April 6, 2023

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: Final Technical Report and Recommendation Regarding a High Flow Experiment (HFE) at Glen Canyon Dam, April 2023

I. Recommendation Summary

Based on the LTEMP Record of Decision (ROD) and by way of a Supplemental Information Report, 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 HFE at Glen Canyon Dam. At first the PI Team focused on considering a recommendation to implement a Spring HFE as the term is used and defined in LTEMP (i.e., a sediment-related experiment triggered by sediment input from the Paria River during a December to June accounting period) but the PI Team quickly concluded that there would not be enough sediment to trigger a Spring HFE. The PI Team then changed focus and began to consider a recommendation to implement an alternative HFE. This HFE is defined here as an "April HFE" to distinguish it from the term "Spring HFE" found in the LTEMP. The PI Technical Team's recommendation regarding implementation of a spring 2023 high flow release is based on a careful assessment of resources and best available science. The PI Technical Team was unable to come to a consensus recommendation on an April HFE, partly because the legal rationale for authorizing implementation of an April HFE was undefined at the time, but Department of Interior agencies and the Arizona Game and Fish Department were all in support of an HFE and all other voting members were interested in forwarding the report along with a recommendation that the Leadership Team take up the spring high flow release concept below for consideration.

By a non-consensus vote, the PI Team recommends that the Leadership Team take up consideration of a 72-hr duration high flow release in April 2023. Six entities support the technical merits of a spring high flow release, five entities supported referral of the decision to the leadership team without a technical recommendation, and four entities abstained entirely from casting a recommendation.

Support for moving consideration of the April HFE to the Leadership Team by PI Team State participants was based on the following conditions: 1) that Reclamation acknowledges this action does not create precedent for future or similar actions that might be proposed outside the analysis of environmental impacts considered in the LTEMP; 2)that a Supplemental Information Report (SIR) will be prepared to document the review of new information to determine the sufficiency of the existing LTEMP analysis and subsequent decision; 3) that the state participants have an opportunity to review the SIR before an April HFE is implemented; 4) that this expedited review is outside of standard LTEMP practices and must not become a regular tool; and 5) that this expedited process created additional uncertainty for Planning and Implementation members that is greater than during the usual consideration given when being asked for guidance regarding flow recommendations.

Table 1. Technical position of Planning and Implementation Technical Team members for consideration of a 2023 high flow event.

Entity	Technical Team	Technical Recommendation
DOI-BOR	Kathy Callister	Supports HFE
DOI-NPS	Hanna Chambless (substitute) / Bud Fazio	Supports HFE
DOI-FWS	Dan Leavitt	Supports HFE
DOI-USGS	Andrew Schultz	Supports HFE
DOI-BIA	Chip Lewis	Supports HFE
WAPA	Shane Capron	Abstain
AZGFD	Dave Rogowski	Supports HFE
Basin States	CO – Michelle Garrison	Abstain
Basin States	CA – Shana Rapoport	Supports referral of recommendation to LT
Basin States	WY – Mel Fegler	Supports referral of recommendation to LT
Basin States	AZ – Emily Higuera	Supports referral of recommendation to LT
Basin States	NV – Seth Shanahan	Abstain
Basin States	NM – Christina Noftsker	Abstain
Basin States	UT - Scott McGettigan	Supports referral of recommendation to LT
UCRC	Sara Larsen	Supports referral of recommendation to LT

Purpose of the Recommendation Memo

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

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 strives to provide a consensus technical recommendation but was unable to reach that benchmark because this process in March and April 2023 considers an HFE that is not explicitly triggered under the LTEMP HFE protocol and due to limited technical information available as a result of the condensed time frame during which this experiment was considered. Instead, contained in this document is a split recommendation to the Leadership Team to take up consideration of an April HFE at the Leadership Team level. Support was as follows: DOI agencies and Arizona Game and Fish Department recommended an April high flow experiment, WAPA does not recommend a spring high flow release, and state representatives either abstained or are supportive of the Leadership Team considering an April HFE but they cited concerns about setting precedent with the LTEMP HFE protocol.

