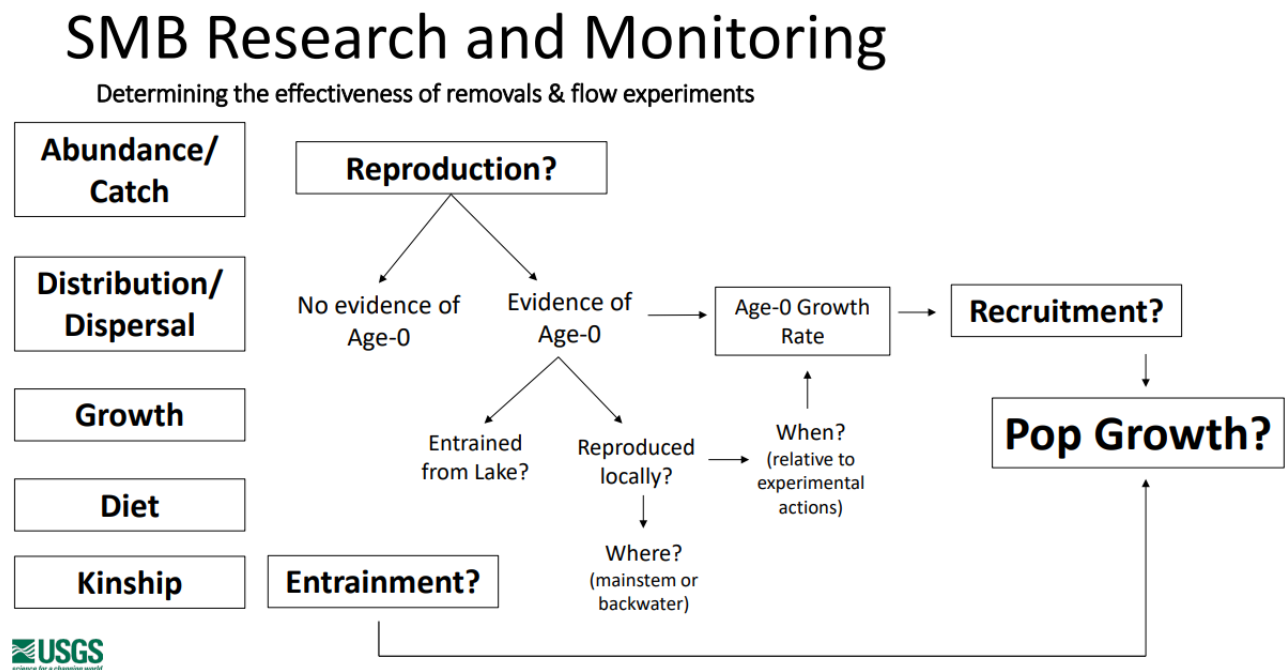


Figure 10. Conceptual model of the monitoring approach taken to determine the effectiveness of Smallmouth Bass Flows. Figure from D. Eppehimer, 2025, unpublished data presented at the Glen

Canyon Dam Technical Work Group Meeting Presentation on October 29-30, 2025.

The monitoring plan relies on data collection from multiple LTEMP monitoring programs. These monitoring programs are discussed below.

Project I, *Nonnative Aquatic Species Monitoring and Research* is an essential component to implementation of the Smallmouth Bass Flow Experiment Protocol under LTEMP. Under Project I, GCMRC will assess the efficacy of management actions to control populations of smallmouth bass. Specifically, Project I.4 will focus on modeling nonnative fish data from GCMRC, NPS, AZGFD, USFWS, and other cooperators. This modeling will support refinement of existing smallmouth bass models, help determine the effectiveness of LTEMP SEIS ROD Smallmouth Bass Flow experiments and smallmouth bass removal actions and provide science to support discussions of offramps laid out in the Invasive Fish Species Strategic Plan (Smallmouth Bass Ad Hoc Group, 2023).

National Park Service (NPS) will continue to conduct surveillance and removal efforts detailed in the 2025 Rapid Response Annual Report (Shollenberger et al. 2026). This effort includes monitoring the presence and distribution of smallmouth bass and other warmwater invasive species, evaluating distribution trends over time within specific reaches downstream to Badger Rapid (~ RM 8), and monitoring for smallmouth bass nest presence/absence and possible recruitment (Shollenberger et al. 2026). Monitoring downstream of Badger Rapid is inherently difficult and would require a significant financial and logistical consideration if any additional rapid response effort were needed. In partnership with the GCMRC, a 2024 science plan was developed to better monitor smallmouth bass and other high-risk non-native fish species along the Colorado River from GCD to Badger Rapid and downstream areas. The plan addressed key questions regarding distribution, dispersal, and in situ reproduction, along with evaluations of abundance trends, growth rates, and dietary habits across life stages. A multifaceted approach was employed, utilizing a range of field techniques, including boat electrofishing, fyke and hoop netting, seining, and environmental DNA sampling, and was executed on a seasonally structured schedule. Targeted genetic and otolith analyses are ongoing to further enhance the ability to investigate population dynamics (Shollenberger et al. 2026).

GCMRC collects data on cultural resources, water quality (including nutrients), native and nonnative fishes, aquatic invertebrates, riparian plants, and other resources as described in the GCDAMP Fiscal Year (FY) 2025-2027 Triennial Budget and Work Plan (TWP). These projects from the TWP will help to inform whether Smallmouth Bass Flow experiments influence downstream resources of Glen, Marble, and Grand Canyons. Projects from the TWP that contribute to monitoring Smallmouth Bass Flow experiments are further discussed below. Specifically, Project G, Humpback Chub Population Dynamics throughout the Colorado River ecosystem, continues long-term monitoring in Grand Canyon and will provide information about potential response of Humpback Chub (*Gila cypha*) to a summer Smallmouth Bass Flow experiment and whether these experimental flows have any influence on the stability of the population.

IV. Assessment of Resources

Assessment of Resources consistent with the 2016 LTEMP ROD and LTEMP SEIS ROD (all resources were evaluated for both a summer Cool Mix Flow and Non-bypass Flow). *For more detailed information please refer to the 2024 LTEMP FSEIS and LTEMP SEIS Cool Mix Flow ROD.*

Hydropower and Energy

The Glen Canyon Dam (GCD) Powerplant is the largest power plant in the Colorado River Storage Project (CRSP) and provides electricity to municipalities, rural cooperatives, irrigation districts, and Native American Tribes in six western states. Operations at GCD affect the Basin Fund, federal power customers, and Upper Colorado River Basin states. Revenues from power generation are deposited into the Basin Fund, which is used to fund the operation, maintenance, and replacements of the CRSP initial units. The Basin Fund is also used to repay the construction costs of the CRSP initial units allocated to the power purpose, as well as irrigation, salinity, and several environmental studies. Approximately \$240 M in revenue is needed each year to fund Reclamation and WAPA operations and maintenance needs for the CRSP.

The costs to purchase replacement power for experimental releases at GCD are booked as a non-reimbursable expense to the U.S. Treasury as authorized in Section 1804e of the Grand Canyon Protection Act. This allows experimental costs to be booked as a constructive return for repayment towards the construction costs of the CRSP initial units. This shifts the financial burden of GCPA-related activities (i.e., LTEMP experiments) from the power customers to the Federal Government (i.e., the U.S. taxpayer). High non-reimbursable expenses, however, can force a rate of return that gets ahead of schedule while also depleting the Basin Fund of cash needed by Reclamation and WAPA for the operation and maintenance of the CRSP. Reclamation and WAPA are approximately \$800 M ahead in their scheduled returns of the construction costs of the CRSP initial units.

The cost of replacement power needed for the 2024 and 2025 Cool Mix experiments were \$19.1 M and \$6.5 M, respectively (Table 4). The cost estimate for 2026 is preliminary and work is being conducted by Argonne National Laboratory to complete a formal analysis before the end of FY26.

Table 4. Pre-Experiment Estimates provided to the Planning and Implementation Team vs Actual Costs Determined After the Experiment.

	Description	GCMRC estimate (Median)	WAPA estimate (Median)	Actual cost
2024 (LTEMP SEIS)	Cool Mix, RM 61, Temperature offramp	\$10.8 M***	\$15.4 M***	\$19.1 M*
2025	Cool Mix, RM 30, Oct 20 offramp	\$2.5 M	Dry trace: \$8.2 M Median trace: \$4.3 M Wet trace: \$2.0 M	\$6.5 M**

* Ploussard, Quentin, et al. "Financial Analysis of the Smallmouth Bass Flows implemented at the Glen Canyon Dam during Water Year 2024." Sep. 2025. <https://doi.org/10.2172/2587737>

** Argonne National Laboratory will complete a formal analysis before the end of FY26.

*** Number calculated from Figures 3-16 and 3-17 of 2024 LTEMP SEIS by dividing average by 4 years.

Revenues from the Basin Fund were used to purchase replacement energy for these experimental releases. Since 2019, the Basin Fund balance has ranged from \$79 M to \$230 M. This includes a reimbursable addition of \$85 M from the Infrastructure Investment and Job Act in 2022/2023. The Basin Fund began FY25 with a balance of \$185 M and ended FY25 with a balance of \$200 M. This ending balance is 59% of the FY26 Basin Fund Reserve target of \$339 M. The Basin Fund Reserve target is the projected cost of WAPA and Reclamation capital replacements, replacement power purchases for the next three years, and the cost of operations and maintenance for the next three months. The Basin Fund Reserve target does not include funds needed to offset the costs of experimental and voluntary nonnative fish control actions at Glen Canyon Dam.

The Basin Fund is within an acceptable level of risk to WAPA in FY26, but the 2024 Cool Mix experiment created a funding shortfall for the capital replacements program for the CRSP system. This prompted WAPA to make a \$6.8 M (approx. 30%) cut to its capital program and Reclamation used \$36 M in carryover and other miscellaneous revenues of offset reductions in its capital program to keep the Basin Fund operating at an acceptable level of risk. These cuts resulted in more than 18 capital replacement projects being deferred to future years. Continuation of the Cool Mix experiment in FY26, and in future years, will continue to result in additional deferral of many of these capital replacement projects. Deferral of these capital replacement projects could increase the risk of system failures in the CRSP.

The 2024 LTEMP SEIS assumed replacement power would be generated primarily from existing thermal powerplants on the WECC regional grid and found the Cool Mix alternatives would have the greatest impact on the regional generation of greenhouse gas emissions. A warming climate has been associated with reduced snowpack, increased evaporation, drier soils, and reduced runoff in the Colorado River basin. The SEIS found that the Non Bypass alternative could potentially result in a reduction in regional greenhouse gas emissions (see Section 3.9 Air Quality, pages 3-227 to 3-236).

WAPA remains concerned that continuation of the Cool Mix experiment will result in unsustainable impacts to critical infrastructure and the programs the Basin Fund supports. Reclamation and WAPA rely on the Basin Fund to meet their water and power delivery obligations. WAPA's view is that the Basin Fund is not structured to offset the impacts of non-reimbursable costs of an experiment of this magnitude and that it cannot absorb these impacts. If experiments that require large amounts of bypass continue to be implemented, Reclamation and WAPA will need to proactively work to offset impacts to the Basin Fund to maintain the stability of the CRSP system and ensure the financial viability of the Project. Implementation of a Cool Mix experiment triggered at any of the modeled river miles and for any of the modeled durations in FY26 would put the Basin Fund in an unacceptable level of risk in FY27.

