September 30, 2022

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

From: Glen Canyon Dam Technical Planning / Implementation Team

Re: Final Recommendation Regarding a Fall 2022 High Flow Experiment (HFE) at Glen Canyon Dam, November 2022

## I. Recommendation Summary

Based on the LTEMP Record of Decision (ROD), the Glen Canyon Dam technical implementation/planning team (PI Team) has worked over the past several weeks to evaluate existing information and data in determining this recommendation regarding a HFE at Glen Canyon Dam. The PI Team's recommendation regarding implementation of a fall 2022 HFE is based on a careful assessment of resources and best available science.

**By consensus, the PI Team does not recommend that the Department implement any duration of HFE in fall 2022.**

*Purpose of the Recommendation Memo*

The purpose of this memorandum is to transmit a recommendation to the Glen Canyon Leadership Team (Leadership Team) and to the Department of Interior (Department) in accordance with the LTEMP ROD. The PI 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).

As noted above, the PI Team has worked over the past several weeks to evaluate existing data and coordinate the potential implementation of an HFE. The PI Team evaluated the latest data from agency experts and considered multiple issues in making its recommendation, as summarized below. The PI Team arrived at this recommendation after several weeks of PI Team conference calls and after receiving feedback from Adaptive Management Program stakeholders. The Secretary of the Interior and/or her Designee will consider the recommendation of the PI Team but retains sole discretion to decide how best to accomplish operations and experiments in any given year pursuant to the LTEMP ROD and other binding obligations for Glen Canyon Dam. The PI Team incorporated the most current science and data and considered multiple issues with agency experts, as summarized below, in making this final recommendation.

*24-hour, 48-hr, 96-hour, 144-hour, and 192-hour Fall HFE*

The PI Team arrived at this recommendation after several weeks of PI Team conference calls, and after receiving feedback from Adaptive Management Program stakeholders. **By consensus,**

**the PI Team is opposed to implementation of any duration (24-hour to 192-hour) HFE in fall 2022.** The PI Team identified the following resource concerns associated with any duration of a fall HFE: 1) the increased risks to non-native fish, including the potential to transport juvenile smallmouth bass downstream; 2) challenges and risks associated with reallocating large volumes of water for longer duration HFEs; uncertainties and risks associated with exacerbating low reservoir elevations (e.g. lower annual minimum and risk of falling below minimum power pool); 3) impacts to hydropower production; and 4) increased risk of fish entrainment at lower reservoir elevations.

They also noted that in LTEMP, fall HFEs were predicted to be conducted frequently (~3 out of every 4 years) and it has been four years since the most recent HFE (fall 2018) was triggered and implemented, such that this HFE would rebuild some of the beaches that were lost during this time. GMCRC noted that sandbar benefits from even a 24-hour HFE would likely provide a good learning opportunity and likely have some measure of sediment benefits. It was noted that maintaining camping beaches is important for the LTEMP sediment resource goal. Also noted is the potential for improved legacy of sandbar increases resulting from a fall HFE (predicted +20% sandbar size in April 2022 relative to October 2021) due to relatively low winter flows consistent with the 7.0 maf annual release pattern planned for Lake Powell in Water Year (WY) 2023. The GCMRC highlighted the learning value of implementing an HFE in November 2022 in that it would contribute to addressing, 1) the long-term question about the cumulative effect of multiple HFEs over the 20-year period of the LTEMP, and 2) questions about the effects of shorter duration and lower magnitude HFEs. Although the best available science indicates a fall HFE could result in some unknown level of increased to undesired non-native species (smallmouth bass and green sunfish), the consequences to humpback chub of dispersing new young-of-year non-native smallmouth bass is very high. Thus, expert opinion among fishery biologists was that even a 24-hour fall HFE could substantively increase the risk to endangered and native fishes in Grand Canyon.

*Scope of Assessment*

Flow Experiments at Glen Canyon Dam are an important feature of the LTEMP ROD that will help determine specific dam operations that could be implemented to improve conditions, continue to meet the Grand Canyon Protection Act's (GCPA) requirements, and to minimize adverse impacts on the downstream natural, recreational, and cultural resources. Per the LTEMP ROD, the PI Team is charged with seeking a consensus technical recommendation regarding the assessment of resources at and below Glen Canyon Dam (see Section III for list of resources). Water management activities occurring elsewhere within the Colorado River Basin (Basin) may be relevant to the Department's decision of whether to implement flow experiments but are being addressed separately outside the scope of this technical assessment. For example, water managers, including many PI Team members, are concurrently working to evaluate the potential effects of drought on water resources throughout the Basin, including evaluations of options to minimize the risk of Lake Powell falling below the "Target Elevation" of 3,525 ft. under the Drought Response Operations Agreement. The LTEMP process for evaluating potential flow experiments requires assessment of the effects on resources and provides an offramp in the event of unacceptable adverse impacts. If implemented, flow experiments cannot change the annual release volume from Glen Canyon Dam. The PI Team appreciates the opportunity to provide this report and anticipates that the Leadership Team may wish to address considerations that were outside of the scope of this technical assessment.

## II. Introduction

The purpose of HFEs conducted in the context of the LTEMP ROD is to determine if sandbar building during HFEs exceeds sandbar erosion during periods between HFEs, such that sandbar size can be increased or maintained over the 20-year period of the LTEMP. This study supports the LTEMP Resource Goal for the sediment resource to "Increase and retain fine sediment volume, area, and distribution in the Glen, Marble, and Grand Canyon reaches above the elevation of the average base flow for ecological, cultural, and recreational purposes" (Department of Interior (DOI) 2016b). It also supports several other LTEMP goals such as recreation, riparian habitat, and archaeological resources that depend on river sand bars to support and sustain desired resource conditions. Table 4 in Appendix B of the LTEMP ROD summarizes implementation criteria for LTEMP experiments, and an excerpt of the criteria for fall HFEs is provided below (**Table 1**).

**Table 1. LTEMP Implementation Criteria for Fall High Flow Experiments.**

| Experimental Treatment | Trigger[a] and Primary Objective | Replicates | Duration | Annual Implementation Considerations[b] | Long-Term Off-Ramp Conditions[c] | Action if Successful |
|---|---|---|---|---|---|---|
| ***Sediment-Related Experiments (Cont.)*** | | | | | | |
| Fall HFE ≤96 hr up to 45,000 cfs in Oct. or Nov. | Trigger: Sufficient Paria River sediment input in fall accounting period (Jul.–Nov.) to achieve a positive sand mass balance in Marble Canyon with implementation of an HFE<br>Objective: Rebuild sandbars | Implement in each year triggered, dependent on resource condition and response | ≤96 hr | Potential short-term unacceptable impacts on resources listed in Section 1.3; unacceptable cumulative effects of sequential HFEs | This type of fall HFE is not effective in building sandbars; or long-term unacceptable adverse impacts on the resources listed in Section 1.3 are observed | Implement as adaptive treatment when triggered and existing resource conditions allow |
| Fall HFEs longer than 96-hr duration up to 45,000 cfs in Oct. or Nov. | Trigger: Sufficient Paria River sediment input in fall accounting period (Jul.–Nov.) to achieve a positive sand mass balance in Marble Canyon with implementation of an HFE longer than a 96-hr, up to 45,000-cfs flow<br>Objective: Rebuild sandbars | Implement in each year triggered; limited to total of four tests in LTEMP period | Up to 250 hr depending on availability of sand duration of first test not to exceed 192 hr | Potential short-term unacceptable impacts on resources listed in Section 1.3; unacceptable cumulative effects of sequential HFEs | Extended-duration fall HFEs are not effective in building sandbars; resulting sandbars are no bigger than those created by shorter-duration HFEs; or long-term unacceptable adverse impacts on the resources listed in Section 1.3 are observed | Implement as adaptive treatment when triggered and existing resource conditions allow |

a Triggers will be modified as needed during the 20-year LTEMP period in an adaptive manner through processes including ESA consultation and based on the best available science utilizing the experimental framework for each alternative.

b Annual determination by the DOI. Any implementation will consider resource condition assessments and resource concerns using the annual processes described in Sections 1.3 and 1.4.

c Suspension of experiment if the DOI determines effects cannot be mitigated.

Source: LTEMP ROD (DOI 2016b), Appendix B, Table 4 – Implementation Criteria for Experimental Treatments of Alternative D

To date, five HFEs have been conducted under sand-enriched conditions since the HFE Protocol was initiated in 2012. Those HFEs occurred in November each year in 2012, 2013, 2014, 2016, and 2018. In each case, sandbar building results were consistent with the results from previous HFEs (Grams 2019). All HFEs resulted in substantial deposition at all sandbar types (see Mueller et al. 2018 for description of sandbar types), with some evidence of cumulative gains in sandbar volume over multiple HFEs. While observations demonstrate that HFEs benefit campsites and cause temporary increases in campsite area, vegetation encroachment continues to cause progressive declines in campsite areas at some locations.

## III. LTEMP Process for Implementing Experiments

The LTEMP ROD provides the framework for implementing flow-based experiments at Glen Canyon Dam when resource conditions warrant. The purpose of LTEMP experiments is to learn, through adaptive management, how to better protect, mitigate adverse effects to, and improve resources downstream of Glen Canyon Dam, while complying with relevant laws. Ongoing research and monitoring through the Glen Canyon Dam Adaptive Management Program ensures the best science and data are available for making decisions related to flow experiments.

Under the LTEMP, the Department may conduct flow-based experiments (HFEs, Bug Flows, Trout Management Flows, and Low Summer Flows) at Glen Canyon Dam when resource conditions warrant and if it is determined that there will not be unacceptable adverse impacts on other resources.