The Secretary of the Interior and/or her Designee will consider the recommendation of the PI Team and Leadership 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.

72-hour High Flow Release at 39,500 cubic feet per second

The PI Team carefully monitored sediment conditions throughout the spring accounting period. To date, the bulk of the Paria River runoff has not started and, a Spring HFE is not triggered under the LTEMP HFE protocol. Further, projected monthly releases in April-June are high enough to erode sediment and reduce the chances of the sand budget model triggering a spring HFE to nearly zero (projected 9.5 million acre-feet (maf) based on latest runoff forecasts), despite the unusually high snowpack and high anticipated cumulative sediment load. Because it is unusual to start the year at 7.0 maf and then switch to balancing for a 9.0 to 9.5 maf release or similarly high release volume year, it causes high monthly volume releases for the remaining months. The volumes released in the remaining months will be higher than monthly volumes for a 10 maf release year, which in this case is projected to transport the accumulated sand from 2021 and 2022 downstream where it will be unavailable for widespread benefit. Thus, the PI Team examined a high flow release scenario using a 1-yr accounting period to determine if leftover sediment from the fall 2022 Paria River runoff season in Marble Canyon was enough to warrant an HFE (Figure 2). The 1-yr accounting window Sand Budget Model did show a trigger of a 72-hr HFE at a maximum magnitude of 39,500 cfs during the period in late April where there are 8 generating units and full bypass available at Glen Canyon Dam.

Scope of Assessment and Summary of Exceptional Circumstances Warranting an HFE

Sediment conditions are currently ideal for supporting an HFE that will effectively rebuild sandbars because of a short window in late April where all eight generating units at Glen Canyon Dam are available to create a maximum magnitude of 39,500 cfs including full bypass. Fall 2021 and Fall 2022 were both major years for sand inputs from the Paria River. In both years, enough sand was supplied to support a full length HFE (i.e., 96 hours) but concerns due to drought and non-native species resulted in no HFEs being run in either year. Since July 1, 2022, ~1.7 million metric tons of sand have been supplied by the Paria, and between July 1 2021 and July 1 2022, ~1.5 million metric tons have been supplied. For context, the annual mean sand load (from 1997-2022) for the Paria is ~830 thousand metric tons, so both years are close to double the annual mean. Whereas HFEs have been shown to be effective in rebuilding sandbars (Hazel et al. 2022), the lack of HFEs since 2018 has resulted in continued bar degradation.

The HFE protocol in LTEMP defines two accounting periods for sediment, July 1 to November 30, and December 1 to June 30. A sediment-triggered HFE can occur when the Marble Canyon mass balance is predicted to remain positive at the end of the accounting period according to the Wright et al. (2010) Sand Routing Model. The mass balance in Marble Canyon reflects the sand inputs from the Paria River and sand export at River Mile (RM) 61; when sand inputs exceed export, the mass balance is positive.

Under LTEMP, the sediment accounting period resets on December 1, meaning that even when sand is in the system, it does not "count" towards triggering a subsequent HFE. However, there technically could be an abundance of sand in Marble Canyon that a high flow event would utilize for beach building. The rationale behind the LTEMP windows is to encourage HFEs as soon as possible following fall sand inputs, considering that winter dam operations could potentially export a substantial fraction of the sand supplied during the previous fall. In recent years, however, drought conditions have resulted in low winter dam releases, and consequently low sand export. As shown in Figure 1, large sand inputs to Upper Marble Canyon occurred in Fall 2021 and Fall 2022, followed by little export (most of the sand is still in Upper Marble Canyon).