Cool Mix Flow

Please See Screening Tool and GT Max Results Above (Table 2; Figure 4)

Smallmouth Bass (Micropterus dolomieu)

Smallmouth bass are a high-risk, invasive species within the Colorado River basin that established in both Lake Powell following stocking in the 1980s, and in Lake Mead (as well as throughout many river sections in the Upper Colorado River Basin). Smallmouth bass are a highly valued sport fish that have been introduced throughout the globe and have often spread extensively beyond their initial point of introduction (Loppnow et al. 2013). Smallmouth bass invasion into rivers throughout the globe have been associated with substantial population declines, and in many instances and extirpations of native fish species (Brown et al. 2009; Loppnow et al. 2013). In the Upper Basin, smallmouth bass are considered the greatest threat to the persistence of threatened and endangered fish species (Johnson et al. 2008). Smallmouth bass are highly fecund, adaptable to a substantial range of environmental conditions, and extremely capable predators able to consume many size classes of the federally listed humpback chub and razorback sucker (*Xyrauchen texanus*; Edwards et al. 1983; Johnson et al. 2008; Ward and Vaage, 2019). These traits have allowed smallmouth bass to quickly increase in abundance and exert population level impacts on species that did not co-evolve with them. As an example, humpback chub populations in Echo Park, near the confluence of the Green and Yampa Rivers, declined by ~90% within 3 years of increases in smallmouth bass abundance which also coincided with several years of exceptionally low flows in the Yampa River.

Fish “flushing” or the pushing of smallmouth bass further downstream during these proposed experiments would pose no further risk than expected from normal high monthly volume operations, so no increase above baseline risk is expected. The Fall 2022 High-Flow Experiment Technical Memo acknowledges the uncertainty and potential for a High-Flow Experiment (HFE) to cause downstream dispersal of smallmouth bass, particularly <25 mm TL (Harvey 1987). All smallmouth bass observed in 2024 were greater 25 mm TL, suggesting they are less susceptible to downstream dispersal. A smallmouth bass movement study in the Yampa River noted that smallmouth bass can move great distances upstream and downstream (Hawkins et al. 2009), thus smallmouth bass may be likely to move downstream regardless of a Smallmouth Bass Flow experiment.

Entrainment of fish, including smallmouth bass, through Glen Canyon Dam is dependent on Lake Powell elevations. Smallmouth bass catches in 2025 below the Glen Canyon Dam have remained lower than any year since 2023 (Shollenberger et al 2026; Kim Dibble, Adaptive Management Work Group Annual Reporting Meeting, February 2026) during Lake Powell elevations > 3540. As of April 17, 2026, Lake Powell is near 3,528 feet and predicted to be near 3,515 feet by June according to the April Colorado River Mid-term Modeling System (CRMMS) projection. Friesen (2024) found that fish occupy the forebay when Lake Powell is stratified and smallmouth bass are likely to inhabit the upper 65 feet of the water column in the forebay. Additionally, fish entrainment is thought to increase when elevations go below 3,540 feet (Eppehimer et al. 2025). Current elevations and predicted elevations for June would put entrainment at a higher probability than if elevations were greater in Lake Powell. Therefore, entrainment may increase resulting in increased capture of smallmouth bass of all sizes below the Glen Canyon Dam. However, elevations predicted for this year are expected to be similar to 2022 when entrainment at the dam was thought to be high. Exactly how high is still unknown since it

has not been quantified.

Cool Mix will likely keep smallmouth bass from spawning below the dam but will not stop entrainment through the dam. An increase in the smallmouth bass population (i.e. a positive λ) is expected in 2026 regardless of any action taken at the dam short of going to full bypass for the summer. Entrainment of smallmouth bass or any other fish species was not considered in the modeling analysis. However, as lake elevations drop and uncertainty in hydrology remain, risks of higher entrainment are expected to increase. Smallmouth bass that are entrained through the Glen Canyon Dam could be considered additional to the modeled λ values (Figure 2). Even when a Cool Mix flow is implemented, if entrainment is high, it could result in higher λ values. Therefore, it is important to understand that using additional management tools besides Cool Mix will become crucial to achieve successful management of nonnative fish species like smallmouth bass. Currently, monitoring is planned for 2026 and will continue to provide data to better understand entrainment risks of nonnative fish species.

The slough at -12 river mile has been modified to reduce smallmouth bass spawning, eliminating one known spawning location for smallmouth bass. There has been concern that if river flow drops too low the slough potentially could become disconnected from the river posing a risk to nonnative fish spawning. The exact flows that would disconnect the slough from the river has not been identified but is suspected to be around 6,800 cfs. Other backwater areas also exist within the Colorado River that may potentially be favorable to nonnative species recruitment, however, uncertainty exists around those locations and how much risk they pose.

In the summer of 2024 and 2025 during Cool Mix Flows, reproduction, growth, relative abundance, and recruitment of smallmouth bass were thought to be reduced because of decreased river temperatures below GCD. A multi-agency, multi-method sampling effort detected no evidence of smallmouth bass reproduction below GCD, and the smallest capture was 73 millimeters. Monitoring revealed the presence of two cohorts in 2022 and 2023 when release temperatures were much higher. The smallmouth bass growth rate was estimated to be reduced by more than 60% in 2024, which likely prevented many of these fish from reaching spawning size (estimated 200 mm TL) for 2025. In 2025, the furthest downstream environmental DNA detection was at RM 39.0 on river left (Shollenberger et al. 2026). The total number of smallmouth bass collected since cool-mix flows have been implemented have greatly reduced from the two previous years, though this may be due in part to reduced catchability in low temperatures (DOI 2025).

Cool Mix Flow

Please See Screening Tool Results Above (Figure 2)

Non-bypass Flow

Please See Screening Tool Results Above (Figure 2)

Sediment

The 2024 and 2025 Cool Mix Flow experiments were conducted by discharging water through the ROW that otherwise would have been discharged through the power units. Therefore, the

experiment did not result in a change in the total release of water through the dam. Because sediment transport is controlled by discharge and only very weakly affected by water temperature, the experiment had a negligible effect on sediment transport in 2024 and 2025 (DOI 2025). There was a minor localized effect on a sand bar immediately downstream from GCD, because the ROW created a different velocity pattern at the base of the dam (DOI 2025).

Cool Mix Flow

Extended implementation of Cool Mix Flows were analyzed in the 2024 LTEMP FEIS and found that Cool Mix Flows would not have any significant effects to sediment. Secondary effects from Cool Mix Flows would include decreased HFE magnitude, in addition to coarser bed grain size which reduces suspended sand concentrations and, hence, sandbar deposition rate. Overall, LTEMP SEIS modeling demonstrated a negligible difference between sand mass export compared to the No Action Alternative (DOI 2024b).

Non-bypass Flow

Analysis included in the 2024 LTEMP FEIS found that the Non-bypass Flow would cause the greatest reductions in the sediment mass balance relative to other alternatives considered. This alternative would generally produce the second-smallest sandbars compared to all the potential flow alternatives analyzed in 2024 LTEMP FEIS (DOI 2024b), slightly surpassing volumes that would be generated under alternatives without flow spikes.

The analysis showed that sandbar volume growth would closely follow trends under the No Action Alternative through the fall of 2025. Non-bypass Alternative sandbar volumes would then differ slightly for a roughly yearlong period, fluctuating approximately 5 to 10 percent higher and then lower than volumes under the No Action Alternative. Following this period, erosion that would likely result from the relatively frequent non-bypass fluctuations would cause slower sandbar volume recovery, relative to the No Action Alternative.

Archaeological and Cultural Resources

Overall conditions for cultural resources remain like those described in the 2016 LTEMP FEIS. As defined in the 2016 LTEMP FEIS, cultural resources are: "...typically categorized as archaeological resources, historic [buildings and structures] and prehistoric structures, cultural landscapes, traditional cultural [places], ethnographic resources, and museum collections. Many natural resources, such as plants and plant gathering areas, water sources, minerals, animals, and other ecological resources, are also considered cultural resources, as they have been integral to the identity of Tribes in various ways. For some Tribal people, archeological resources are considered to be markers left by their ancestors, the embodiment of those who came before and are imbued with the spirits of the ancestors. They represent a physical link to the past. The physical attributes of cultural resources are often nonrenewable, especially archaeological sites, which often represent ancestral homes for the park's traditionally associated Tribes." (DOI 2016a).

The 2024 and 2025 Cool Mix Flows have not shown to have any significant impacts on Archaeological and Cultural Resources.

Cool Mix Flow

No additional impacts beyond those analyzed in the LTEMP FEIS (DOI 2024b) are expected for archaeological sites. The daily available sediment would be similar to that under the No Action Alternative.

Non-bypass Flow

Low flows may expose previously inundated historic properties, which could lead to damage or disturbance from wave action, wet/dry effects, and increased visitation. However, the daily available sediment would be similar to that under the No Action Alternative.

Natural Processes (Flow Regime)

The pre-dam Colorado River was characterized by spring snow-melt floods that often exceeded 100,000 cfs and typically peaked in late June, followed by flash flood flows during the summer monsoon season, and extensive low base flows from the fall through early spring (Topping et al. 2003). This seasonally variable flow regime was an important driver of natural processes in the Colorado River, and the unique fish species that evolved here were adapted to frequent flow disturbances. For example, the small eyes and tiny embedded scales that are common to several native fish are thought to be adaptations to the sediment-laden floods that scoured the Grand Canyon annually. In the pre-dam river, turbidity was always high (Voichick et al. 2016), suggesting that algae growth was likely restricted to the river's edge or shallow cobble habitats; detritus and leaf litter are thought to have been primary sources of energy fueling food webs (Blinn and Cole 1991). Regulation of the Colorado River by GCD in 1963 eliminated the annual spring high-flow disturbances. It also substantially increased base flow, thereby eliminating periods of low flows, and hourly variation in discharge increased substantially owing to hydropower production (Topping et al. 2003, Kennedy et al. 2016). In addition to changing the river's flow regime, GCD also changed other aspects of the physical template, particularly temperature, sediment, and nutrient regimes (Dibble et al. 2020, Topping et al. 2000, Yackulic et al. 2018, Kelly 2001).

Soluble Reactive Phosphorus (SRP) is a form of phosphorus that is dissolved in the water and is immediately available for biological uptake. Typically, high levels of SRP can be harmful to aquatic environments causing degraded water quality and eutrophication (Wilhelm et al 2018), whereas very low SRP can limit food web production (Elser et al 2007). Worldwide, among unpolluted rivers, average SRP is ~10 µg/L (Meybeck 1982, 1993). Over the past ~30 years, concentrations of SRP at Lees Ferry have averaged 4 µg/L (Andrews and Deemer 2024). During the 2024 Cool Mix Flow experiment, SRP in the dam draft tubes was <1µg/L, but concentrations of SRP at the depth of the bypass intake were higher, resulting in tailwater SRP concentrations of about 3 µg/L (Bridget Deemer per comm). Although there was an increase in SRP during the 2024 Cool Mix Flow experiment, the value (3 µg/L) is well below the average for unpolluted rivers (10 µg/L) and is still below the long-term average SRP for Lees Ferry (Andrews and Deemer 2024).