> *Prior to implementation of any experiment, the relative effects of the experiment on the following resource areas will be evaluated and considered: (1) water quality and water delivery, (2) humpback chub, (3) sediment, (4) riparian ecosystems, (5) historic properties and traditional cultural properties, (6) Tribal concerns, (7) hydropower production and WAPA's assessment of the status of the Basin Fund, (8) the rainbow trout fishery, (9) recreation, and (10) other resources.*
>
> --P. B-8, Implementation Process for Experiments Under Alternative D (DOI 2016b)

The process for recommending experiments under the LTEMP, which has been used for past experiments and has been followed here, involves outreach to Glen Canyon Dam Adaptive Management Program (GCDAMP) partners through regular meetings and additional notification to Tribes inviting consultation. The process also involves coordination with the PI Team to plan for the possible experiment, evaluate the status of resources, and make the technical recommendation of whether to conduct an experiment. The PI Team presents its recommendation to the Leadership Team, which makes a recommendation to The Department. The Secretary's Designee to the Adaptive Management Work Group (AMWG) is the chair of the Leadership Team and may make the decision for the Department regarding the experiment, as delegated by the Secretary of the Interior.

### *LTEMP HFE Protocol*

As described in the LTEMP ROD, HFEs are experimental in nature and are designed to achieve a better understanding of whether, how, and when to incorporate high releases into future dam operations in a manner that maintains or improves beaches, sandbars, and associated habitat. The LTEMP HFE Protocol establishes a decision-making framework consisting of three components: (1) planning and budgeting, (2) modeling, and (3) decision and implementation.

Under the LTEMP, HFE releases are restricted to limited periods of the year when the highest volumes of sediment are most likely available for building sandbars. Sediment-triggered HFEs may be implemented in spring (March or April) or fall (October or November; **Figure *1***). Fall extended-duration HFEs range from greater than 96 hr to 250 hr. Spring and fall HFEs that are not extended-duration range from less than 1 hr to 96 hr. Proactive HFEs may be implemented in spring or early summer (April, May or June), and have a duration range up to 24 hr. HFE magnitudes range from 31,500 cfs to 45,000 cfs. The frequency of HFEs is determined by tributary sediment inputs, annual release volumes, resource conditions, and decision of the Department. Extended-duration fall HFEs are limited to a frequency of 4 times total in the 20-year LTEMP period. As of September 2022, no extended-duration HFEs have been implemented under LTEMP.

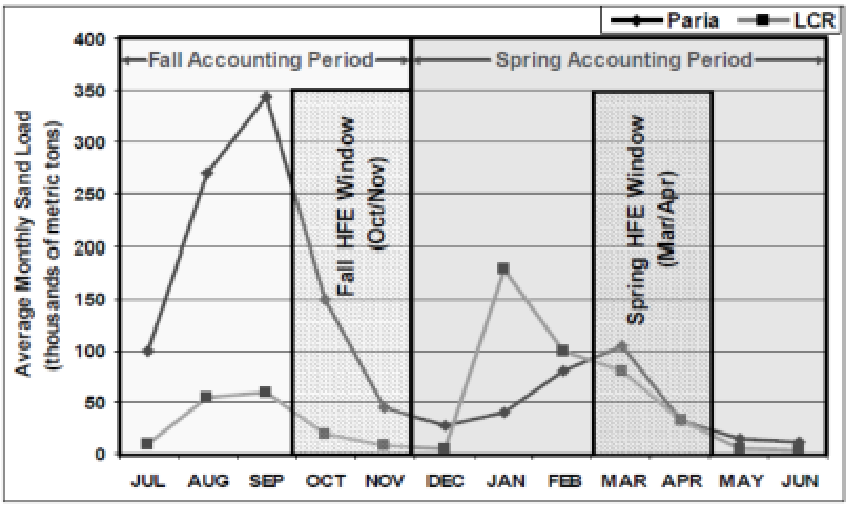


**Figure 1. Average monthly sand load from the Paria River (1923-2010) and Little Colorado River (1987-2010) showing the fall and spring HFE accounting periods and implementation windows (DOI 2016a).**

*HFE Sand Budget Model*

The LTEMP HFE Protocol uses predictive models to make recommendations for the magnitude and duration of potential HFEs using real-time measurements and models of sand inflow from the Paria River and forecasted hydrologic data to determine whether suitable sediment and hydrology conditions exist for a high-flow experimental release.

A sand transport/budget model (Wright et al. 2010) was used to predict the mass of sand that would be transported by an HFE and to estimate if a potential HFE would transport more or less sand than had been delivered from the Paria River to the Colorado River during the fall accounting period (July 1 to November 30). Only HFE durations that resulted in a “positive sand balance” were considered. Output of the modeling runs provides the initial recommendation for the magnitude and duration of the HFE. However, because modeling only considers a simple range of possible HFE peak magnitudes and durations, the HFE Protocol includes a review of the model output that may modify the recommended HFE to benefit relevant resources.

In addition to reviewing the sand budget model output, the PI Team assessed the status of the LTEMP resources and the potential effect of an HFE on these resources in making the recommendation described here.

## IV. Hydrograph Alternatives

### *HFE Sand Budget Model Results*

Throughout the summer and fall, and in accordance with the HFE Protocol, Reclamation and GCMRC regularly updated the modeling estimates based on cumulative sediment inputs to determine the largest HFE that resulted in a positive sand balance in Marble Canyon. The modeled HFE shape was based on past years' input from scientists at GCMRC and designed to meet the twin objectives of providing the greatest resource benefit and developing scientific information that will help better inform future decision making. Hydrology inputs were provided as hourly Glen Canyon Dam releases (historic and future) for the accounting period (July 1 – November 30). To drive the sediment routing model, observed discharges at the river mile (RM) 30, 61 and 87 gages were used for the period up to August 31, 2022, and modeled discharges based on the Colorado Flow River and Stage (CRFS) model were used for the period of September 1 through November 30, 2022, using the historic and projected Glen Canyon Dam releases.

The September 21, 2022 model results predicted there was sufficient sediment for implementation of a 192-hr extended duration HFE (**Figure 2**). The final Paria cumulative sand load estimates as of the September 28, 2022 model run were 793,000 and 1,177,000 metric tons, for the lower and upper bounds, respectively. This model run used the conservative lower bound estimate for Paria River sand input and estimated 114,000 metric tons would remain within Marble Canyon on November 30, 2022 following a 192-hour extended duration HFE and at the end of the accounting period.

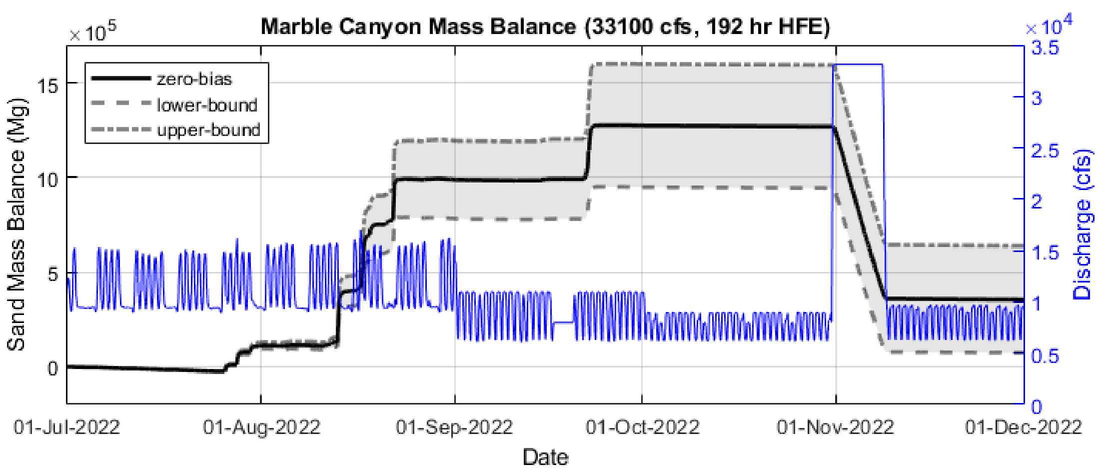


**Figure 2. Sand Budget Model Results for Fall 2022 Accounting Window, 192-hour HFE. Analysis was performed on hydrology and hydropower impacts up to a 144-hour HFE, as a 192-hour was not triggered until the end of the deliberation process.**

### *Hydrograph Alternatives*

In response to resource impact concerns and increased risk of dropping Lake Powell elevations by using water from later months (***Figure 3***), the PI Team focused consideration on two hydrograph alternatives (24-hour and 48-hour) that had potential to reduce negative impacts to the annual low in the 24-month study analysis while still meeting objectives for sediment benefits and learning (**Figure 4**). Particular focus was given to the 24-hour option, with increased analysis provided below. These shorter duration alternatives reduced the number of hours of the experiment while still using the full magnitude of releases available (**Table *2***).