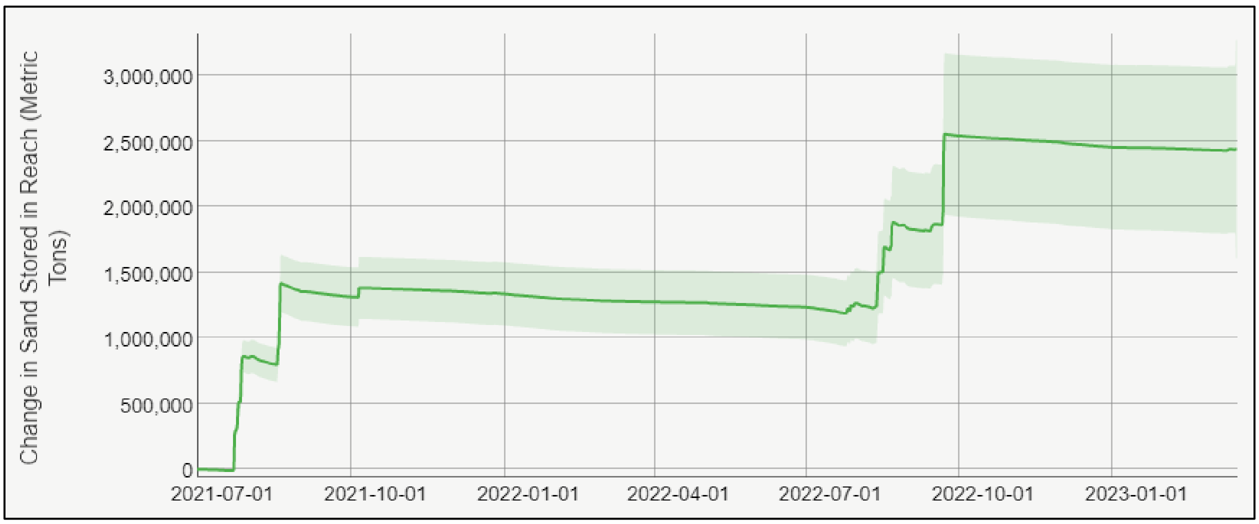

Figure 1: Upper Marble Canyon Mass Balance since 2021. Most of the sand supplied in 2021 and 2022 is still in Upper Marble Canyon. Source: https://www.gcmrc.gov/discharge_qw_sediment/

Additionally, if not for the potential for high dam releases in April, May, and June, it is likely that enough sand could be supplied this spring to trigger an HFE under the existing spring accounting period. If we were to assume the typical 600 kaf releases for April, May, and June, the Sand Routing Model indicates that ~200,000 metric tons of sand are needed to trigger a 12-hour Spring HFE. The latest data from the GCMRC sediment website (https://www.gcmrc.gov/discharge_qw_sediment/) indicates that approximately 100,000 metric tons of sand have been supplied so far. The snowpack in the Paria watershed is unusually high, and when it melts we expect to exceed 200,000 metric tons of sand inputs. However, there is uncertainty in when the snow melt will arrive; it could occur gradually once the weather warms, or in a major flood if a rain-on-snow event were to occur. If a slow melt occurs, we predict a total of 200,000 to 400,000 metric tons of sand, but if a rain-on-snow event occurs, totals could quickly exceed 500,000 metric tons of sand. Given this uncertainty, it is unlikely that there will be sufficient lead-time to plan an HFE, even if one is ultimately triggered. This scenario changes substantially if high dam releases occur in April, May, and June. Assuming releases of 800 kaf in April, 1.1 maf in May, and 1.09 maf in June, the elevated releases would erode an extra ~880,000 metric tons according to the Sand Routing Model (Figure 2). This would preclude a sediment-triggered HFE under the Spring accounting period. For context, 880,000 metric tons of sand is roughly equivalent to the amount of sand exported by a 96-hour full-length HFE.