The 2024 and 2025 Cool Mix Flows have not shown to have any significant impacts on Natural Process (Flow Regime).

Cool Mix Flow

A Cool Mix Flow does not mimic a more natural flow disturbance (pre-dam peak flow), because hydrology will mimic scheduled dam operations. Releases from the ROW could result in higher phosphorus concentrations due to withdrawing from deeper in the water column which could stimulate food base production. Cooler temperatures could support higher nutrient concentrations which could stimulate food base production but is a departure from the natural warm temperature regime the river historically experienced.

Non-bypass Flow

A Non-bypass Flow does not mimic a more natural flow disturbance (pre-dam peak flow), because the peak flow is not large enough to inundate flood plain areas limiting the benefits provided by larger flows. Additionally, the duration of high-flows is minimal compared to pre-dam natural flow disturbances.

Aquatic Food Base

Flood disturbance is a critical natural process in streams and rivers (Poff et al. 1997). By disrupting ecosystem structure and altering the availability of substrates and resources, flow disturbance can help maintain native biological diversity (Carlisle et al. 2017). Disturbance magnitude, for example the extent of drying at low flow or the proportion of the bed that is mobilized at high-flows, can influence ecosystem outcomes by determining the extent of biomass loss and the quantity of newly scoured habitat patches available for recolonization by fast-growing algae and aquatic insects. Disturbance frequency and timing (e.g., spring vs. fall) can also influence the rate and trajectory of ecosystem recovery from disturbance. The life cycles of many species of native algae, insects and fish are directly tied to flood disturbances, and alterations to river flood regimes can adversely affect ecosystem health. A national synthesis of flow and biological data from over 700 streams and rivers in the lower 48 states found that intact and healthy communities of native aquatic invertebrates and fish were most often present where flood disturbance still occurred, and where flood timing was seasonally appropriate (i.e., similar to the natural condition; Carlisle et al. 2017). Although the Colorado River in Grand Canyon could not be included in this 2017 synthesis owing to the absence of pre-dam ecological data, the mechanisms linking periodic flow disturbance to stream ecosystem health were evaluated in a wide variety of streams and regions. It is therefore reasonable to predict that similar mechanisms linking appropriately timed flow disturbance to ecosystem health also operate in the Colorado River.

Changes to the physical template of the Colorado River have led to dramatic changes in the natural processes that sustain river food webs. For example, Colorado River food webs are now primarily built upon algae production owing to clear water (Stevens et al. 1997, Cross et al. 2013). Many types of aquatic insects have been extirpated from Grand Canyon owing to multiple stressors including cold water temperatures and hourly fluctuations in discharge that leads to acute mortality of aquatic insect eggs laid along constantly changing shorelines (Kennedy et al. 2016). Three species of native fish have also been extirpated from Grand Canyon owing to cold water, predation by non-native fish, and dams that block migration routes (Minckley 1991).

Meanwhile, many species of non-native invertebrates (e.g., *Gammarus lacustris*, New Zealand

mud Snails (*Potamopyrgus antipodarum*), quagga mussels (*Dreissena bugensis*)) and fish (e.g., rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*)) have become established throughout the Grand Canyon segment because they are well-suited to this new physical template and altered flow regimes. Predation by non-native fish species is a constant and potentially growing threat to many native fish species that remain in Grand Canyon.

Additionally, simplified food webs that are inherently unstable and overall low food base production arising from nutrient limitation have been shown to limit native and desired non-native fish populations in some reaches and years (Cross et al. 2013, Korman et al. 2021). Despite these changes to the ecosystem and the natural processes that support food webs, native fish populations in Grand Canyon have been relatively stable over the past two decades compared to other segments of the Colorado River (Yackulic et al. 2014, Healy et al. 2020, Dibble et al. 2020).

The 2024 and 2025 Cool Mix Flows have not shown to have any significant impacts on Aquatic Food Base.

Cool Mix Flow

Cooling release temperatures is a further departure from the pre-dam natural temperature regime. However, the cooler temperatures are not expected to negatively affect the aquatic food base. Cooler temperatures could support higher nutrient concentrations which could stimulate food base production and favor cool water adapted macroinvertebrate species, such as midges and blackflies.

Non-bypass Flow

The Non-Bypass Alternative could negatively affect the food base in Lees Ferry and Grand Canyon. The effects of high-flows following low-flow events would likely result in lower diversity and productivity rates. Although the low flow would occur for 4 hours during nighttime in Lees Ferry, during hot summer months Blinn et al. (1995) found nighttime exposure and desiccation had similar adverse effects on food base organisms as daytime desiccation. Specifically, the 12-hour daytime desiccation and 12-hour nighttime desiccation treatments repeated over 5 days described in Blinn et al. (1995) both resulted in >50% loss of algae (*Cladophora*) biomass, >75% reduction in Chironomid biomass, and >75% reduction in Gammarus biomass compared to control treatments that were not exposed to desiccation. The low-flow would only be around 5,000 cfs and shorter than 4 hours near the Little Colorado River owing to hydrodynamics, but this could still have an adverse impact on the food base, because most of the primary and secondary production in Grand Canyon is restricted to shallow shelves that would be exposed by the low-flow (Cross et al. 2013). The low-flows would last for 4 hours at Lees Ferry and would be even shorter duration at downstream locations, which could reduce the impact of the low-flow compared to the 12hr desiccation trials repeated over 5 days that are described in Blinn et al. (1995). Additionally, the low-flows would only occur once per week, which could allow for some recovery of the food base, compared to the 5 sequential days of desiccation that are described in Blinn et al. 1995. However, the low-flow would be repeated for 12 weeks including late in the summer, which may potentially limit recovery of the food base. The low-flows would also be followed by a high-flow of up to 26,900 cfs (magnitude will decrease in the downstream direction), which could scour food base organisms that had previously been desiccated and weakened by the low-flow. Thus, the Non-

bypass Flow could have an adverse impact on food base diversity and production in both Lees Ferry and Grand Canyon.

Humpback chub (Gila cypha) and Native Fish

Humpback chub populations in the Little Colorado River aggregation remained relatively stable over the decade from 2009-2019, a period that included HFEs in 2012, 2013, 2014, and 2016 and increased water temperatures (Kennedy and Ralston 2011, USFWS 2018). In 2024, FWS conducted two spring and two fall monitoring trips on the Little Colorado River (LCR) to generate population estimates for humpback chub and to monitor trends of other native fishes. Since 2006, the LCR population of humpback chub has significantly increased in size. In the LCR during spring monitoring, adult population estimates representing resident and migrant fish in spring 2024 were similar to those of 2023, which marked the highest abundance recorded since standardized monitoring began in 2000. Adult population estimates representing resident humpback chub in fall 2024 were similar to recent years. FWS monitored the success of upstream translocations of humpback chub within the LCR, and successfully translocated 455 new fish to this area.

A small reproducing population of endangered razorback sucker occurs downstream in Lake Mead, and past monitoring data indicate that razorback sucker occupy and were spawning in western Grand Canyon (Kegerries et al. 2017). In 2012, a single adult was captured near Spencer Canyon (Bunch et al. 2012) and several other sonic-tagged individuals were detected in the same relative area (Kegerries et al. 2017). Razorback suckers have been captured in small numbers in this same area in subsequent years including two adults, one untagged and one sonic tagged, in 2013, one sonic-tagged adult in 2016, and one untagged adult in 2018 (AZGFD unpublished data). Razorback sucker larvae were captured as far upstream as river mile 127.3 in 2019; however, numbers of larvae found during standardized monitoring have steadily declined since 2014 from 462 to 0 in 2020, 2021 and 2022 (Kegerries et al. 2021, S. Platania, ASIR, Inc., personal communication). In recent years, native fish have increased in abundance (or remained stable) and distribution in western Grand Canyon, with large numbers of juvenile humpback chub and flannelmouth sucker (*Catostomus latipinnis*) present (Kegerries et al. 2021, Van Haverbeke et al. 2017, Rogowski et al. 2018).

Humpback chub did not appear to experience any negative impacts from the 2024 Cool Mix flows, as water temperature was greater than the ~12°C growth threshold. Growth was estimated to be reduced by 4 mm during the 2024 Cool Mix Flows compared to growth without Cool Mix Flows. However, the observed growth (8 mm/month) during Cool Mix Flows is average for humpback chub in the Grand Canyon (DOI 2025) because these fish regularly experience temperatures produced by the Cool Mix Flows. The relative condition of humpback chub during the 2024 Cool Mix Flow experiment did not deviate from the average relative condition (1) of humpback chub in the mainstem Colorado River from previous years. One exception was condition for adult humpback chub around RM 61 during the summer season. This value fell below 1, but this could be normal for a fish that is actively growing and expending their energy into growing longer and not fatter. This would produce a relative condition of below 1.

The 2024 and 2025 Cool Mix Flows have not shown to have any significant impacts on Humpback chub (*Gila cypha*) and Native Fish.

Cool Mix Flow

The humpback chub and razorback sucker are not likely to be negatively affected by a lower-temperature regime because these fish existed in the Colorado River downstream of GCD when dam release temperatures were generally below 15°C (59°F) prior to 2022. Although humpback chub are found upstream of the LCR (as an aggregation at RM 30 Spring and near the confluence of the LCR at RM 61), the majority of the population is now found downstream in western Grand Canyon between Havasu Rapid (RM 157) and Pearce Ferry (RM 280; Rogowski et al. 2018). The razorback sucker is found primarily in the Lake Mead inflow with a few individuals moving upstream into the Colorado River.

Under the Cool Mix Flow, the presumed distributions of these species would remain about the same and are expected to persist. Cooler water temperatures would likely slow the growth of humpback chub, razorback sucker and other native fishes (Robinson et al. 2001); however, these could lead to improvements in survival if the predation risk by nonnative species declines. The temperatures proposed under this alternative would be consistent with the conditions present when the analysis for the LTEMP FEIS (DOI 2016a) was conducted. In other words, impacts on the humpback chub would not likely be different from those analyzed in the LTEMP FEIS. Cooler temperatures may also benefit humpback chub and razorback sucker by limiting the reproductive capabilities of parasites, such as Asian tapeworm and anchor worm, which require 18°C (64.4°F) or higher to mature and reproduce (Hoffnagle et al. 2006).

Cooler temperatures are not expected to negatively affect the following species and their food base: flannelmouth sucker (*Catostomus latipinnis*), bluehead sucker (*Catostomus discobolus*), or speckled dace (*Rhinichthys osculus*). Native fish species below GCD routinely encounter temperatures colder than the target temperatures for all flow options (Yackulic et al. 2014). It is possible that cooler water temperatures in Marble Canyon may limit natural reproduction in the mainstem for flannelmouth sucker and razorback sucker in this reach (M. Dzul personal communication and AZGFD unpublished data). Even though cooler temperatures would slow growth and limit reproduction of these species, cooler water may increase native fish survival by disadvantaging nonnative species and reducing their predation rates.