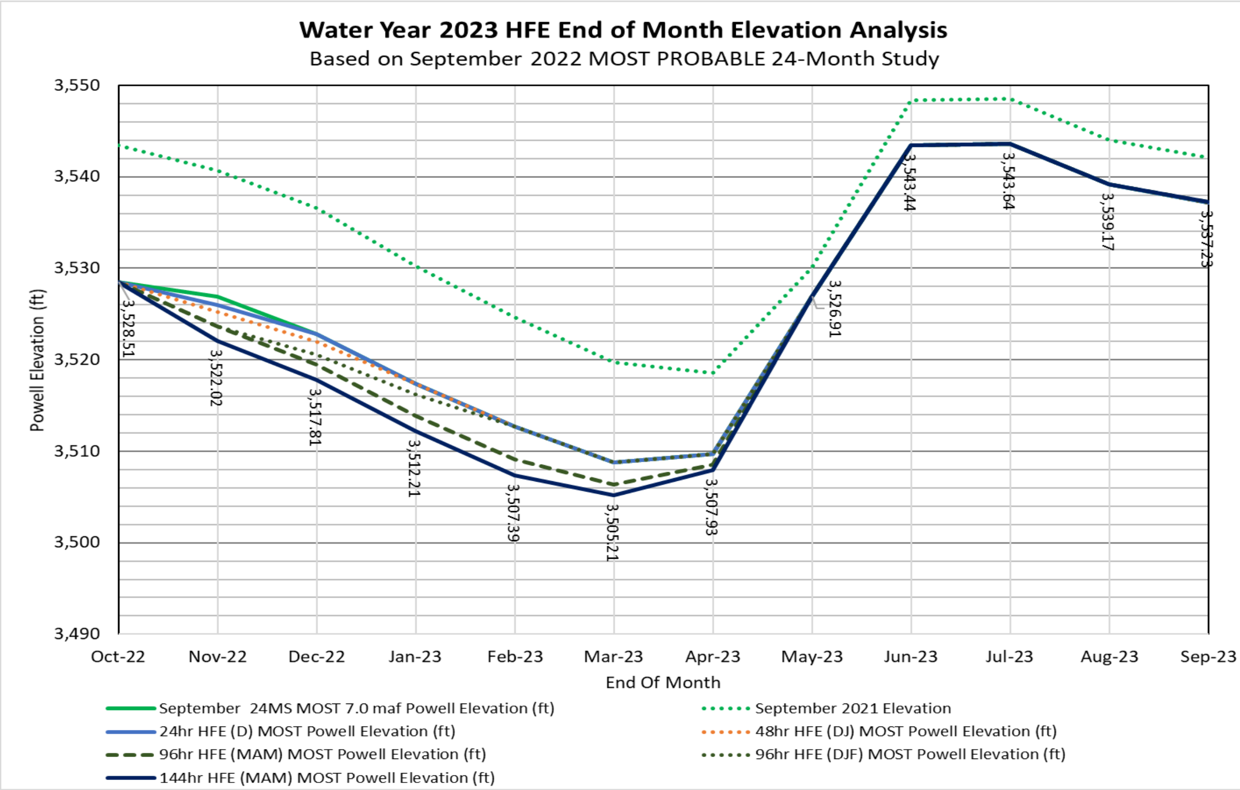


**Figure 3. Water Year 2023 HFE end of month elevation analysis for 24hr, 48hr, 96hr, and 144hr HFEs with the associated months in which reallocations would occur. Reallocations are denoted by month: D = December; MAM = March, April, and May; DJ = December and January; and DJF = December, January, and February.**

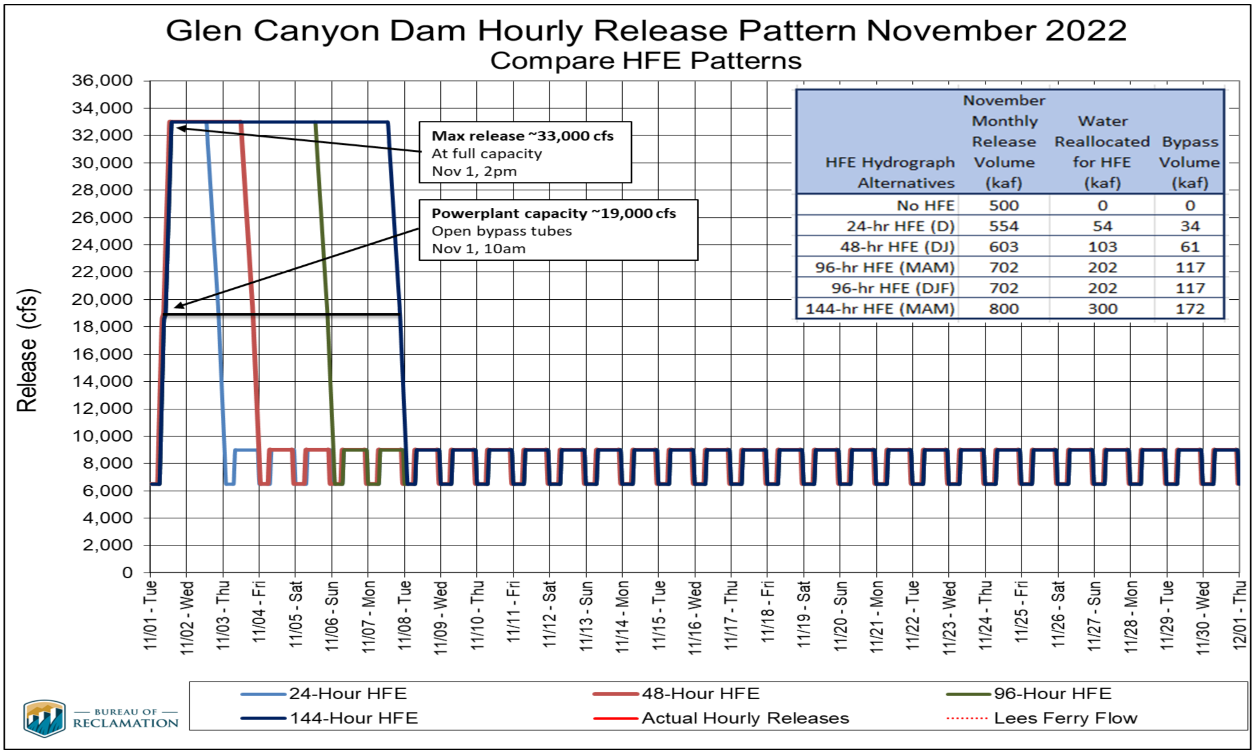


**Figure 4. November 2022 Schedule of Releases for Alternative Fall HFE Hydrographs**

**Table 2. Summary of Water Releases, Pool Elevation, and Basin Fund Impacts for Alternative Fall HFE Hydrographs. Analysis was not performed for hydrological impacts to certain reallocation options, noted below. The 192-hour HFE option was not analyzed since it was triggered during the last day of technical team deliberations.**

| Fall HFE Hydrograph Alternatives | Water Release | | Power Generation | Pool Elevation[2] | | Relative Impact to Basin Fund |
|---|---|---|---|---|---|---|
| | November Total Release Volume (kaf) | Bypass Volume (kaf) | MWh Reduction Bypass+ | End of November Elevation (ft) | WY 2023 Minimum (ft) Difference from No Action | |
| **No HFE** | 500 | 0 | NA | 3526.88 | 0 | $0 |
| **24-hr HFE (D)[3]** | 554 | 34 | -12,872 | 3526.01 | 3508.81 (0.0) | $1.10M |
| **24-hr HFE (AM)** | 554 | 34 | -14,492 | *Not analyzed* | *Not analyzed* | $0.56M |
| **48-hr HFE (MAM)[3]** | 603 | 61 | -26,120 | *Not analyzed* | *Not analyzed* | $1.12M |
| **48-hr HFE (DJ)[3]** | 603 | 61 | -23,824 | 3525.22 | 3,508.82 (0.01) | $2.19M |
| **96-hr HFE (MAM)** | 702 | 117 | -50,416 | 3523.63 | 3506.40 (2.41) | $2.14M |
| **96-hr HFE (DJF)** | 702 | 117 | -45,956 | 3523.63 | 3508.82 (0.01) | $4.13M |
| **144-hr HFE (MAM)** | 800 | 172 | -74,490 | 3522.02 | 3505.21 (3.60) | $3.18M |
| **144-hr HFE (DJF)** | 800 | 172 | -67,825 | *Not analyzed* | *Not analyzed* | $6.13M |

1 – Peak capacity for all alternatives is 33,000 cfs.
2 – Assumes most probable hydrology as indicated in the September 2022 24 Month Study.

3 – Refers to the months in which less water would be released in order to balance a November HFE: December (D), December and January (DC), March, April, May (MAM) or December, January, February (DJF).

*Experimental Design and Description – 24-Hour Duration*

Potential 24-hour HFE Hydrograph (**Figure *5***):

- Ramp-up from base releases at 4,000 cfs/hr at approximately 7:00 am on Tuesday, November 1, 2022 (all times Mountain Standard Time) until reaching powerplant capacity (~19,000 cfs)
- Open first bypass tube at 10:00 am on November 1
- Ramp-up from powerplant capacity to full bypass (~33,000 cfs) at one full bypass tube (~3,500 cfs) per hour in 4 hrs
- Stay at peak release (~33,000 cfs) for 24 hrs
- Ramp-down from peak release to base releases at beginning at half bypass of 1,750 cfs/hr until reaching powerplant capacity and then decreasing at 2,500 cfs/hr

These recommendations result in the following release schedule at Glen Canyon Dam (also, **Figure *5***):

- Begin ramp-up from 6,500 cfs at 7:00 am on November 1 (Tuesday)
- Reach powerplant capacity at approximately 10:00 am on November 1
- Open bypass tubes at approximately 10:00 am on November 1
- Reach full bypass at 2:00 pm on November 1
- Begin ramp-down from bypass at 2 pm on November 2 (Wednesday)
- Complete HFE (back to 9,000 cfs) at 2 am on November 3 (Thursday)