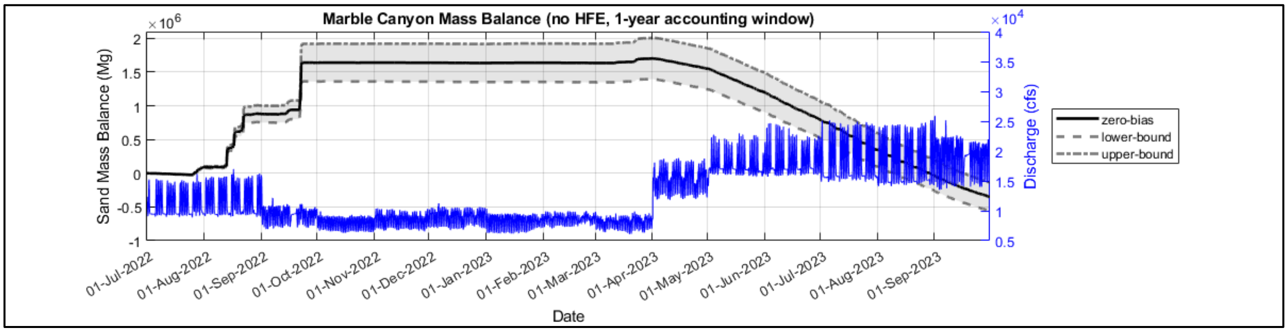

Figure 2. Marble Canyon Sand Mass Balance showing effects of high monthly volumes resulting from balancing for a 9.0 maf or higher Water Year.

Examining the sediment mass balance window from December 1, 2022 back to July 1, 2022, which would better reflect the amount of cumulative sand load present in the system during the recent period of low monthly volume releases (i.e., sand that hasn't yet been scoured), we find that there is adequate sand in Marble Canyon to support an HFE, even considering elevated spring monthly release volumes. Specifically, under a 1 -year accounting window, we obtain a sediment-triggered HFE duration of 72 hours (Figure 3). This estimate is still conservative, given that only sand inputs from Fall 2022 and beyond are considered, and not inputs from Fall 2021 nor spring 2023 deposits which have yet to arrive. We also used the standard conservative approach of considering the lower uncertainty-bound estimate of Paria supply for finding the sediment-triggered HFE duration.

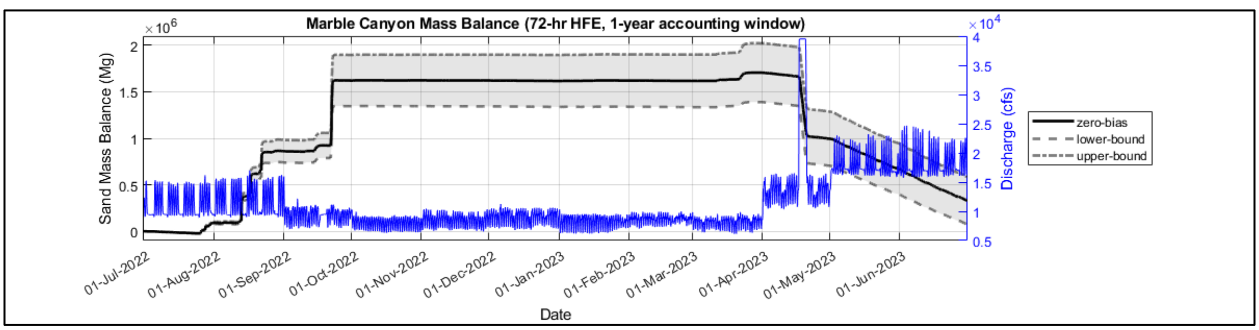

Figure 3. Mass balance in Marble Canyon predicted by the Sand Routing Model (Wright et al. 2010) with a 1-year accounting window and a 72-hour HFE in April with a maximum magnitude of 39,500 cfs.

In generating the above prediction, we used the latest available data for gage discharges and Paria inputs as of 3/27/2023. For the period beyond the availability of gage discharges at RM30 and RM61, we used the Colorado River Flow and Stage (CRFS) model to transform discharges from Lee's Ferry to discharges at RM30 and RM61 (CRFS implements the Wiele et al. 1997 model). Projected hourly releases were not available at the time of this document, and so we used the observed hydrograph from 2022 and rescaled the discharges to match the projected monthly releases of 800 kaf, 1.1 maf, and 1.09 maf for April, May, and June, respectively. The 72-hour HFE was added on top of the April hydrograph, resulting in a total monthly release for April of 974 kaf. Although the details of the fluctuations are therefore likely to change, we do not expect this to substantially alter the results shown above or change our conclusions.