Model results from Eppehimer and Yackulic (2024), which supported the LTEMP SEIS analysis indicate no smallmouth bass population growth for any of the years at either RM locations.

However, that modeling does not include entrainment. Due to expected low elevations of Lake Powell, there is an increased probability of entrainment occurring. That entrainment is likely to add to the smallmouth bass population below Glen Canyon Dam regardless of a Cool Mix Flow.

Non-bypass Flow

High-flows of up to 26,900 cfs are not expected to negatively affect large juvenile and adult humpback chub or razorback sucker. This level of river discharge within the powerplant's capacity is experienced by these species during normal operations and some HFE events. Some young fish may become displaced and exposed to increased predation risk, and the effects of these high-flows on humpback chub, razorback sucker, and other native fishes is highly uncertain. Low-flow events, including discharge levels of 2,640 cfs, have rarely been seen in the Colorado

River downstream of GCD in recent decades. In 1990–1991, “research flows” were released as low as 1,000 cfs on weekends from Labor Day to Easter, but an in-depth evaluation was not done on resource responses to these low-flow events.

Studies of humpback chub (Valdez and Ryel 1995; Converse et al. 1998) indicated that much of the shoreline talus habitat and the backwaters used by juveniles were dewatered during extreme low-flow events, forcing the fish to move to mainstem habitats where they were possibly at greater risk of predation. Adult humpback chub and razorback suckers most likely moved to more suitable habitats during extreme low-flows and were not affected by these short-term events. Age-0 and juveniles of both species could be at risk of predation or starvation if they are displaced from their habitats by the extreme low- (2,640 cfs) and high- (26,900 cfs) flows of this alternative. Also, the most upstream reproducing aggregation of humpback chub at RM 30 (Valdez and Masslich 1999) could be negatively affected by the low-flows that could strand the warm shoreline spring that provides a warm water refugium in an otherwise cold river. If larvae or age-0 fish are present, the low flow could strand the fish and the high flow could displace them downstream, reducing survival.

High- and low-flows under Non-bypass Flows are proposed to occur such that as the high-flow wave travels downstream, it catches and then collapses the low-flow trough by the time it reaches the LCR. Doing this would prevent the minimum flow near the LCR from decreasing below 5,000 cfs. Similarly, with distance from GCD, the duration of any low-flow trough would also be reduced. However, the phenomenon of a collapsed trough is not likely to occur at the location of the upstream-most aggregation of the humpback chub at RM 30.

High-flows within the powerplant’s capacity are experienced by flannelmouth sucker, bluehead sucker, and speckled dace. Young life stages would likely remain along sheltered talus shorelines. Although some young fish may become displaced from shorelines or backwaters and exposed to predation and starvation, the effect of these high-flows on these species is expected to be minimal. Flows of 2,640 cfs, if they occurred April–June, could negatively affect young and juvenile flannelmouth suckers and bluehead suckers that could be displaced from dewatered shoreline habitats and backwaters. Older juveniles and adults are not expected to be negatively affected by short-term low-flows followed by high-flows. Speckled dace have been observed to move and adjust locations along shoreline habitats with flow stages (Valdez and Ryel 1995; Webb et al. 1999). The native Colorado River Basin fish evolved in a highly variable environment of flow, turbidity, and temperature variation.

This flow variability is not characteristic of post-dam Colorado River hydrology, which is better described as increasing flows in late winter and early spring to peaks flows in spring then a declining hydrograph, all taking place generally from about April to mid-June. Monsoonal floods in summer may be akin to the high releases of this alternative, but they are not generally followed by an extremely low-flow (2,640 cfs). Hence, the response by the native fish to the hydrology of this alternative is uncertain, but the contrast in hydrology between high and low-flows could displace and stress some fish, especially younger fish. Also, the extremely low-flows of 2,640 cfs is likely to dewater shallow and shoreline habitats. Although these flow variations are expected to ameliorate downstream, effects on habitat and fish displacement could be experienced by the

humpback chub aggregation at RM 30 and possibly further downstream to the mouth of the LCR at RM 61. Continued warmer releases under the Non-Bypass Flows are likely to increase the infestation rates of certain fish parasites, including the Asian tapeworm and the *Lernaea* copepod.

Recreational Experience

Cool Mix Flow

Impacts on Fishing in the Glen Canyon Reach

The Cool Mix Alternative would reduce water temperatures at a target RM, with the aim of achieving the target temperature of 15.5°C (60°F). This could benefit the rainbow trout fishery in the short term because rainbow trout are a cold-water species and colder water temperatures (7-12°C) are more favorable to rainbow trout relative to the other non-native species in the system. The long-term benefits could improve water quality and enhance the rainbow trout fishery, which would likely result in higher angler satisfaction in the long-term than under the No Action Alternative.

Under the Cool Mix Alternative, total discharge volumes would be approximately the same as the No Action Alternative; therefore, the impacts on fishing in the Glen Canyon reach resulting from the volume of water discharged would be the same as described under the No Action Alternative.

Additionally, use of bypass has the ability to increase dissolved oxygen. This may be of consideration in a year where inflows in Lake Powell result in anoxic plumes hitting Glen Canyon at the elevation of the penstocks. The 2024 and 2025 Cool Mix Flows have not shown to have any significant impacts on fishing in the Glen Canyon Reach.

Non-bypass Flow

Impacts on Fishing in the Glen Canyon Reach

Under the Non-Bypass Alternative, high-flows are not anticipated to affect adult rainbow trout; however, they are likely to displace young and juvenile rainbow trout and expose these fish to starvation and predation or possibly displace them downstream to population centers of native fishes where they can prey on and compete with those fish. Adult rainbow trout would not be as negatively affected as the larger fish are able to shift habitats during dramatic flow changes. Reducing the overall rainbow trout population could negatively affect the rainbow trout fishery, particularly when combined with the adverse effects of additional high-water temperature, low dissolved oxygen, additional predation, and other recent poor health indicators. Rapid changes in water levels would occur at night therefor not directly affect the safety of wading anglers. To mitigate impacts on the food base and upstream boat travel for angling, Sunday nighttime operations are recommended. Non-bypass Flows are also less likely to benefit the rainbow trout fishery by reducing water temperatures compared with the cold-water alternatives.

Impacts on Boating and Camping in the Glen Canyon Reach

Under the Cool Mix Alternative, total discharge volumes would be approximately the same as the No Action Alternative; therefore, the impacts on rafting and camping in the Glen Canyon Reach resulting from the volume of water discharged would be the same as described under the No Action Alternative. The 2024 and 2025 Cool Mix Flows have not shown to have any significant impacts on Boating and Camping in the Glen Canyon Reach.

Impacts on Boating and Camping in the Grand Canyon Reach

Under the Cool Mix Alternative, total discharge volumes would be approximately the same as the No Action Alternative; therefore, the impacts on rafting and camping in the Grand Canyon National Park resulting from the volume of water discharged would be the same as described under the No Action Alternative. The 2024 and 2025 Cool Mix Flows have not shown to have any significant impacts on Boating and Camping in the Grand Canyon Reach.

*Rainbow Trout (*Oncorhynchus mykiss*) Fishery*

The NPS Comprehensive Fisheries Management Plan completed in cooperation and coordination with AZGFD (NPS 2013), and the AZGFD Management Plan (AGFD 2015) establish objectives for the rainbow trout fishery at Lees Ferry. Two of those objectives are to maintain angler catch rates of ≥ 1 rainbow trout per hour, and fish condition ≥ 1 in the summer. After a population crash of rainbow trout in the winter of 2015-2016, the population started rebounding with increased young of the year production in 2017-2018, however that did not result in an increase of catchable fish (Figure 11), and overall abundance has been decreasing since 2018 (Figure 12; Personal Communication from B. Healy, unpublished data presented at the Glen Canyon Dam Technical Work Group Meeting on July 10, 2024). During the 2024 Cool Mix Flows, rainbow trout appeared to be in better condition compared to previous years. However, it remains uncertain whether those changes were due to cooler waters or other factors.

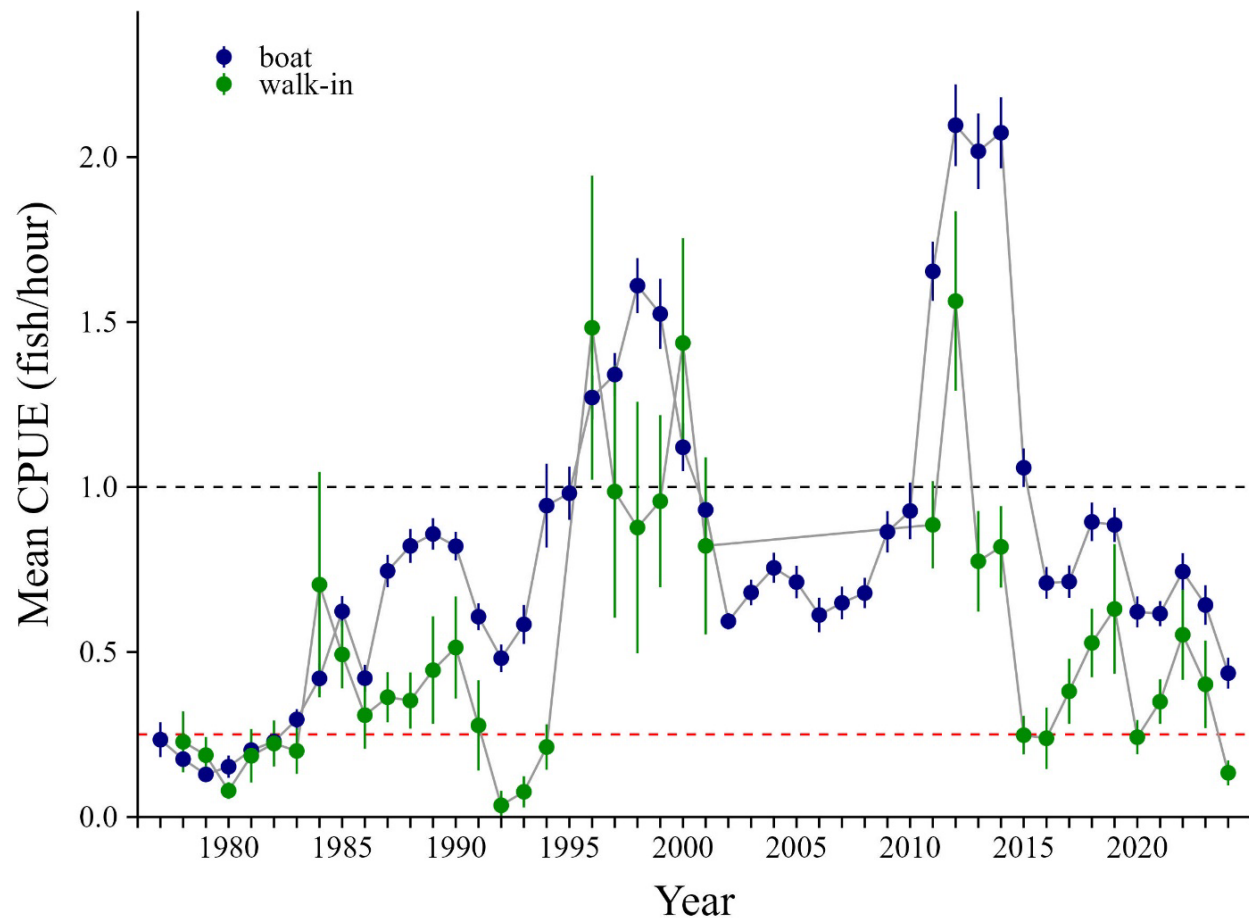
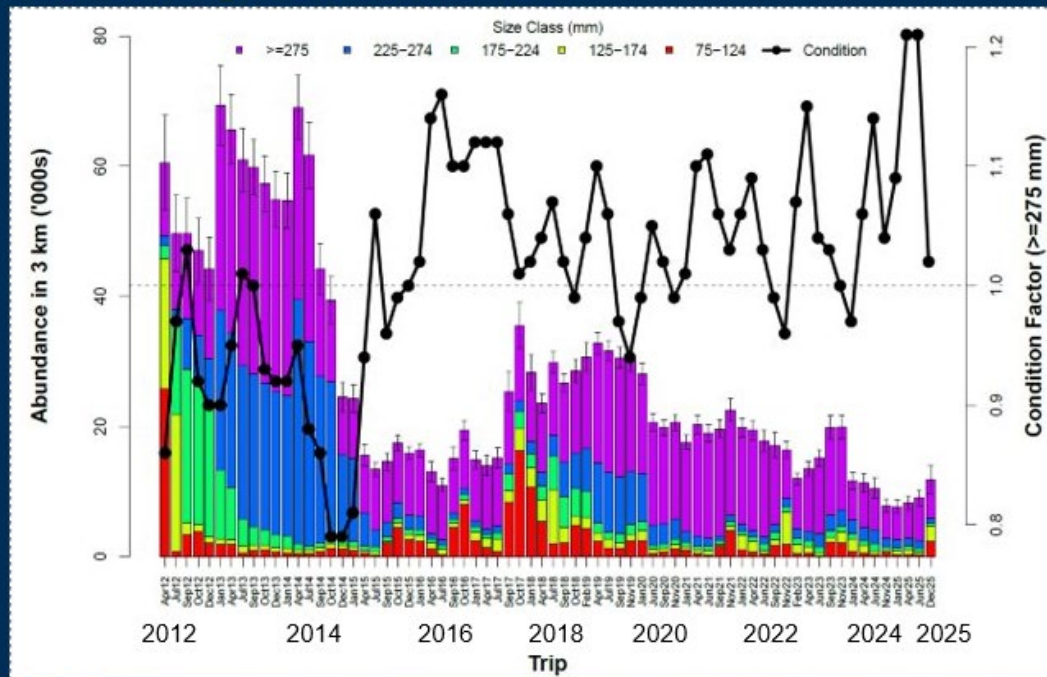