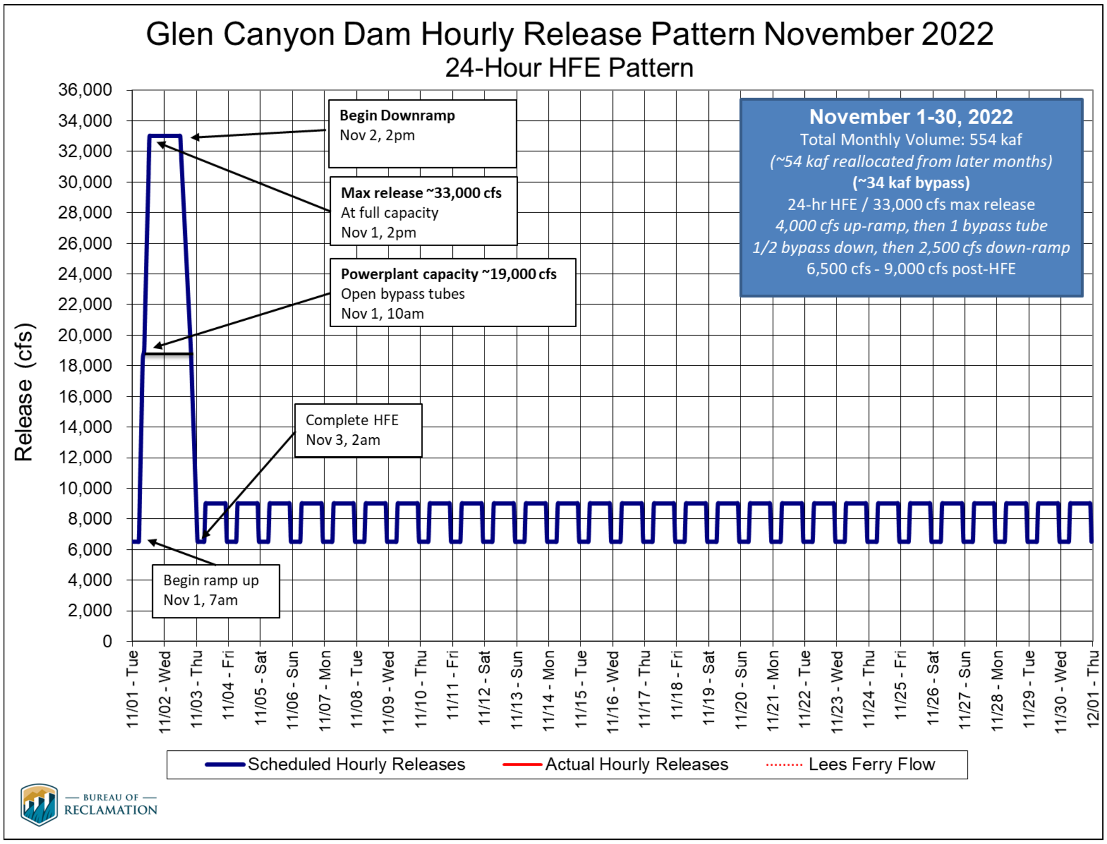


**Figure 5. November 2022 Glen Canyon Dam hourly releases for potential 24-hr HFE.**

## I. Monitoring Plan

GCMRC developed a science plan for the LTEMP that describes a program of monitoring and research activities that support ongoing information needs associated with implementation of the LTEMP and associated experiments like HFEs (Vanderkooi et al. 2017). This approach relies on water quality, sediment, aquatic biology, and other resource monitoring and research projects funded in the GCDAMP Fiscal Year (FY) 2021-2023 Triennial Budget and Work Plan (2020). Additional monitoring by Northern Arizona University was discussed by the PI Team and may warrant more discussion in future PI Team deliberations. These projects will inform the effect of future HFEs on the downstream resources of Glen, Marble, and Grand Canyons. Projects from the TWP specific to monitoring HFEs are further discussed below.

Project A, *Streamflow, Water Quality, and Sediment Transport and Budgeting* in the Colorado River Ecosystem, and Project B, *Sandbar and Sediment Storage Monitoring and Research*, are essential components to implementation of the HFE Protocol under LTEMP because the protocol calls for high flow releases from Glen Canyon Dam whenever a specified minimum amount of fine sediment delivered from the Paria River is exceeded. Under Project A, the measurements needed to trigger HFEs are collected. Project B supports the direct measurements of the volume of fine sediment, especially sand, that is stored on the bed of the Colorado River, in its eddies, or at higher elevation along the river's banks; these measurements allow assessment of the effectiveness of the HFE Protocol. A substantial accomplishment of these programs in previous work plans was the development of web-based interfaces to serve sediment transport and water quality data, calculate fine sediment mass balances (see https://www.gcmrc.gov/discharge_qw_sediment/), and to serve photographs of approximately 50 sandbars located from Lees Ferry to Diamond Creek (see https://www.usgs.gov/apps/sandbar/). The latter data allow stakeholders to evaluate the effects of controlled floods implemented under the HFE Protocol.

As described in the HFE Protocol EA (DOI 2011) and the LTEMP FEIS (DOI 2016a), the potential HFE planned for fall 2022 would not be an isolated event, but a component of a longer-term experiment to restore and maintain sandbars with multiple high flows over a period of several years. The monitoring data that are needed to assess the outcome of this multi-year experiment include annual sandbar monitoring at selected long-term monitoring sites, periodic monitoring of changes in sand storage in the river channel, and measurements of sandbar size at more than 1,000 sites based on aerial photographs that are collected periodically. These activities are described in detail in the TWP (DOI 2020). It is also important, however, to evaluate the sandbar building response of each high flow to assess whether the sandbar building objectives are being achieved incrementally. This evaluation will be based on sites that are monitored by remotely deployed digital cameras and repeat topographic surveys of sites that will occur in fall 2022.

GCMRC scientists have installed digital cameras that capture 5 images every day at 43 sandbar monitoring sites throughout Marble and Grand Canyons between Lees Ferry and Diamond Creek. The images acquired by these cameras will be used to evaluate both the magnitude and spatial distribution of sandbar building caused by the HFE (Grams et al. 2018). They will also be used to assess the rate of post-HFE sandbar erosion. Because the remote cameras are monitoring the same sites that are monitored by the annual surveys and the same sites that were monitored during the previous high flows, it will be possible to evaluate sandbar-building effectiveness of the planned HFE relative to the previous HFEs.

Project D will continue monitoring for changes in sediment storage in dunefields covering archaeological sites. An HFE has not occurred since the NPS LTEMP vegetation management project was implemented to open up sandbar campsites and increase aeolian transport to archaeological sites. Thus, we have data for scenarios 1-3 but not #4 below:

- 1) Year(s) without vegetation removal and without HFE,
- 2) Year(s) without vegetation removal but with HFE,
- 3) Year(s) with vegetation removal but without HFE,
- 4) Year with vegetation removal and HFE.

An HFE implemented in 2022 would provide GCMRC and NPS the opportunity under their collaborative LTEMP vegetation management project to address a critical uncertainty (i.e., scenario #4 above) about the potential combined effects of HFEs and riparian vegetation management.

GCMRC will also collect data on water quality (including nutrients), native and nonnative fishes, aquatic invertebrates, riparian plants, and other resources, as described in the TWP (DOI 2020). Project N, *Hydropower Monitoring and Research*, is focused on conducting monitoring and research of proposed experiments in the LTEMP ROD and considers impacts on hydropower and energy as part of the experimental design. 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 fall HFE.

GCMRC will also collect additional data in support of project O.2, which is a study of channel response to flow pulses in the western Grand Canyon. The HFE will provide the opportunity to measure bed response to a larger (~33,000 cfs) HFE than was measured in the 2021 spring disturbance flow. The required data are repeat measurements of channel bathymetry and bank topography for 3-kilometer long study reach. The objectives and budget are described in Project B.6.5 in the GCDAMP FY 2021-2023 TWP.

## II. Assessment of Resources

In coordination with the GCMRC, the PI Team completed an assessment of key resources that may be impacted or affected by an HFE. This assessment is based on the current condition of resources and on findings and observations from fall HFEs conducted in 2012, 2013, 2014, 2016, and 2018. Key resources were evaluated relative to the timing, duration, and magnitude of the potential fall 2022 HFE using the best available science: November 1, 2022 start date, 24-hour to 144-hr duration, and 33,000 cfs peak magnitude. This section summarizes the assessment of resources and expected effects of the potential HFE.

*Archaeological and Cultural Resources*

Reclamation and NPS (DOI 2016b) determined that HFEs, as identified in the LTEMP, could, through multiple experiments, potentially affect historic properties and the effect would be adverse per 36 CFR 800.5(2)(iv). The agencies also found that adverse effects to sacred sites could result from the HFEs, primarily from limitation of access of tribes to sacred sites during the period of HFE releases. Reclamation, as lead federal agency for National Historic Preservation Act section 106 compliance, completed the LTEMP Programmatic Agreement (PA; Reclamation 2017) with affected tribes and other parties to address these potential effects. Effects of HFEs to cultural resources are primarily from erosion and redistribution of sediment. Inundation can adversely affect sites through erosion, but deposition may help protect sites by providing sources of sand that can bury historic properties via aeolian transport (DOI 2011, DOI 2016b, East et al. 2016). HFEs also may affect access of tribes to historic properties and alter visitation patterns to historic properties (Reclamation 2011, DOI 2016b).

The PA incorporates, by reference and specified in Appendix D, a commitment to the stipulations identified in previous compliance agreements, most notably the Memorandum of Agreement for the 2012 High Flow Experiment. Reclamation, as lead federal agency, notified Tribes and consulting parties on September 27, 2022 identifying the potential for a fall HFE in 2022, in conformance with the stipulations in the PA (and previous MOA).

GCMRC monitoring has shown that HFEs have eroded terraces that contain archaeological sites in Glen Canyon National Recreation Area (GLCA; East et al. 2016). HFEs also rebuild or maintain sandbars that provide sand to resupply aeolian dunefields containing archaeological sites throughout Marble and Grand Canyons (Sankey et al. 2018). Aeolian dunefields were resupplied with sand from HFE deposits in half of the instances monitored after the 2012, 2013, 2014, and 2016 HFEs (Sankey et al. 2018). There is also evidence for cumulative sediment resupply of dunefields when annual HFEs are conducted consistently in consecutive years (Sankey et al. 2018). No adverse effects to historic properties were identified from the 2012, 2013, or 2014 HFEs. Results from monitoring following the 2016 and 2018 HFE showed that several archaeological sites have transitioned from net-erosion to net-deposition dominated topographic changes in association with the higher frequency of HFEs during the time period of the current HFE protocol. Additionally, the NPS LTEMP vegetation management project was implemented beginning in 2019 to open up sandbar campsites and increase aeolian transport to archaeological sites. An HFE has not occurred since the vegetation management experiments were implemented. Thus, questions about the potential combined effects of HFEs and riparian vegetation management for sand storage in aeolian dunefields covering archaeological sites have not yet been addressed. **A fall HFE in 2022 would not pose risks to archaeological and cultural resources.**

*Natural Processes (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, flood 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. In fact, 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.

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 Glen Canyon Dam 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, Glen Canyon Dam also changed other aspects of the physical template, particularly temperature, sediment, and nutrient regimes (Dibble et al. 2021, Topping et al. 2000, Yackulic et al. 2018). These changes to the physical template 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. 2021).