We additionally note that the Little Colorado River (LCR) has also supplied an unusually high amount of sand over the past year. Since July 1, 2022, the LCR has supplied roughly three times the annual mean, based on the period since 1998. The LCR is not formally considered as part of the HFE protocol, but given the exceptional sand load last Fall and this Spring, we expect any HFE to be highly effective downstream of the LCR due to sand-enriched conditions. In other words, sediment conditions are currently ideal for an HFE not only in Marble Canyon, but also in the Colorado River reaches downstream of the LCR.

In summary, there is a significant opportunity to take advantage of the last two years of significant Paria sand inputs to rebuild sandbars in the Colorado River downstream of Glen Canyon Dam with an HFE. As a result of high sediment inputs from both the Paria and the LCR, sediment conditions are currently ideal for rebuilding sandbars via an HFE. However, this opportunity is time-limited: if high dam releases occur as expected this spring into the summer, these will begin to export a significant fraction of the sand currently present in the system. By next Fall, much or all the sand supplied over the last two years could have been exported to lake Mead.

The opportunity to use some of this sand to rebuild sandbars will not persist indefinitely, which is similar in principle to the motivation for including the Proactive Spring HFE in the LTEMP. The intent of the Proactive Spring HFE in the LTEMP protocol was designed for the following, "…proactive spring flows [are] designed to "park' sediment before summer flows in high annual volume years." In addition, the LTEMP ROD states that, 'if it is determined that a sediment-triggered HFE cannot be implemented and the projected annual volume is greater than or equal to 10 maf, a proactive spring HFE will be triggered." The following information suggests that current conditions are similar in principle to a high annual volume year that would trigger a Proactive Spring HFE. The latest runoff forecast suggests that 9.5 maf may need to be released in Water Year 2023, of which, 523 kaf that was intentionally withheld from release early in the water year to maintain Lake Powell water surface elevations must be released in the remaining months of the water year. Additionally, WY2023 started out with low monthly volumes because it was projected as a 7.0 maf release year, but now balancing releases of 9.0 to 9.5 maf year are projected. To ensure releases are achieved before the end of the water year, monthly volumes for the rest of the water year will be as high or higher than those during equalization years ≥10 maf. The necessity to move this water by the end of Water Year 2023 is also addressed in the Grand Canyon Protection Act (GCPA), Section 1802(b), providing that Glen Canyon Dam actions and operations must be fully compliant with the Law of the River. Therefore, the projected releases and unusual water conditions allow the consideration of an HFE to remain within the scope of the GCPA, as the projected water will need to be released with or without a potential HFE.

Additional Compliance: Supplemental Information Report

Reclamation is drafting a Supplemental Information Report (SIR) to review new information to determine the sufficiency of the existing LTEMP analysis and subsequent decision. The SIR will be appended to this technical memo when it is finalized.

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 spring HFEs is provided below (Table 2).

Table 2: LTEMP Implementation Criteria for Spring 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[d]						
Spring HFE up to 45,000 cfs in Mar. or Apr.	Trigger: Sufficient Paria River sediment input in spring accounting period (Dec.–Jun.) to achieve a positive sand mass balance in Marble Canyon with implementation of an HFE Objective: Rebuild sandbars	Not conducted during first 2 years of LTEMP, otherwise 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; sediment-triggered spring HFEs will not occur in the same water year as an extended-duration (>96 hr) fall HFE	Sediment-triggered spring HFEs are 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
Proactive spring HFE up to 45,000 cfs (Apr., May, or Jun.)	Trigger: High-volume year with planned equalization releases (≥10 maf) Objective: Protect sand supply from equalization releases	Not conducted during first 2 years of LTEMP, otherwise implement in each year triggered, dependent on resource condition and response	First test 24 hr; subsequent tests could be shorter, but not longer, depending on results of first tests	Potential short-term unacceptable impacts on resources listed in Section 1.3; unacceptable cumulative effects of sequential HFEs; will not be implemented in the same water year as a sediment-triggered spring HFE or extended-duration fall HFE	Proactive spring HFEs are 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

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. No spring HFEs have occurred. 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 of the Interior. The Secretary's Designee to the Adaptive Management Work Group (AMWG), who 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.