Figure 11. Angler catch per unit effort (Rainbow Trout/hour) with 95% confidence intervals by year and angler type. AZGFD management goal for anglers is one fish per hour (grey dashed line), and 0.25 fish/hour is the level where mitigation is necessary (red dashed line; Fonken and Rogowski 2024; *in review*).

Rainbow Trout Abundance – Glen Canyon Site 1C



Preliminary unpublished data, do not cite

Figure 12. Rainbow trout abundance over time during the Trout Reproductive Growth Dynamics (TRGD) trips. Figure from B. Healy, unpublished data presented at the Glen Canyon Dam Annual Reporting Meeting (February 2026).

The 2024 and 2025 Cool Mix Flows have not shown to have any significant impacts on the Rainbow Trout (*Oncorhynchus mykiss*) Fishery.

Cool Mix Flow

Cooler temperatures may create a more favorable thermal environment for Rainbow Trout. Release temperatures are forecast to reach as high as 22.0°C in 2026 according to the last CRMMs and Temperature model runs (Figure 8-9). These temperatures exceed the optimal rainbow trout life history range between 7°C and 12°C, with increased mortality beyond 15°C for younger fish (Carter 2005; Kwain 1975; Myrick and Cech 2001; Raleigh et al. 1984; Velsen 1987) and could possibly be lethal to rainbow trout. Additionally, rainbow trout have persisted with these lower temperatures since the dam began releasing cold, hypolimnetic waters in the 1970s. Cooler temperatures are not expected to negatively affect rainbow trout's food base, and if anything the releases from the ROW are more suitable for rainbow trout habitat conditions and may increase food base due to elevated phosphorus concentrations.

Non-bypass Flow

High-flows within the powerplant's capacity are experienced by rainbow trout. No effect is expected on adults. Changes in the flow stage are expected to displace young and juvenile trout and expose these fish to starvation and predation, or possibly displace them downstream to population centers of native fish where they can prey on and compete with those fish. Downstream displacement of rainbow trout could lead to increases in interactions with other rainbow trout and humpback chub (Avery et al. 2015). Low flows of 2,400 cfs are not expected to negatively affect eggs and fry through desiccation because rainbow trout spawn from January to March and rainbow trout are expected to be at sizes to withstand fluctuating flows. Adult rainbow trout would not be as negatively affected, as the larger fish are able to shift habitat during dramatic flow changes. In 1980, the Lees Ferry rainbow trout population experienced flow fluctuations in greater magnitude. There was little recruitment during that timeframe which led to enhancement of the fishery through stocking (Maddux et al. 1987; M. Dzul and M. Yard, personal communication).

Nonnative Invasive Species

In addition to smallmouth bass, other nonnative fish species observed in recent years in Glen Canyon that could threaten humpback chub and other native fishes if they became more abundant and widespread in the Colorado River downstream of Glen Canyon Dam include striped bass (*Morone saxatilis*) and walleye (*Sander vitreus*). Striped bass have been periodically captured in Glen Canyon since the early 1980s. More recent captures of striped bass by GCMRC in Glen Canyon include one caught in each 2020 and 2016; two in 2019; and three in 2015. In August of 2018, five striped bass were observed in the slough (GCMRC unpublished data). Approximately 40 were reported between Lees Ferry and the Little Colorado River by the September 2022 FWS/GCMRC seining trip (GCMRC unpublished data). Approximately 50 young-of-year striped bass of uncertain origin have been reported in Marble and Grand Canyons in 2022. No striped bass were captured in 2025 during NPS sampling between the dam and Badger Rapid (Shollenberger et al. 2026) and only a few were reported by other agencies (NPS personal communication).

Small numbers of walleye have been captured annually in Glen Canyon, from 2006 to 2019. AZGFD has captured an average of three (range 0 to 8) each year (AZGFD unpublished data, GCMRC unpublished data), primarily downstream of Glen Canyon Dam, with none captured in 2020 or in 2021. In 2024, a total of 38 walleye were captured above Lees Ferry (Shollenberger et al. 2025). Two walleye were captured during NPS sampling between the dam and Badger Rapid (Shollenberger et al. 2026) in 2025.

With low lake elevations, increased probability of fish entrainment through Glen Canyon Dam and increased river temperatures conducive to warm water invasive fishes exists. At reservoir elevations below ~3,515 ft above sea level, surface levels are less than 20 m away from the penstock centerline and fish entrainment probability increases, as recent monitoring has revealed that the majority of pelagic fish are located in the top 20 m of the water column (Eppehimer et al. 2024 in review). A survey of the forebay with gill nets in early March 2023 captured only one walleye in the vicinity of the penstocks. Catch per unit effort (CPUE) was low compared to fall of 2022, perhaps due to cold temperatures in early March (water temp 7.4 C). Minnow traps set near the dam capture small numbers of juvenile green sunfish and bluegill down to almost the penstock depths (Friesen 2024). Reclamation reported very few fish targets on hydroacoustic surveys in the

forebay at the same time, compared with surveys conducted in March 2022 and fall 2022 (Friesen 2024).

Green sunfish appeared to have a reduction in demographic parameters because of Cool Mix Flows in 2024 and 2025. Green sunfish abundance in 2025 appeared lower than in 2024 and previous years (Dibble et al. 2026 GCDAMP Annual Reporting Meeting). Since the slough has been modified (see -12 mile slough section) there has been an observed reduction in green sunfish presence. The average size of green sunfish in 2024 was higher than in 2023, which might suggest changes in recruitment success and lower survival rates under the cooler water conditions. The highest concentrations of green sunfish captured in 2024 resided around the -12 slough which has since been modified.

Brown trout are a highly piscivorous species known to prey on humpback chub and other native species (Yard et al. 2011; Whiting et al. 2011). Monitoring of juvenile humpback chub suggests that increased rainbow trout abundances (and perhaps brown trout abundances) are associated with lower juvenile chub survival rates (Yackulic et al. 2018); however, this effect is context specific may be weak relative to other drivers of humpback chub dynamics (e.g., temperature, juvenile recruitment, food availability), under current river conditions (e.g. warmer temperatures). Nonetheless, brown trout can have a population-level impact on native fish in the Grand Canyon (Healy et al. 2020). Coinciding with suppression of brown trout in a primary area for reproduction (Bright Angel Creek; Akland et al. 2025) and subsequent suppressed abundance (Healy et al. 2020), brown trout catches at the Little Colorado River confluence have generally been low since implementation of the HFE protocol in 2012 (GCMRC unpublished data). In contrast to observations near the Little Colorado River, brown trout abundance increased in Glen Canyon through 2022 and then declined precipitously with recent warming river temperatures and low dissolved oxygen (GCMRC unpublished data). Nonetheless, if river conditions change (i.e., temperatures remain cool), brown trout may again become a cause for concern (Healy et al. 2023). It is possible that Cool Mix flows could benefit brown trout by providing more suitable temperatures for survival. However, with low numbers currently present, the threat of brown trout is low.

The 2024 and 2025 Cool Mix Flows have not increased the presence of Nonnative Invasive Species and some evidence has shown that has had a negative influence on Nonnative Invasive Species.

Cool Mix Flow

Cool temperatures could negatively affect nonnative, warmwater fish, such as smallmouth bass, green sunfish, fathead minnows (*Pimephales promelas*), red shiners (*Cyprinella lutrensis*), channel catfish (*Ictalurus punctatus*), and common carp (*Cyprinus carpio*). This is the point of the Cool-Mix release option. Cool temperatures could, in turn, benefit the native fish by potentially reducing competition and predation from nonnative species. For example, the cooler temperatures are intended to delay or disrupt maturation and spawning by smallmouth bass, based on observations in the Upper Colorado River (Bestgen and Hill 2016). Smallmouth bass typically spawn from May through July in the Upper Basin shortly after the first day when temperatures increase above 15.5°C (60°F; Bestgen and Hill 2016). Cool temperatures of less than 15.5°C (60°F) year-round are expected to lead to minimal to no initiation of spawning in smallmouth bass and possibly other

species, such as green sunfish, as well as poor growth and survival of early life stages. These species generally require higher temperatures to successfully spawn and incubate their eggs, and survival and growth of early life stages is poor at these temperatures. Timing the releases of the Cool Mix Flows to maximize the impact on smallmouth bass spawning in a way that integrates with the natural downstream warming of the Colorado River to river reaches occupied by a higher abundance of native species, such as the confluence with the LCR (RM 61), requires detailed assessment. An important unknown is whether nearshore thermal environments may persist that would offer warmer refuge for nonnative species.