The LTEMP seeks to enhance key resources through experimentation and management of both flow and non-flow actions. High Flow Experiments are the principal type of flow disturbance evaluated as part of LTEMP. Because the annual snowmelt flood of the Colorado River was in spring and early summer, it has long been hypothesized that spring HFEs would be more likely to benefit natural processes of the river compared to fall HFEs (Kennedy and Ralston 2011). Consistent with these predictions, monitoring of fall HFEs in 2012, 2013, 2014, 2016, and 2018 indicate these flow disturbances have neutral-to-negative effects on algae production, aquatic insect abundance and diversity, and other natural processes (Kennedy and Muehlbauer 2019). Unfortunately, these tools for monitoring natural processes were not in place in 2008 the last time a spring HFE was tested, so the role of spring HFEs in enhancing natural processes remains unclear. Nonetheless, monitoring of natural processes occurred in March 2021 during the spring disturbance flow test at Glen Canyon Dam, and future analysis of these monitoring data may help shed light on whether flow disturbance in spring benefits natural processes. **A 2022 fall HFE would not pose risks to natural processes.**

*Humpback chub*

The adult humpback chub population in the Little Colorado River aggregation is currently above the Tier-1 threshold of 9,000 adults identified in the Biological Opinion for the LTEMP (GCMRC unpublished data, FWS unpublished data). Past HFEs have had no measurable direct effects, positive or negative, on humpback chub or other native fish. Their 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, GCMRC unpublished data). However, populations are now declining in the Little Colorado River aggregation and are expected to continue to decline over the next few years. The three-year average (2018-2020) of large sub-adult humpback chub in the Colorado River mainstem from river mile 63.45 to 65.2 (juvenile chub monitoring reach) was estimated at 600 fish, which is below the 810 fish required to prevent initiation of a Tier 1 fish management action trigger. Fish biologists are working to identify factors that may have led to poor recruitment, assess the current outlook for humpback chub populations in the Grand Canyon, and evaluate early intervention actions that can be taken to reverse the decline.

HFEs may indirectly affect humpback chub through increased risk of dispersal of warmwater nonnative fish which inhabit Lees Ferry, such as smallmouth bass, which are discussed below. Based on provisional unpublished data, humpback chub were not directly affected by the 2012, 2013, 2014, 2016, or 2018 HFEs, with adult populations appearing stable over the period of these HFEs and juvenile populations fluctuating in response to variable recruitment in the Little Colorado River. **A fall 2022 HFE poses unacceptable risks to humpback chub because of the increased risk of distributing smallmouth bass downstream.**

*Hydropower and Energy*

WAPA has firm electric power contracts and is required to continue to meet these contract obligations either with generation from Colorado River Storage Project powerplants or from purchases from the wholesale electrical market. Low-volume releases from Glen Canyon Dam both pre- and post-HFE requires extra electrical purchases to meet WAPA's contract obligations. Conversely, during the HFE, high volume releases from Glen Canyon Dam requires the energy be sold to the open market, and bypass flows result in the reduction of total hydropower produced. WAPA estimated the financial cost of implementing a 2022 fall HFE is between $0.56 million and $6.13 million, depending on duration and which months water is moved from to provide volume for the HFE (***Table 2***). For comparison with past HFEs, WAPA determined the costs at $1.1 million for 2012, $2.6 million for 2013, $2.1 million for 2014, $1.2 million for 2016, and $1.3 million for 2018. Total loss in energy production due to bypass flows and losses in efficiency range from -12,872 MWh to -74,490 MWh depending on the flow duration and month of water exchanges.

Water releases from Glen Canyon Dam during the HFE may be affected by disturbances of the electrical system. Responses to these disturbances are required by Reclamation and WAPA under law, contracts, and other agreements. Regulation and contingency reserves are the two types of assistance provided by the Colorado River Storage Project (CRSP) system for electrical disturbances, and both are managed by WAPA's Western Area Colorado-Missouri (WACM) Balancing Authority. Regulation is used to respond to frequency deviations on the electrical system. Glen Canyon Dam is the only CRSP powerplant capable of the immediate responses required for regulation which can increase or decrease releases by as much as ±1,300 cfs (40 megawatts (mw). However, WAPA could move contingency reserves to an alternate CRSP unit for a fall 2022 HFE after determining this will not likely result in additional cost.

WAPA estimates that the balance of the Upper Colorado River Basin Fund (Basin Fund) will be approximately $115 million at the end of fiscal year 2022. This increase from last year is the result of temporary mitigation efforts including Reclamation's use of miscellaneous receipts and carryover funds ($34 million), appropriations received by Reclamation to fund the environmental programs ($21.4 million), utilization of funds from the Bipartisan Infrastructure Law (BIL) ($29.8 million), and deferrals of O&M expenses and capital projects. WAPA also implemented a new rate, which increased the rate of energy and also significantly reduced the amount of hydropower being delivered to CRSP customers. This action mitigated $98 million of purchase power O&M expense in FY22. Many of these mitigation efforts will not be available to WAPA in the future. As a result, WAPA projects significant reductions in the Basin Fund balance over the next two years. The project is facing reduced reservoir levels (hydraulic head), low annual releases from Glen Canyon Dam (7.0 maf in WY 2023) and has further concerns about the risk of going below minimum power pool at Glen Canyon Dam.

If an HFE is conducted, WAPA will determine the cost of the HFE utilizing the same methods as has been done in the past, and will account for them as a constructive return. Given the extraordinary measures taking place to maintain the Basin Fund by deferring millions of dollars in expenditures, and with the new rate substantially reducing hydropower deliveries to customers, WAPA is very concerned with actions that would further exacerbate the Basin Fund balance with actions that use bypass when customers' energy deliveries have been reduced. **Multiple PI Team members cited the current status of the Basin Fund and the hydropower resource as cause for concern regarding implementation of a Fall 2022 HFE without considerable risk of adverse impacts and exacerbation of the system.**

*Other Native Fishes*

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 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 (AGFD 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 and 2021 (Kegerries et al. 2021, S. Platania, ASIR, Inc., personal communication).

Regardless of declines in observed larvae, changes in flows due to a fall HFE are unlikely to have a substantial effect to razorback suckers, since life stages that might be sensitive to higher flows (e.g., spawning adults, larval fish) are not present in the fall months. 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).

Rainbow trout in Marble Canyon may benefit from a fall HFE through reduced turbidity after the HFE and enhanced growth and survival (Korman et al. 2021), which could lead to indirect effects on native fishes, this through predation. In addition, if an HFE led to dispersal of smallmouth bass, it could then lead to indirect impacts on native fish such as humpback chub through future predation. Nonetheless, this potential indirect effect depends on factors driving turbidity that are less certain, such as additional tributary sediment inputs. **Thus, no direct unacceptable negative response would be expected among native fishes to a fall HFE this year, based on current monitoring results and previous HFEs. However, indirect effects from potential expansion of smallmouth bass create an unacceptable risk to native fish.**

*Recreational Experience*

The majority of recreational users along the river in both GLCA and Grand Canyon National Park (GRCA) access the river by boat. Upriver trips from Lees Ferry are primarily related to day use activities such as angling, motorized and non-motorized watercraft use, and camping. GLCA has seen a significant increase in non-motorized watercraft (kayaks, canoes, paddleboards) since 2019 and the commercial outfitters that use motorized watercraft to transport these boaters upstream (i.e., backhaul services) have also increased significantly during the fall months. Recreational use is now throughout the week with higher numbers on the weekends as opposed to previously. If a HFE is implemented, press, website, and social media posts as well as direct contacts with the commercial operators will need to occur to inform potential recreationists. Day use visitors also use Paria Beach for picnicking and shoreline recreation but most use in this area is during the summer and early fall, with limited use in the colder, late fall into winter months. Consequently, little to no impact to shoreline users would be anticipated from the HFE.

Both commercial and private angling trips for rainbow trout and now for brown trout under the Incentivized Harvest program also occur on all days of the week and may be increasing in early November as brown trout start appearing in and around their fall spawning beds. During the peak flow of the HFE, there would be a direct impact to fishing as it would produce flows large enough to impede fishing activity and may also affect foraging behavior of trout immediately following the HFE, reducing catch rates.

White-water boating in Grand Canyon is a year-round recreational experience, and all Grand Canyon river users with permits for use of the river during the HFE could be affected by changing flow patterns. Effects would primarily be related to safety considerations, covered in Section VII of this report. Day raft trips from Glen Canyon Dam to Lees Ferry, conducted under contract by Wilderness River Adventures (WRA), cannot operate during HFEs because flow into the Colorado River uses the bypass tubes at Glen Canyon Dam near the launch point for these trips. This commercial operator would be notified of the HFE dates and may be closing their limited 2022 operations around the time of the HFE.

Impacts to recreational experiences associated with the HFE would be both short- and long term in GRCA. Although the HFE is proposed to take place when only non-commercial launches are permitted, there be commercial rowing trips on the water from launches during the two weeks prior to the HFE. Some private trips may choose to cancel rather than be on the water during the high flows. Both commercial and private trips may alter their itineraries to avoid rafting if they are near rapids, which become more dangerous at high flows. The stage elevation changes (5 – 10 feet (ft) depending on the camp, per Magirl's models) at the start and end of the flows may create problems in camp and make some campable areas unusable. Medium- to long term impacts to recreational experience would be expected to be minimal as flows of this magnitude are unlikely to alter the rapids. **The HFE should benefit recreational users through improvements to campable area and vegetation reduction in the near shore habitat.**

*Sediment*

During the period between the last HFE in November 2018 and July 1, 2022, roughly 1 million metric tons of sand have accumulated in Marble and Grand canyons. Large magnitudes of sand deposition occurred in Upper Marble Canyon, Lower Marble Canyon, and West-Central Grand Canyon, with sand eroded from Eastern Grand Canyon and East-Central Grand Canyon. The changes in sand mass were as follows: Upper Marble Canyon (RM 0–30) +660,000 ±370,000 metric tons; Lower Marble Canyon (RM 30-61) +380,000 ±170,000 metric tons; Eastern Grand Canyon (RM 61–87) -120,000 ±360,000 metric tons; East-Central Grand Canyon (RM 87–166) -290,000 ±370,000 metric tons; West-Central Grand Canyon (RM 166–225) +400,000 ±300,000 metric tons. Importantly, whereas the sand eroded from Eastern Grand Canyon and East-Central Grand Canyon likely came, in part, from high-elevation sandbars, the sand that was deposited in Upper Marble Canyon, Lower Marble Canyon, and West-Central Grand Canyon was deposited at lower elevations in the channel and eddies but not in high elevation sandbars. Sandbar monitoring data collected in October 2021 show erosion of sandbars since the fall 2018 HFE caused both by normal dam operations and extensive gully erosion at many sandbars in Marble Canyon and Grand Canyon caused by thunderstorms in summer 2021. Additional gully erosion has occurred in the summer 2022 monsoon season.