IV. HFE Analysis and Planning

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 3). 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 for the first test. 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. However, modeling conducted in the LTEMP FEIS anticipated that conditions could trigger as many as 15 fall HFEs, 5 spring HFEs, and 2 proactive HFEs in the 20-year LTEMP period. Extended-duration fall HFEs are limited to a frequency of 4 times total in the 20- year LTEMP period.

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 spring accounting period (December 1 to May 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.

The timing of the proposed April 2023 HFE takes advantage of a short period of time in calendar year 2023 where all eight generating units at Glen Canyon Dam are available for use, which enables a maximum magnitude (powerplant capacity plus bypass) of 39,500 cfs. The proposed HFE would start on April 24 and conclude on April 27. Start/end times to be determined.

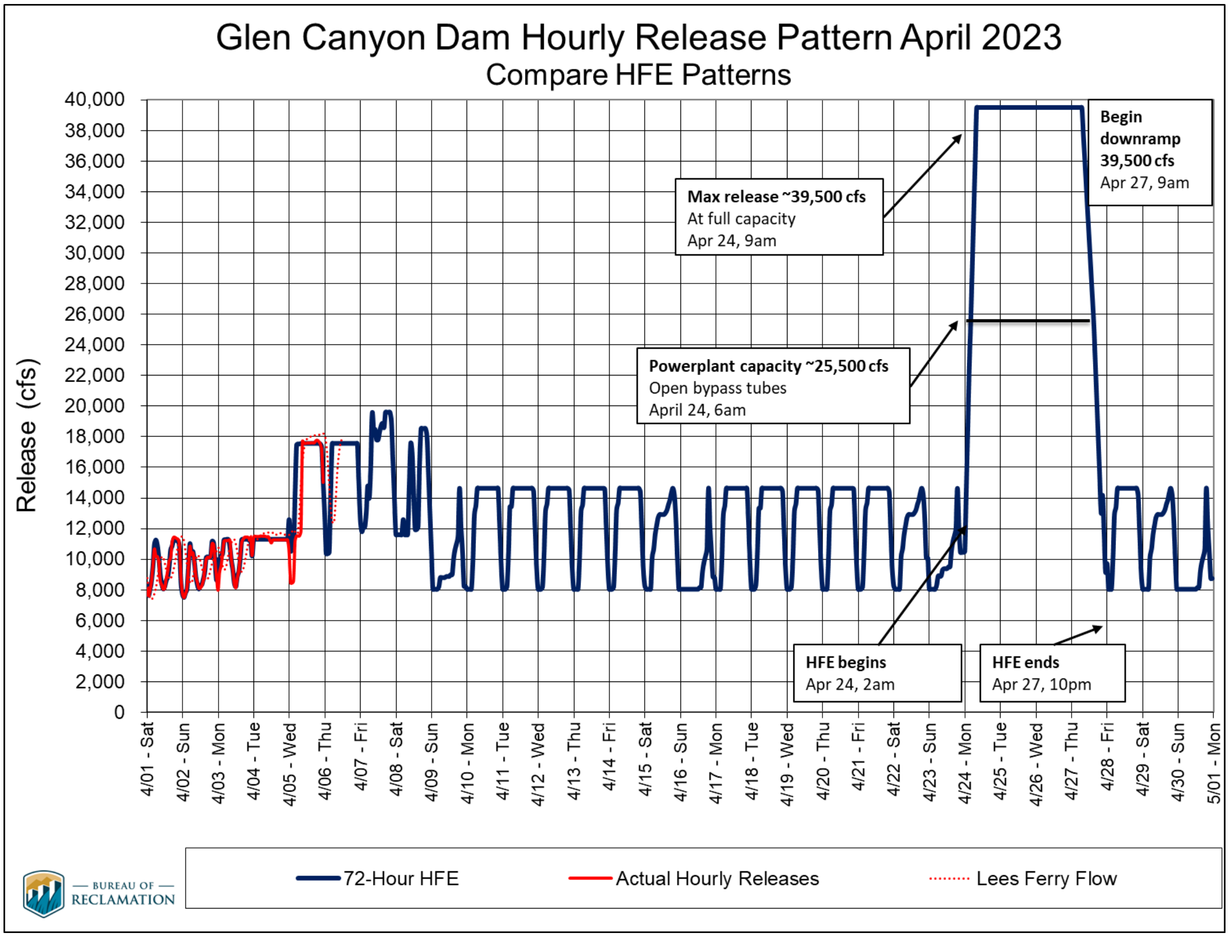

Figure 4. Hydrograph for proposed April 2023 spring High Flow Experiment. Subject to minor revision.