It may only be possible to maintain temperatures below 15.5°C (60°F) from below the GCD through river mile 45 in Marble Canyon when GCD releases are low; however, it may also be possible to release enough cold water to overcome a lower volume of warmer water going through the penstocks (USGS 2022) and increase the distance of effect to RM 61 at the mouth of the LCR. However, since smallmouth bass have been detected mainly in the Glen Canyon reach, implementation of this alternative could still be effective at reducing the likelihood of successful spawning of smallmouth bass where most fish have been found as of the end of 2023. Eppehimer and Yackulic (2024) predict that the river can be cooled with releases downstream to RM 15 or 30.

Non-bypass Flow

High-flows within the powerplant's capacity are not expected to negatively affect adult nonnative fish; however, some young could be displaced from their habitats, but these fish experience this flow range under current operations. Weekend flows of 2,640 cfs could negatively affect nonnative, warmwater fish, such as smallmouth bass, green sunfish, channel catfish, common carp, fathead minnows, and red shiners. These low-flows would dewater shallow shoreline habitats and backwaters that are preferred (but not required) habitats of these species and displace them to the mainstem, leading to increased predation and starvation. For smallmouth bass, rising water would flush solar-warmed shoreline nest areas with water at the temperature of main river, potentially causing nest desertion and halting embryo development if the main river temperatures are significantly lower. Rising flows could also displace juvenile and adult smallmouth bass from preferred habitats and possibly lead to starvation and predation. Subsequent falling water levels could drive spawning females and guarding males from nests, exposing the eggs and fry to predation and to less water circulation and aeration of the eggs. The low-flow (2,640 cfs) element of the Non-bypass Flow will dewater margins and shallow habitats, negatively affecting young trout and their food base.

Native Riparian Vegetation

As described in the 2016 LTEMP FEIS (DOI 2016a), vegetation along the Colorado River corridor from GCD to Lake Mead is affected by the peak magnitudes, daily fluctuations, and seasonal patterns of river flows. Most evidence indicates that riparian vegetation composition, structure, distribution, and function are closely tied to ongoing GCD operations (DOI 2016a). Since GCD operations began, there have been dramatic changes in the distribution and composition of riparian vegetation communities (Sankey et al. 2015; Turner and Karpiscak 1980; Webb et al. 2011). There has been a net increase in riparian vegetation cover and density as a result of altered flow regimes, including increases in both native and nonnative species (Dunning et al. 2021; Sankey et al. 2015; Stevens et al. 1995).

The implications of hotter temperatures of eastern and western Grand Canyon modify preferred hydrologic conditions for some plant species, particularly, on large sandbars (Yackulic et al. 2024). The prevalence of native species in this system is related to the timing of both high- and low-flow periods, where high-flows during the summer maximize native plant richness and low-flows in the winter are associated with great proportions of native species relative to nonnative species. Thus, air temperature, the minimum discharge of the daily fluctuations during the lowest streamflow period, the peak discharge of daily fluctuations during highest streamflow period, and maximum discharge of the year (larger for HFE years) are key variables shaping riparian plant communities along the Colorado River corridor (Yackulic et al. 2024). The 2024 and 2025 Cool Mix Flows have not shown to have any significant impacts on Native Riparian Vegetation.

Cool Mix Flow

The Cool Mix Flow would have consistent releases that result in flow patterns similar to the patterns under current management. Therefore, overall, this alternative is expected to have similar impacts on riparian vegetation as the No Action.

Non-bypass Flow

The Non-Bypass Flow would result in higher daily fluctuations in flows with weekly drops in flow to a minimum of 2,640 cfs followed by a steep increase in flow to a maximum of ~26,900 cfs. These changes would last for approximately 8 hours at the GCD. Compared with the other flow alternatives, the Non-Bypass Flow would have daily flow fluctuations that may reduce shoreline stability.

Water Delivery - Monthly, Daily, and Hourly Releases

Cool Mix Flow

Impacts on system hydrology under the Cool Mix Flow would be temporary and would not exceed compliance for any water delivery. Releases will be adjusted due to DROA and 6c adjustments. Current estimates for monthly volumes are ~ 460 thousand acre-feet (kaf). The 2024 and 2025 Cool Mix Flows have not shown to have any impacts on Water Delivery - Monthly, Daily, and Hourly Releases. Additionally, the use of bypass for Cool Mix flows may provide additional understanding of the use of ROW for water delivery under low reservoir conditions.

Non-bypass Flow

The minimum and maximum proposed flows would exceed the maximum daily range as developed in the LTEMP ROD (DOI 2016b). However, monthly and annual release volumes would be the same and would be temporary and not exceed compliance for any water delivery. Releases will be consistent with monthly releases as described in LTEMP and annual releases as described in the 2007 Interim Guidelines.

Water Quality

The Cool Mix flow implemented in 2024 was effective in cooling the river below 15.5 °C (60°F) to RM 61 from July 8th to November 18th. A total of 14 days exceeding that temperature after implementation began, compared to a modeled 135 (±5) days of temperatures over 15.5 °C had flows not been implemented. Temperatures at the Lees Ferry gage, immediately downstream of

where most smallmouth bass have been detected, averaged 14.1 °C for the duration of the experiment.

The 2025 Cool Mix flow implementation faced more complexity but yielded similar results to 2024. In 2025, Cool Mix flows were successful at cooling the Colorado River below 15.5 °C (60°F) to RM 30 from August 12th to October 20th. During that time the Colorado River at RM30 exceeded daily average of 15.5 °C (60°F) for a total of 26 days. Discharges from the Glen Canyon Dam were more unpredictable in 2025 leading to more uncertainty when modeling bypass releases. Additionally, due to low elevation in Lake Powell, rough zone operations made planning for releases more complex and required additional effort to maintain temperatures below 15.5 °C (60°F).

Impacts to water quality, including dissolved oxygen, specific conductivity, and soluble reactive phosphorus, were largely negligible during the Cool Mix Flows. Dissolved oxygen (DO) concentrations did increase during the Cool Mix Flow releases to near the EPA limit; however, no gas bubble disease was detected during any of the sampling trips. The 2024 and 2025 Cool Mix Flows have not shown to have any impacts on Water Quality.

Cool Mix Flow

Under the Cool Mix Flow, adding more bypass through Cool Mix operations would result in a decreased total release temperature during summer periods compared with the No Action Alternative.

Under the Cool Mix Flow, there would be an increase in salinity when compared with the No Action Alternative. While there would be an increase, salinity would remain lower than the historic early spring salinity concentration peaks, so the increase would be within normal range.

Under the Cool Mix Flow, low DO events, where summertime mean DO is less than 5.2 mg/L (the threshold below which oxygen concentrations are stressful to trout) would be less probable than under the No Action Alternative.

Non-bypass Flows

Impacts on temperature under the Non-bypass Alternative would be similar to those under the No Action Alternative since the Non-Bypass Alternative would not involve the use of Glen Canyon Dam's bypass system to cool the river and would instead focus on changes in daily release volumes. The Non-bypass Alternative would result in slightly lower temperatures compared to the No Action; however, these temperatures would not be cool enough to impact smallmouth bass spawning.

Impacts on salinity under the Non-bypass Alternative would be similar to those under the No Action Alternative. This alternative would be similar to the No Action Alternative, since the Non-bypass Alternative would not involve the use of Glen Canyon Dam's bypass system and would instead focus on changes in release volumes.

Impacts on DO under the Non-bypass Alternative would be similar to those under the No Action

Alternative. This alternative would be similar to the No Action Alternative, since the Non-bypass Alternative would not involve the use of Glen Canyon Dam’s bypass system and would instead focus on changes in daily release volumes.

Other Consideration

Slough

Cool Mix Flow and Non-bypass Flow

Construction of the slough channelization by the NPS and Reclamation finished June 2, 2025. This project channelized the slough at river mile –12, and vegetation restoration and monitoring will be done in following years. The project reduced suitable habitat for reproduction of smallmouth bass and other warm water high-risk species at this location and reduced the likelihood of downstream expansion and establishment in Glen, Marble, and Grand Canyons. Details of the slough modification efforts can be found here: [ParkPlanning - Warmwater Nonnative Fish Management at the -12-Mile Slough](#). In order to maintain a cool flow through the modified slough a minimum flow of 6,800 cfs has been suggested by National Park Service. This would allow the slough modification to maintain its goal of cooler, flowing water to help limit nonnative spawning and refuge. If flow and low temperatures cannot be maintained in the slough it is possible that it could become more suitable for smallmouth bass and other nonnative fish spawning.

Dam Maintenance and Operations

Cool Mix Flows and Non-bypass Flow

Cool Mix Flows operate within the current dam maintenance schedule. **No infrastructure damage was observed during 2024 and 2025 Cool Mix Flows**, and no negative effects on dam infrastructure are anticipated from either Cool Mix Flows. However, the River Outlet Works (ROWs) were not designed nor intended for long-term use at low reservoir levels so uncertainty does exist if there was prolonged use of the ROWs (DOI 2024a).

Other LTEMP Experimental Flows (i.e., HFEs)

A Cool Mix Flow is not expected to pose any direct impacts on the ability to conduct LTEMP experimental flows in the future. While the LTEMP SEIS modeled for the possibility of both a High-Flow Experiment and Smallmouth Bass Flow occurring in the same Water Year, discussion and comparison of impacts between the two flows did not occur in depth during PI Technical Team meetings. There could be hydropower impacts that cumulatively have adverse effects to the Basin Fund that will need to be considered for future LTEMP Experimental Flows.

V. GCDAMP and LTEMP PA Consultation

Notification of the potential for a LTEMP Smallmouth Bass Flow experiment was communicated to Glen Canyon Dam Adaptive Management Program (GCDAMP) stakeholders at the April 17, 2026, TWG meeting and at the April 9, 2026, GCDAMP informational meeting. A follow-up email will be distributed to the GCDAMP stakeholders informing them of the final recommendation.

On March 3, 2026, the required 30-day advance notification and offer for consultation were sent electronically to the Tribes and Parties to the 2017 LTEMP Programmatic Agreement regarding

the potential for a Smallmouth Bass Flow experiment. A follow-up notification will be sent electronically to the Programmatic Agreement signatories, including Tribes, following the Department's decision regarding the potential Smallmouth Bass Flow experiment. As of April 17, 2026, no tribes have asked for a consultation.

The period for tribal consultation extended beyond the timeline for the PI Technical Team to make the recommendation discussed in this report. Tribal consultation is a nation-to-nation process and the PI Technical Team may not be aware of concerns raised during that process.

VI. VIII. Conclusion

Determining whether to recommend a Summer of 2026 Smallmouth Bass Flow required coordination and effective communication among the technical staff of multiple agencies. The PI Technical Team relied heavily on and would like to acknowledge the contributions of staff from GCMRC, Reclamation, FWS, NPS, AZGFD, and WAPA in making this recommendation. The PI Technical Team has thoroughly evaluated the issues discussed above and has taken into consideration the information and analyses included in the LTEMP FEIS (DOI 2016a), ROD (DOI 2016b), LTEMP SEIS ROD (DOI 2024a). The PI Technical Team's recommendation regarding implementation of a summer 2026 Smallmouth Bass Flow is based on a careful assessment of resources and best available science.