See discussion in Section IV for current sediment conditions relative to the HFE Protocol. Five HFEs have been conducted under sand-enriched conditions since the HFE Protocol was initiated in 2012. Those HFEs occurred in November of 2012, 2013, 2014, 2016, and 2018. In each case, sandbar building results were consistent with the results from previous sand-enriched HFEs as described by Schmidt and Grams (2011). All prior HFEs resulted in substantial deposition at all sandbar types (see Mueller et al. 2018 for description of sandbar types) followed by erosion of about half the new deposits within six months. Response immediately after the 2018 HFE based on digital camera images of sandbars from Lees Ferry to Diamond Creek indicated that there was a substantial gain (deposition) for 28 sandbars (66% of sites), no substantial change for nine sandbars (22% of sites), and substantial loss (erosion) for five sandbars (12% of sites) (Grams 2019). The HFE deposits typically begin eroding immediately following each HFE and the bulk of the newly deposited sand persists for approximately six to 12 months. Annual topographic surveys of sandbars were conducted between September 30 and October 17, 2021. Data from these surveys indicate there was net increase in the size of reattachment sandbars between the beginning of the HFE protocol in 2012 and conditions in fall 2019, following the most recent HFE that occurred in November 2018. Thus, repeated HFEs under the protocol have caused some cumulative increases in the size of some sandbars. Deposition of sand during HFEs resulted in temporary increases in campsite area; however, there has been a net long-term decline in campsite area caused mostly by vegetation encroachment (Hadley et al. 2018a, Hadley et al.

2018b). All sandbar types have decreased in size between fall 2019 and fall 2021. Hillslope runoff from summer rainstorms caused substantial erosion at many sandbars during summer 2021 and summer 2022. These eroded sandbars will not rebuild without an HFE.
Sandbars provide sand to resupply dunefields via aeolian transport throughout Marble and Grand Canyons (Sankey et al. 2018). Aeolian dunefields were resupplied with sand from HFE deposits in half of the instances monitored after the 2012, 2013, 2014, and 2016 HFEs (Sankey et al. 2018). There is also evidence for cumulative effects of sediment resupply of dunefields when annual HFEs are conducted consistently in consecutive years (Sankey et al. 2018). In 2019, under the LTEMP vegetation management project, NPS began experimentally removing riparian vegetation that creates a barrier for aeolian transport of sand from sandbar campsites to dunefield archaeological sites. An HFE has not occurred since the vegetation management experiments were implemented. Thus, questions about the potential combined effects of HFEs and riparian vegetation management for sand storage in aeolian dunefields covering archaeological sites have not yet been addressed.

The aggregate sand mass-balance conditions since inception of the HFE Protocol (i.e., for the period between July 1, 2012, and September 1, 2022) for the different segments of the Colorado River in Marble Canyon (from https://www.gcmrc.gov/discharge_qw_sediment/reaches/GCDAMP) are:

- Upper Marble Canyon: +2.90 million metric tons (the range of this measurement is between -0.16 and +6.00 million metric tons)

- Lower Marble Canyon: +1.40 million metric tons (the range of this measurement is between +0.41 and +2.40 million metric tons)

Thus, there was likely more sand in the Colorado River corridor in Marble Canyon on September 1, 2022, than on July 1, 2012, when the HFE Protocol was first implemented. **The potential fall HFE does not pose risks to the sediment conditions that were not previously analyzed in the LTEMP and will benefit most sediment resources.**

*Tribal Resources*

All resources in the canyon are of importance to Tribes, thus all resources are tribal resources. As such, careful consideration of the potential effects of an HFE on all resources has been considered. In addition, the taking of life in the canyon is a serious concern expressed by Tribal partners. The potential HFE would not be expected to directly or indirectly result in increased taking of life in the canyon, either during the experiment or in the future as a result of the experiment. Consultation to tribes as Parties to the LTEMP Programmatic Agreement was offered on September 27, 2022. **The potential experiment would not be expected to cause unacceptable adverse impacts to tribal resources.**

*Rainbow Trout (Oncorhynchus mykiss) Fishery*

The NPS Comprehensive Fisheries Management Plan completed in cooperation and coordination with AGFD (NPS 2013), and the AGFD 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, and overall abundance has been decreasing since 2018.

Overall, angler catch rates for rainbow trout have decreased from 2018 to 2020 with catch rates in 2021 similar to 2020. Results from 2021 creel surveys for boat anglers was 0.617 fish/hr (confidence interval (CI) 0.578, 0.656), and preliminary data from 2022 (January - August) revealed a similar result of 0.750 fish/hr [CI 0.680, 0.821]. In 2021, walk-in anglers had a catch per unit effort of 0.534 fish/hr [CI 0.0615, 0.419], and preliminary data for 2022 was estimated as 0.534 fish/hr [CI 0.338, 0.730]. These values are below the targeted minimum catch rate of one fish/hr identified within AGFD's Management Plan.

Fish condition of rainbow trout has been shown to be negatively correlated with abundance. There is a limited food base in Glen Canyon for sub-adult and adult fish, and as fish abundance increases, food becomes limiting and fish condition begins to decline. In 2021, the relative condition of rainbow trout accessible to anglers (> 6 inches) was greater than one indicating healthy fish (AGFD unpublished data).

The natal origins and trout recruitment and growth dynamics projects led by GCMRC to more closely examine rainbow trout have provided data to assess the effect of fall HFEs on rainbow trout abundance and vital rates in Lees Ferry and at the Little Colorado River (LCR). Analysis of data from fall HFEs conducted in 2004, 2012, 2013, 2014, 2016, and 2018 indicates a weak negative effect of fall HFEs on the rainbow trout growth in Lees Ferry (Korman et al. in review), however this effect is smaller than the expected impacts of current high temperature and low dissolved oxygen, which are likely negatively impacting the fishery. Rainbow trout growth has been high in years both with and without HFEs. Additionally, modeling indicates other factors besides HFEs, including fish density/competition and reservoir effects on nutrient dynamics and food base production are more important determinants of the health and abundance of the rainbow trout population in Lees Ferry (Korman et al. 2021). Further, there is no direct link between fall HFEs and emigration of rainbow trout out of Lees Ferry. **As such, a fall 2022 HFE would not be expected to have negative impacts on the rainbow trout fishery aside from the temporary and direct effect of the HFE on angling access that are described in the recreation section.**

Downstream near the LCR, fall HFEs may temporarily lead to higher growth, survival, and reproduction of rainbow trout owing to a period of relatively low turbidity after the HFE that benefits these visual sight-feeding fish (Korman et al. 2021). Conducting an HFE in fall 2022 may lead to slightly lower turbidity at the LCR over the winter compared to no-HFE, however the marginal effect of conducting an HFE on overwinter turbidity is somewhat uncertain owing to the absence of a quantitative model of turbidity and the unknown amount of moisture this winter. Analysis of historic turbidity data demonstrates that tributary flooding has an overriding influence on turbidity over the winter (Voichick and Topping 2014). But in the absence of any tributary flooding over the winter, conducting an HFE in fall 2022 could lead to small increases in water clarity (less turbid water) compared to if no-HFE were conducted. Analysis of historic turbidity data indicate marginal increase in water clarity without conducting an HFE would be very small. However, rainbow trout growth and predation rates decline exponentially as a function of turbidity. Therefore, because the relation between turbidity and rainbow trout growth is exponential, even small increases in water clarity associated with no-HFE, when compounded over several months, could have a significant effect on rainbow trout predation at the LCR. Maintaining elevated turbidity in Marble Canyon has been discussed as a potentially useful strategy for limiting rainbow trout populations and associated predation on native fish since at least 2011 (Runge et al. 2011).

If conducting an HFE in fall 2022 does in fact lead to clearer water conditions around the LCR confluence area, then prior research demonstrates this would lead to improved feeding efficiency and predation by rainbow trout, and lower juvenile humpback chub survival rates until the next major turbidity flooding event resets and increases turbidity in Marble Canyon (Korman et al. 2021, Yackulic et al. 2018).

*Nonnative Invasive Species - Green Sunfish (Lepomis cyanellus)*

New cohorts of young nonnative green sunfish were observed by NPS staff in the Upper and Lower Slough within Glen Canyon in August of 2022. A rotenone treatment was conducted on the slough on September 17-18, 2022 primarily targeting smallmouth bass, but also affecting green sunfish. Roughly 3,000 common carp, 800 green sunfish, four bluegill (*Lepomis macrochirus*), four rainbow trout, and one smallmouth bass were removed prior to the rotenone treatment.

Within Grand Canyon, individual green sunfish were detected in several locations in 2022. Arizona Game and Fish Department captured one green sunfish (128 millimeter (mm) total length (TL)) at RM 190.45 on our downstream trip in April 2022, in 2021 we captured 4; 2 at RM 157.8. 1 at 159.2, and one at 175.4.