Experimental Design and Description – 72-Hour Duration

Potential 72-hour HFE Hydrograph (4):

- Ramp-up from base releases at 4,000 cfs/hr at approximately 2:00 AM on Monday, April 24, 2023 (all times Mountain Standard Time and not hour ending) until reaching powerplant capacity (~25,500 cfs)
- Open first bypass tube at 6:00 AM on April 24
- Ramp-up from powerplant capacity to full bypass (~39,500 cfs) at one full bypass tube (~3,500 cfs) per hour in 4 hrs reaching total releases at 9:00 AM on April 24
- Stay at peak release (~39,500 cfs) for 72 hrs
- Ramp-down from peak release to base releases at beginning at 9:00 AM on April 27 using 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 *4*):

- Begin ramp-up from 10,500 cfs at 2:00 AM on April 24 (Monday)
- Reach powerplant capacity at approximately 6:00 AM on April 24

- Open bypass tubes at approximately 6:00 am on April 24
- Reach full bypass at 9:00 am on April 24
- Begin ramp-down from bypass at 9:00 AM on April 27 (Thursday)
- Complete HFE (back to 14,000 cfs) at 10:00 PM on April 27 (Thursday)

V. 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). 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 sediment-transport measurements needed to trigger and evaluate 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 April 2023 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 spring 2023.

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 2023 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 spring HFE. The interagency Lake Powell water quality monitoring program will collect water quality profiles before during and after the HFE at seven long term monitoring sites that extend from the dam uplake to the confluence with the San Juan River.

Glen Canyon National Recreation Area and Grand Canyon National Park have tentative plans to conduct a pre-post non-native fish survey in the Lees Ferry reach and downstream to Badger Rapid. These surveys will be intensive 4-5 nights of electrofishing sampling to monitor the age-1 smallmouth bass before and after the potential spring HFE in the three-mile stretch of river directly below Glen Canyon Dam, which is the location where the majority of smallmouth bass were discovered in the fall 2022 rapid response action. Sampling downstream to Badger Falls will use seining and backpack electrofishing gear types.

VI. Assessment of Resources

In coordination with the GCMRC, the PI Technical 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 spring 2023 HFE using the best available science: April 24, 2023 start date, 72-hr duration, and 39,500 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 February 22, 2023, identifying the potential for a spring HFE in 2023, 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 can be addressed if a spring HFE occurs in 2023.

A spring HFE in 2023 would not pose additional risks to archaeological and cultural resources. A spring HFE in 2023 could help increase the potential for achieving the

management goal to maintain or improve site integrity in situ (preservation in place) for some archaeological sites in Grand Canyon National Park.

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. **A 2023 spring HFE would not pose risks to natural processes.**

Humpback chub

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 (2019-2021) 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 433 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.

Thus, no direct unacceptable negative response would be expected to humpback chub from a spring HFE this year, based on current monitoring results and previous HFEs.

Hydropower and Energy

The HFE will require a modification of operations at Glen Canyon Dam that may include changes in release timing, which may require energy to be sold to the open market at reduced energy prices. In addition, bypass flows will result in a reduction of total energy produced. WAPA estimates the financial impact of implementing a 2023 Spring HFE at $1.4 million. For comparison with past HFEs, WAPA determined the financial impact 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 are estimated to be -29,741 MWh.

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 spring 2023 HFE if doing so will not likely result in additional cost.

As multiple experiments are being proposed this year that may have significant and varying impacts on the Basin Fund, a detailed Basin Fund analysis has not been conducted for the proposed experiment. If an HFE is conducted, WAPA will determine the financial impact of the HFE utilizing the same methods as has been done in the past, and will account for them as a constructive return.