“By a consensus/majority recommendation, The Planning and Implementation (PI) Technical Team recommends the PI Leadership Team consider the following Long-Term Experimental and Management Plan (LTEMP) Supplemental Environmental Impact Statement Alternative Flow for implementation in the Summer/Fall of 2026:

- **Flow Option = Cool Mix**
- **River Mile Target and On-ramp = When average daily temperature at River Mile 15 exceeds 15.5°C for three consecutive days.**
- **Off-ramp Date = October 20th, 2026**

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VIII. Appendices

Appendix A. Summarized TWG/AMWG comments for the Smallmouth Bass Flow Experiment being considered for the summer of 2026. Summarized TWG/AMWG comments were summarized through Artificial Intelligence and may contain errors.

1. Purpose and Urgency

- The Smallmouth Bass Flow experiment (often referred to as “CoolMix” flows) is designed to control water temperature below Glen Canyon Dam, aiming to suppress the reproductive success and establishment of invasive smallmouth bass and other warmwater non-native fish.
- There was strong consensus that temperature control via these flows is the most effective short-term tool available to prevent smallmouth bass from becoming established and threatening native fish, especially humpback chub

2. Operational Challenges

- The group acknowledged increasing difficulty in implementing CoolMix flows due to declining reservoir elevations and hydropower constraints. Lower water levels make it harder to maintain the desired cool temperatures, and the cost of replacement power is significant.
- There was discussion about the need for modeling exercises to explore combinations of shorter smallmouth bass flows with high peak HFEs, aiming to balance benefits across multiple resources while minimizing negative impacts

3. Stakeholder Perspectives

- **Strong support for continuing CoolMix flows:** Many stakeholders, including resource managers, scientists, and recreation advocates, emphasized the importance of maintaining CoolMix flows this summer. They argued that failing to do so would risk losing the progress made in controlling smallmouth bass and protecting native fish.
- Concerns about decision timelines: Several participants expressed concern that decisions about implementing CoolMix flows need to be made quickly, as temperature thresholds are likely to be reached earlier than usual this year. There was a call for contingency planning in case the flows cannot be implemented
- Hydropower and economic impacts: Hydropower representatives voiced concerns about the financial impact of bypass flows required for CoolMix, especially given current energy market conditions and supply chain challenges. Some stated they could not support experiments that include bypass flows at this time.

4. Scientific and Technical Considerations

- The technical team is developing screening tools to model population growth, costs, and operational scenarios for CoolMix and alternative flow regimes. Results are expected soon,

but there is concern that decisions may need to be made quickly as temperature thresholds are likely to be reached earlier than usual

- There was discussion about the need for robust monitoring to assess the effectiveness of CoolMix flows and their impact on both native and non-native fish populations.

5. Contingency and Alternative Actions

- Several participants stressed the need to plan for alternative rapid response actions (e.g., hotspot treatments, rotenone application) in case CoolMix flows cannot be implemented due to operational or hydrological constraints.
- There was a call for more nimble and flexible management, including having teams and resources ready to respond quickly to emerging threats

6. Long-Term Strategy

- While CoolMix flows are seen as the best short-term tool, there was recognition that long-term solutions (e.g., temperature control devices, exclusion barriers) are needed. The group discussed the importance of ongoing research, feasibility studies, and inter-basin collaboration to develop sustainable strategies

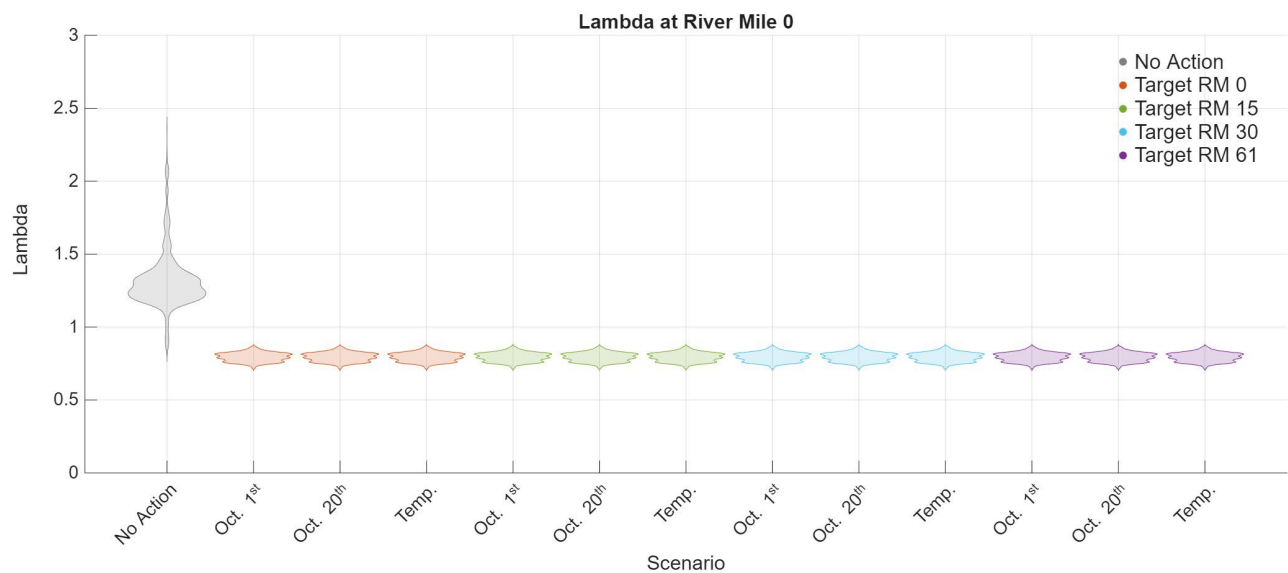
Key Takeaways

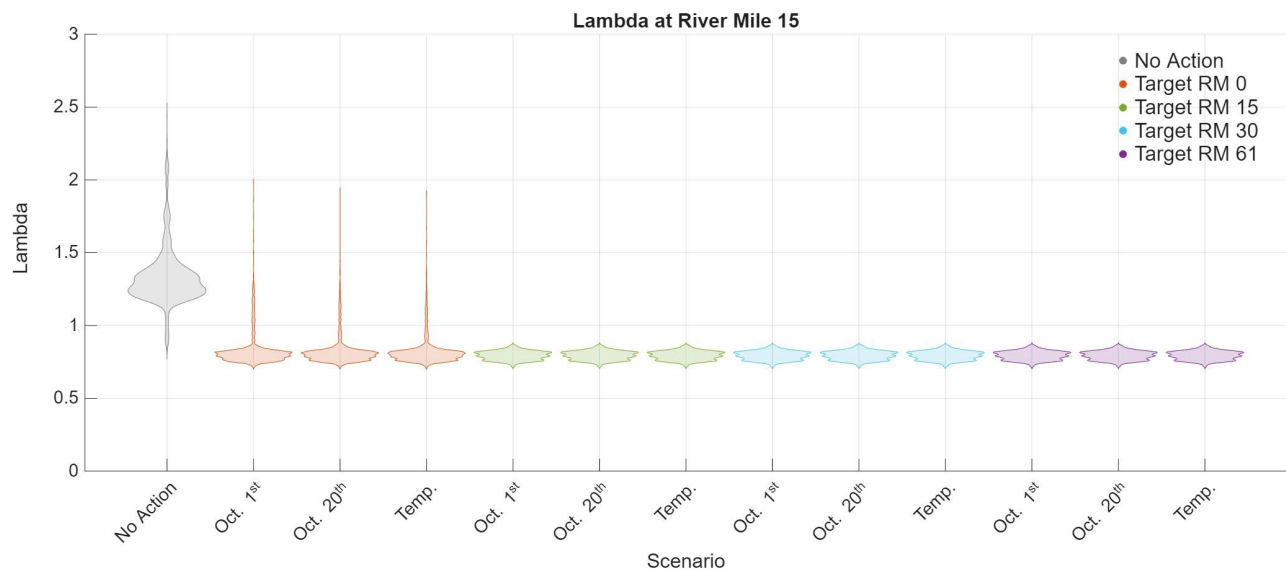
- Cool Mix flows are widely supported as the most effective immediate tool for controlling smallmouth bass, but operational and financial constraints are increasing.
- Stakeholders urge rapid decision-making and contingency planning for alternative actions if Cool Mix flows cannot be implemented.
- There is a need for robust monitoring, ongoing research, and development of long-term solutions to address the invasive species threat.
- Hydropower and economic impacts are significant concerns, and some stakeholders cannot support bypass flows under current conditions.

Appendix B. On April 21, 2026, the Planning and Implementation team was asked to rank their top 10 preferred Smallmouth Bass Flow scenario with 1 being the most favorable. These rankings were based on each member's technical assessment of how well each scenario impacts all of the resources identified in LTEMP. A total of 13/15 members of the PI Technical Team responded to the survey.

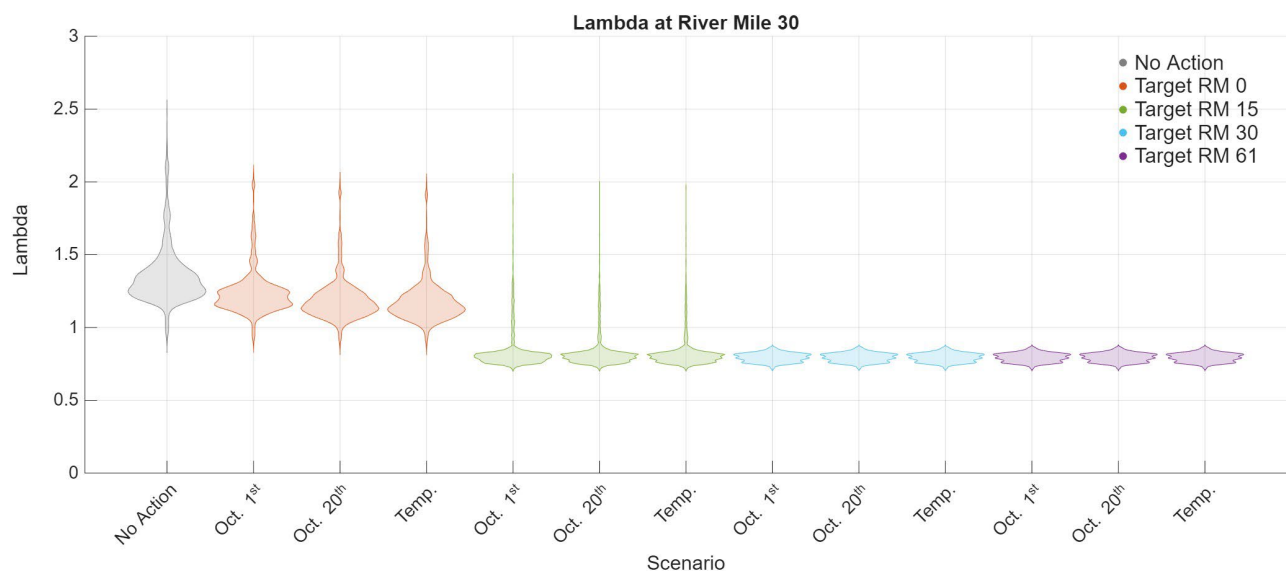
Flow Option-River Mile-Off Ramp Date	Sum	Overall Rank	# Reponses
Cool Mix - RM 15 - October 20th	84	1	12
Cool Mix - RM 0 - October 20th	77	2	11
Cool Mix - RM 15 - October 1st	66	3	11
Cool Mix - RM 0 - October 1st	58	4	10
Cool Mix - RM 30 - October 20th	52	5	11
Cool Mix - RM 0 -Temperature Driven	49	6	10
Cool Mix - RM 30 - October 1st	44	7	11
Cool Mix - RM 15 -Temperature Driven	41	8	9
Cool Mix - RM 30 -Temperature Driven	29	9	9
Non bypass - RM 0 - October 20th	18	10	4
Cool Mix - RM 15 - September 15th	15	11	2
Non bypass - RM 15 - October 20th	15	11	2
Cool Mix - RM 60 - October 20th	13	13	3
Non bypass - RM 0 - October 1st	11	14	2
No SMB Flow	10	15	1
Cool Mix - RM 30 - September 15th	9	16	2
Non bypass - RM 60 - October 20th	9	16	1
Cool Mix - RM 0 - September 15th	8	18	1
Non bypass - RM 0 -Temperature Driven	8	18	4
Non bypass - RM 30 - October 20th	8	18	1
Non bypass - RM 15 - October 1st	7	21	1
Non bypass - RM 15 -Temperature Driven	6	22	2
Cool Mix - RM 60 - October 1st	5	23	3
Non bypass - RM 60 -Temperature Driven	5	23	1
Cool Mix - RM 60 -Temperature Driven	4	25	2
Non bypass - RM 30 -Temperature Driven	4	25	1
Non bypass - RM 0 - September 15th	3	27	1
Non bypass - RM 60 - October 1st	1	28	1
Cool Mix - RM 60 - September 15th	0	29	0
Non bypass - RM 15 - September 15th	0	29	0
Non bypass - RM 30 - October 1st	0	29	0
Non bypass - RM 30 - September 15th	0	29	0
Non bypass - RM 60 - September 15th	0	29	0