Though there are several locations of green sunfish in Grand Canyon, an HFE would still present an elevated risk of dispersal if a fall HFE pushed a large number of green sunfish downstream from Lees Ferry. **Fall HFEs do pose an unacceptable risk to humpback chub recovery when there are high numbers of green sunfish and other warmwater nonnative fish found in Glen Canyon that could be dispersed downstream.**

*Nonnative Invasive Species- Brown Trout (Salmo trutta)*

Brown trout are a highly piscivorous species known to prey on humpback chub and other native species (Yard 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 uncertain and may be weak relative to other drivers of humpback chub dynamics (e.g., temperature, juvenile recruitment, food availability). Nonetheless, brown trout can have a population-level impact on native fish in Grand Canyon (Healy et al. 2020). Coinciding with suppression of brown trout in a primary area for reproduction (Bright Angel Creek; 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 has increased in Glen Canyon in recent years and is a cause for concern. This species is known to be a fall-spawner that has successfully spawned and recruited in Glen Canyon since implementation of the HFE protocol in 2012 (Runge et al. 2018).

The model of Lees Ferry brown trout populations developed for the 2018 Brown Trout report (Runge et al. 2018) and subsequent updates suggest that high immigration of adult brown trout into the Lees Ferry reach has occurred concurrent with some, but not all, fall HFEs (i.e., 2014 and 2018 fall HFEs are associated with immigration of ~1000 medium-large brown trout into Lees Ferry, while HFEs in 2012, 2013, and 2016 are not associated with high immigration; Yackulic 2021). Further, high immigration of adult brown trout into Lees Ferry has never occurred in the absence of a fall HFE. A separate model of brown trout movement developed using individually tagged brown trout throughout Marble and Grand Canyon also suggests that movement probability of brown trout to Lees Ferry is greater during intervals that include fall HFEs (Healy et al. in prep.). Of 39 brown trout implanted with sonic tags in Glen Canyon, three fish were found to make temporary downstream movements – one of which was detected in the vicinity of the LCR, and then returned to Glen Canyon within ~5 days (Schelly et al. 2021). In addition, brown trout favor food items in the mainstem (Gammarus and mud snails) that have shown increases during the period where regular testing of fall HFEs has occurred (Kennedy et al. 2019). Although fall HFEs have been linked to increased immigration of adult brown trout into Lees Ferry and potential food base changes that may also favor brown trout, there is not strong evidence linking fall HFEs to increased brown trout recruitment in Lees Ferry; specifically, years with the largest recruitment of new juvenile brown trout in Lees Ferry are not associated with fall HFEs (i.e., two of the highest years of brown trout recruitment are in fall of 2016 and fall of 2020, but no fall HFE occurred in the year prior). Increases in adult numbers due to immigration could nullify existing suppression efforts and may lead to increased brown trout production. Nonetheless, a leading hypothesis suggests the number of rainbow trout spawners may influence brown trout recruitment through interference spawning.

Given increases in the estimated brown trout population, GLCA implemented an Incentivized Harvest program targeting brown trout in November of 2019, with lower than expected voluntary participation by anglers, and lack of tribal youth trips due to Covid, and limited population-level impacts (Healy et al. 2022). The HFE may impact fishing in early November during the high flows, but fishing would return to normal after the HFE. **Although a November 2022 HFE may trigger additional immigration of adult brown trout into Lees Ferry, brown trout populations in Lees Ferry are large enough at this point that additional immigration arising from a fall HFE is not anticipated to substantively increase the risk to endangered and native fishes that are downstream in Grand Canyon above the existing level of risk.**

*Nonnative Invasive Species – Smallmouth Bass (Mircopterus dolomieu)*

Smallmouth bass are a high-risk, invasive species within the Colorado River basin that is established in both Lake Powell following stocking in the 1980s, and in Lake Mead (as well as throughout many river sections in the Upper 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, 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 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 and this humpback chub population is now believed to be extirpated. Annual catch of smallmouth bass through sampling by USGS and AGFD in the Lees Ferry reach has averaged 0-3 fish per year until 2022. The most recent USGS trip captured 30 young of year smallmouth bass (58-93 mm fork length (FL)), and 20+ young of year detected in the slough this year through sampling by NPS. This represents the first evidence of spawning below Glen Canyon Dam. Most smallmouth bass captured so far have come from the first 5 miles below Glen Canyon Dam (e.g., only three smallmouth bass were caught in the lower Lees Ferry site located around 4 mile bar, while 27 were captured just upriver of the slough) suggesting that the extent of the smallmouth bass invasion may still be limited to the upper portions of the river nearest Glen Canyon Dam. Evidence of the smallmouth bass invasion being limited to the Lees Ferry stretch is further supported by a September 2022 river-wide seining trip targeting backwaters for smallmouth bass which discovered zero smallmouth bass downstream of Lees Ferry.

It is not known what the response of smallmouth bass might be to a high flow event. There is some evidence that smaller fish (<25 mm TL) are more susceptible to being displaced by higher flows compared to larger fish (Harvey 1987). The HFE could displace them further downstream, or it may not have any effect. Smallmouth bass prefer water velocities of < 0.2 meters per second (m/s) (Todd and Rabeni 1989) and during a HFE one could assume that they would be actively searching for areas of low water velocity. **A fall 2022 HFE poses unacceptable risk to endangered and native fishes due to the potential for increasing downstream movement of smallmouth bass.**

*Nonnative Invasive Species – Other Fishes*

In addition to those noted above, 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). Small numbers of walleye have been captured annually in Glen Canyon, from 2006 to 2019 AGFD has captured an average of three (range 0 to 8) each year (AGFD unpublished data, GCMRC unpublished data), primarily downstream of Glen Canyon Dam, with none captured in 2020 or in 2021. Approximately 50 young-of-year striped bass of uncertain origin have been reported in Marble and Grand Canyons in 2022. There is no evidence that detection of these non-native species in recent years is related to past HFEs.

With low lake elevations, increased risk of fish entrainment through Glen Canyon Dam and increased river temperatures conducive to warm water invasive fishes exists. At reservoir elevations below ~3,530 ft, surface levels are less than 20 m away from the penstock centerline and fish entrainment risk increases, as recent monitoring has revealed that the majority of pelagic fish are located in the top 20 m of the water column (Utah State University, unpublished data). **A November 2022 fall HFE may pose unacceptable risks to endangered and native fishes from non-native fish that may be entrained through the penstocks during a fall HFE.**

*Riparian Vegetation*

The primary impact would be to extend the active channel upslope, which is the zone of daily inundation, for the duration of the HFE. This may slightly extend the suitable habitat for obligate wetland herbaceous species that respond positively to inundation, though longer-lived perennial species are unlikely to respond significantly to this short-term increase in inundation (Butterfield et al. 2018). Nonetheless, possible impacts of HFEs will be assessed through analysis of annually collected long-term monitoring data. **There is no evidence that a fall HFE would significantly impact riparian vegetation resources.**

*Water Delivery - Monthly, Daily, and Hourly Releases*

The 24-hour HFE considered by the PI Team would result in changes to the weekly release prior to and after the HFE and the monthly volume distribution during WY 2023. Neither the tier determination nor the annual release volume as outlined in the 2007 Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lakes Powell and Mead (Reclamation 2007) would be impacted by a potential HFE. Reclamation determined the annual release volume for WY 2022 with Lake Powell operating in the Lower Elevation Balancing Tier where Lake Powell and Lake Mead will balance contents with Glen Canyon Dam, to be no less than 7.0 million acre-feet (maf) and no more than 9.5 maf in accordance with the 2007 Interim Guidelines process and the August 2022 24-Month Study January 1, 2022 elevation projection. Consistent with the provisions of the 2007 Interim Guidelines, and to preserve the benefits to Glen Canyon Dam facilities from 2022 Operations into 2023 and 2024, Reclamation will consult with the Basin States on monthly and annual operations. Reclamation will also ensure all appropriate consultation with Basin Tribes, the Republic of Mexico, other federal agencies, water users and non-governmental organizations with respect to implementation of these monthly and annual operations.

- The Glen Canyon Dam annual release for WY 2023 has initially been set to 7.00 maf, and in April 2023 Reclamation will evaluate hydrologic conditions to determine if balancing releases may be appropriate under the conditions established in the 2007 Interim Guidelines;

- Balancing releases will be limited (with a minimum of 7.00 maf) to protect Lake Powell from declining below elevation 3,525 feet at the end of December 2023;

- Balancing releases will take into account operational neutrality of the 0.480 maf that was retained in Lake Powell under the May 2022 action. Any Lake Powell balancing release volume will be calculated as if the 0.480 maf had been delivered to Lake Mead in WY 2022

The best estimate for total release from Glen Canyon Dam for a HFE in November 2022 is 33,000 cfs (19,000 cfs through the powerplant and 14,000 cfs of bypass). This estimate is based on the most recent unit testing completed in August 2022, a maintenance assumption that six of the eight units at Glen Canyon Powerplant would be available in November 2022, and an approximately 100% gate opening on the available six units. In addition, this estimate assumes that 40 mw (approximately 1,300 cfs) of system regulation will be maintained at Glen Canyon.

The release volume required in November for the potential 24-hour HFE is 554,000 acre-feet. The September 24-Month Study projected 500,000 acre feet release volume in November, therefore it is necessary to reallocate 54,000 acre-feet from December into November. The November total volume for a 48-hour HFE is 603,000 acre-feet and bypass volume is 61,000 acre-feet. WAPA and Reclamation would coordinate on the scheduled reallocation of monthly release volumes with the goal of protecting minimum monthly thresholds for daily release fluctuations whenever practicable as described in the LTEMP as well as maximizing the economic value of hydropower. The September 24-Month Study most probable annual release for WY 2022 under Interim Guidelines is projected to be 7.0 maf, with all months projected to be above the minimum monthly thresholds regardless of the HFE release.

The LTEMP maximum ramp rates (4,000 cfs per hour when increasing and 2,500 cfs per hour when ramping down) would be adhered to throughout the experiment, as would the maximum daily fluctuations (9 times the monthly release volume in December. Hourly releases for the days prior to and after the potential HFE in November are anticipated to fluctuate between 6,500 to 9,000 cfs, which complies with the daily fluctuating range not to exceed 8,000 cfs outlined in the LTEMP. In addition, minimum releases of 5,000 cfs during the nighttime and 8,000 cfs during the daytime would be maintained. **A fall 2022 HFE poses progressive risk to critical Lake Powell elevations with increasing duration HFE alternatives.**

*Water Quality*

**A fall 2022 HFE does not pose unacceptable risks to water quality in the Colorado River and an HFE may help mitigate poor water quality (high temperature, low dissolved oxygen) depending on when lake turnover occurs.** The bypass tubes withdraw water from deeper in the reservoir than the penstocks. As such, releasing water from the bypass tubes during an HFE temporarily cools water temperatures, increases dissolved oxygen concentrations, and increases concentrations of dissolved nutrients. During an HFE, water temperatures in the Glen Canyon reach can be around 1-2 degrees Celsius (°C) colder compared to normal operations when the bypass tubes are not in operation. However, turnover in Lake Powell reservoir can occur from mid-October to November. Thus, depending on when lake turnover occurs, an HFE could mitigate undesired effects of warm water temperatures and low dissolved oxygen conditions which currently exist in Lees Ferry. Notably, during an HFE, dissolved oxygen concentrations in the Glen Canyon reach are 100% saturated (*i.e.,* no oxygen deficiency), because bypass tube releases effectively aerate the water. **A fall 2022 HFE does not pose unacceptable risks to water quality in the Colorado River and an HFE may help mitigate**

**poor water quality (high temperature, low dissolved oxygen) depending on when lake turnover occurs.**

## III. Safety Considerations

*Recreational Safety*

As identified in the LTEMP HFE Protocol, potential effects on public health and safety could occur in conjunction with an HFE, primarily impacting recreational anglers and boaters. All daily fluctuations, minimum flows and maximum flows associated with any potential HFE are within the range experienced by recreational users in the past. Reclamation and NPS continue to work together to ensure that safety measures are implemented, including restricting access to the river immediately below the dam during potential HFEs, and, as noted below, providing public notice about the timing of the HFE implementation. NPS Boating Safety Rules always apply to all boaters using the river.

Reclamation and NPS coordinate to address safety and security issues related to HFEs. Additionally, the three park service units affected, GLCA, GRCA and Lake Mead National Recreation Area (LAKE) will work together to collaboratively plan necessary actions for a potential HFE. NPS units work to maximize continuity of efforts and resources, particularly in those areas where responsibilities are shared, specifically Lees Ferry and Pearce Ferry. Each park has clearly designated responsible parties and staffing needs and actions that need to occur prior to and during an HFE. The parks have coordinated communications plans, medical plans and resource capabilities for search and rescue responses. The three park units maintain frequent communication and information sharing leading up to and during any implemented HFE.

In preparation for an HFE, GRCA, GLCA, and LAKE identify and communicate with all commercial operations on the river, as well as permitted Colorado River trip permit holders that have the potential to be impacted by the HFE while rafting the Colorado River within each respective park unit. Planning is implemented to provide alternative trip dates for trips potentially affected by an HFE. All permit holders are directed to access up-to-date information provided by Reclamation, NPS, and the USGS/GCMRC websites. Additionally, all backcountry hikers who access the Colorado River as part of their backcountry hike are alerted to potential campsite inundation areas.

Prior to an HFE, GLCA communicates with the holders of commercial use authorizations for commercial services (raft trips, back-haul services, fishing guides, etc.) on the Colorado River within GLCA to provide information on the time and duration of the HFE. During past HFEs, relatively few recreational boaters traveled upstream from Lees Ferry as the event was occurring. Information about a pending HFE and safety considerations are provided to recreational users at Lees Ferry in coordination with the PI Team Communications group. Information is also provided via public media, the GLCA website and on-site NPS staff. A fact sheet explaining potential impacts to park visitors is distributed to potentially affected visitors. Notifications are provided at Lees Ferry and Phantom Ranch and the fact sheet is available at these locations, as well as the GRCA Backcountry Information Center and primary visitor center.

*Res*earch and Monitoring Safety

In addition, safety considerations regarding sampling efforts by GCMRC have been incorporated into planning to ensure that safety of field staff is an overarching priority. GCMRC crews are deployed to locations in the days before the high flow release and will be supported by motorized rafts, and boats and cableways. They take critical measurements of discharge, suspended sediment transport, and organic drift. There is a lag between the time that water is released from the dam and the time that water arrives at a particular downstream location (often referred to as "travel time"). GCMRC crews deployed during the experimental flows would be made aware of the timing of the experimental flows. The range of flows for the potential HFE are within the range GCMRC and contracted boat operators have experienced in the past.

At sites downstream from the Paria River (RM 1), work can only be safely conducted during daylight hours. This is especially the case on the first day of an HFE when the water surface typically is covered with woody debris that potentially can clog props of outboard engines or snag equipment suspended from cableways. Likewise, large logs that float just below the water surface can pose a threat to the safety of sampling staff. To address these issues, all field measurements by GCMRC personnel would be done during daylight hours to maximize the safety of field personnel.

## IV. Communications Plan

The potential HFE presents an opportunity to share with the public the purpose of the LTEMP flow-based experiments and anticipated benefits to resources downstream of Glen Canyon Dam. The communications plan for a fall 2022 HFE would consist of communications product development and media coordination; no public or media events at Glen Canyon Dam would be planned.

Prior to HFE implementation, Reclamation's Upper Colorado Basin Region Public Affairs Office, in coordination with NPS, USGS, WAPA, and the Department, would develop a communications plan. In the instance of an event, an initial media advisory is sent to alert media representatives and the public of the HFE, including its purpose and expected start and finish dates. A more detailed news release for publication on or near the HFE dates may be prepared for distribution by the Department. Social media outlets are also used to communicate with the public leading up to and during the experiment, including to share imagery of the HFE. If determined necessary, newsworthy, and prudent by the communication team, the same methodology may be used if a determination not to conduct an HFE is made.

## V. Monitoring and Coordination During Experiment Implementation

If a fall 2022 HFE is implemented, members of the PI Team would continue to meet regularly prior to, during, and following implementation of the experiment. Ongoing communication occurs through the regularly scheduled monthly Glen Canyon Dam operations coordination calls and through additional coordination calls, as needed. Scientists conducting field surveys during the experiment and agency technical experts report on data collected and preliminary results to the Department and the GCDAMP at regularly scheduled meetings. Glen Canyon Dam operations may be adjusted in the event of unexpected impacts from the HFE and/or in the event of an emergency.

## VI. Post Experiment-Reporting and Planning for Future Experiments

The PI Team would coordinate to report initial findings at the 2022 GCDAMP Annual Reporting Meeting, scheduled for January 2023 in Phoenix, AZ.

- Monitoring of sediment transport and sandbar responses to an HFE would include measuring sediment transport at several sites in Marble and Grand Canyons as well as the volume of fine sediment, especially sand, that is stored on the bed of the Colorado River, in its eddies, or at higher elevation along the river's banks as described in Section V. GCMRC will also collect data on water quality (including nutrients), native and nonnative fishes, aquatic invertebrates, riparian plants, and other resources as described in the TWP (DOI 2020). GCMRC will use the information from these studies to evaluate the effects of HFEs on downstream resources in Glen, Marble, and Grand Canyons and to help in the design of future experiments.
- The 7.0 maf releases will lead to lower sand export compared to typical 8.23 maf release patterns.
- The PI Team would meet in early 2023 to review the implementation and results of all 2022 experimental activities, and to begin coordination on the evaluation of resources and potential experiments that may be conducted in 2023.
- In addition, the PI Team would report ongoing findings at meetings of the GCDAMP Technical Work Group (TWG) and AMWG. Reclamation has a commitment to provide an annual monitoring report to the FWS Arizona Ecological Services Office (AESO) in compliance with the 2016 Biological Opinion; this report will also include a summary of the effects of any flow experiments conducted under the LTEMP ROD. Reclamation would use the monitoring information and feedback from AESO and GCDAMP stakeholders to inform monitoring for future experiments, and to design and implement any measures necessary to address any adverse effects that may occur due to these flows.
- In accordance with the LTEMP, the Department may make the decision to conduct future flow-based experiments (High Flow Experiments, Bug Flows, Trout Management Flows, and Low Summer Flows) at Glen Canyon Dam if it is determined that there are no unacceptable adverse impacts on other resource conditions. Information and data from this or other experiments will be considered in future recommendations and decisions.

## VII. Consultation

Reclamation and GCMRC provided much of the information in this report that was available at the time in the GCMRC 2021 Annual Report. Newer not yet published information was reported to the Adaptive Management Program Partners at the GCDAMP Annual Reporting Meeting in January 2022 as well as to the AMWG at its August 17-18, 2022 meeting. Notification of the potential for a 2022 fall HFE was communicated to GCDAMP stakeholders on August 17, 2022. A follow-up informational webinar was held on September 27, 2022 with GCDAMP stakeholders as an opportunity to ask questions and provide feedback. Representatives from the

Basin States participated in the development of this recommendation. Based on feedback and discussion at the GCDAMP webinar, the recommendation and report were finalized without major changes.  Reclamation and GCMRC will present the findings and recommendation of this report to the TWG on October 12-13, 2022.

On September 27, 2022, the required 30-day advance notification and offer for consultation were sent electronically to the Tribes and Parties to the LTEMP Programmatic Agreement regarding the potential for a High Flow Experiment beginning November 1, 2022. As of September, 30, 2022, Reclamation has not received any requests for consultation on the potential experiment. A follow-up notification will be sent electronically to the Programmatic Agreement signatories, including Tribes, following the Department's decision regarding the potential High Flow Experiment.

## VIII. Conclusion

Determining whether to recommend an HFE required coordination and effective communication among the technical staff of multiple agencies. The PI Team relied heavily on and would like to acknowledge the contributions of staff from GCMRC, Reclamation, and WAPA in making this recommendation.

The PI Team has thoroughly evaluated the issues discussed above and has taken into consideration the information and analyses included in the LTEMP FEIS and ROD. The PI Team's recommendation regarding implementation of a fall 2022 HFE is based on a careful assessment of resources and best available science. **By consensus, the PI Team is opposed to recommending that the Department implement a 24-hour, 48-hour, 96-hour, 144-hour, or 192-hour HFE in fall 2022.**

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