Appendix C. Smallmouth bass (SMB) population growth rates (λ) at a specific river mile (Y-Axis) estimates at different scenarios (X-Axis) when the target temperature is held at a specific river mile targets. Violin plots summarize lambda (λ) values from 100 stochastic simulations across CRMMS hydrologic traces that trigger temperature management. Scenarios are grouped by river mile (RM) target (0, 15, 30, and 61) and scenario specifying No Action and off-ramp dates (Oct. 1, Oct. 20, or temperature-driven (Temp)). Lower λ values reflect greater suppression of SMB recruitment; values >1 indicate potential population growth. Temperature driven lambda at RM 0 was not evaluated. The lambda estimates shown here assume reproductive adult SMB are present at the target location. Lambda estimates do not include estimates of either entrained juvenile or adult SMB.

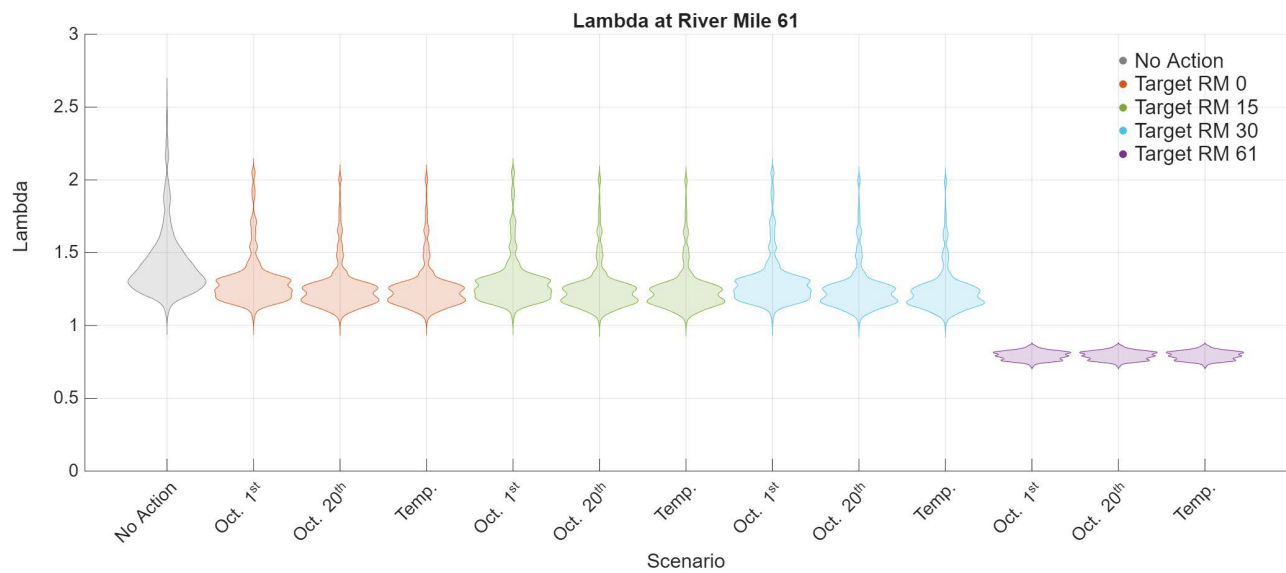




Preliminary data, subject to change



Preliminary data, subject to change

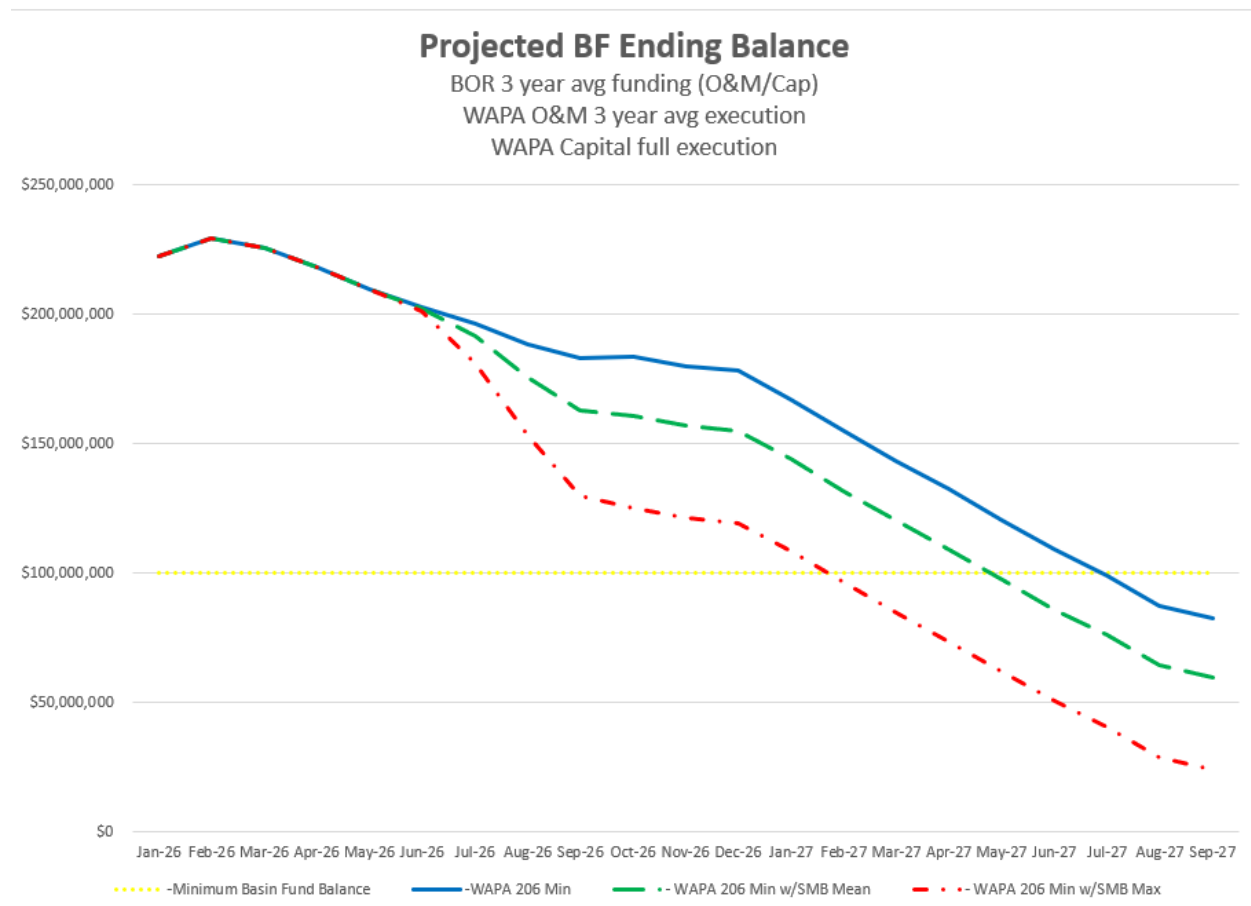


Preliminary data, subject to change

Appendix D. Basin fund information shared at the April 23, 2026 Technical Team meeting.

For almost a decade, WAPA communicated that projections indicate that the Basin Fund cannot sustain funding ongoing non-reimbursable costs. Reclamation has received appropriations for the AMP & RIP program, providing some relief to the Basin Fund. However, much of that savings has been offset by the costs of the Cool Mix experiment implementation and could be exceeded this year. While the Basin Fund balance has hovered at \$200M for the last couple years, we now have reached the point that the Basin Fund cannot support the Cool Mix experiment in 2026.

The Basin Fund cannot afford to fund experiments. Due to continued declining hydrology and Glen Canyon forecasted to fall below minimum power pool in 2026, the Basin Fund is projected to fall below minimum operating levels to \$82M (blue line) before the end of FY27. The minimum operating balance for the Basin Fund is \$100M as monthly expenses range from \$20M to \$50M. Large infrastructure replacements are also required, with a transformer purchase of \$40M planned for FY28.



If Cool Mix is implemented for 2026 with RM0 to Oct 20, the mean cost would drop the Basin Fund to \$60M (green dashed line), max to \$24M (red dashed line). These projections do not include potential costs for bypass in 2027. There is no bounce back from this. WAPA will start a new rate process next year, but the rate only recovers power related costs. WAPA **cannot recover**

non-reimbursable costs through the rate process.

Consequences of the Basin Fund being depleted to this level are not specific to Glen Canyon; CRSP projects are affected – Fontenelle, Flaming Gorge, Morrow Point, Blue Mesa, Navajo & Glen Canyon:

- Reclamation and WAPA O&M and replacement programs may be significantly reduced or eliminated
- Funding may not be available for Reclamation non-power multipurpose costs
- MOA funds may be withheld
- Funding for the salinity control program may be reduced or eliminated
- Revenue may not be available for repayment of aid to irrigation or participating projects
- Funding will not be available for experiments
- WAPA may not be able to provide replacement power for power customers
- High risk to project reliability due to potential failure of critical infrastructure

Reclamation and WAPA have meetings scheduled to discuss how to mitigate impacts from hydrology to the Basin Fund.