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 (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).

Changes in flows due to a Spring HFE are unlikely to have a substantial effect to razorback suckers, since larval life stages that might be sensitive to higher flows (e.g. larval fish) do not seem to be present in Grand Canyon. 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 spring HFE through enhanced growth and survival similar to conditions after the 2008 spring HFE (Korman et al. 2021), which could lead to indirect effects on native fishes, 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 other factors that are less certain, such as the high flows expected in May – September and additional tributary sediment inputs. **Thus, no direct unacceptable negative response would be expected among native fishes to a spring HFE this year, based on current monitoring results and previous HFEs. However, indirect effects from potential expansion of smallmouth bass create a 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 shoulder 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 impacted. 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 2023 operations around the time of the HFE.

Impacts to recreational experiences associated with the HFE would be both short- and long term in GRCA. The HFE is proposed to take place when both commercial and non-commercial launches are permitted. 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 predicted 5-10 feet of stage change at the start and end of the flows will vary by camp (Magirl and others, 2008) and may create problems in camp and make some campable areas unusable during the HFE. 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 March 1, 2023, roughly 4 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 an indeterminate change in sand mass in Eastern Grand Canyon and East-Central Grand Canyon. The changes in sand mass were as follows: Upper Marble Canyon (RM 0–30) +1,900,000 ±760,000 metric tons; Lower Marble Canyon (RM 30-61) +810,000 ±230,000 metric tons; Eastern Grand Canyon (RM 61–87) +170,000 ±850,000 metric tons; East-Central Grand Canyon (RM 87–166) +330,000 ±630,000 metric tons; West-Central Grand Canyon (RM 166–225) +820,000 ±390,000 metric tons. (Owing to equipment problems requiring the laboratory processing of samples that is still ongoing at GCMRC, the West-Central Grand Canyon sand-accumulation value extends only through September 8, 2022.) Importantly, the sand that accumulated 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; this accumulated sand is thus susceptible to erosion and rapid downstream transport to Lake Mead should higher dam releases occur before an HFE is conducted to store part of this accumulated sand in high-elevation sandbars. Sandbar monitoring data collected in October 2022 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. The gully erosion was largely caused by thunderstorms in the summers of 2021 and 2022. Owing to this recent erosion, a substantial number of the long-term sandbar monitoring sites in Marble Canyon now contain the least amount of sand at high elevation since monitoring began in 1990.

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 (Grams et al., 2018). 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 18, 2022. 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 2022. 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 March 1, 2023) 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: +3.20 million metric tons (the range of this measurement is between -0.91 and +5.40 million metric tons)

- Lower Marble Canyon: +1.70 million metric tons (the range of this measurement is between +0.73 and +2.80 million metric tons)

Thus, there was substantially more sand in the Colorado River corridor in Marble Canyon on March 1, 2023, than on July 1, 2012, when the HFE Protocol was first implemented.

The potential spring 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, which is described in part in the other resource sections of this report. Tribal Resources are considered during each HFE consideration process, and to date no potential for negative impacts to Tribal Resources have been discovered. Consultation to tribes as Parties to the LTEMP Programmatic Agreement was offered on February 22, 2023 and again March 29, 2023. To date, no requests for further consultation by tribal partners has been received. **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 AZGFD (NPS 2013), and the AZGFD Management Plan (AZGFD 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.

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 (AZGFD 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.

A spring 2023 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.

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. During the smallmouth bass rapid response electrofishing study in October – December 2022, a total of 274 bluegill, 3031 green sunfish, 1 largemouth bass, 9 walleye and 16 black crappie were captured and removed.

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 the downstream trip in April 2022, in 2021 we captured 4; 2 at RM 157.8. 1 at 159.2, and one at 175.4.

Green sunfish have become more common and widely distributed in Grand Canyon. An HFE may increase the risk of dispersal of green sunfish and other warmwater species; however, expected high flows from April - September may also contribute to dispersal, so the risk to HBC is similar with or without a Spring HFE. **Green sunfish have become more common and widely distributed in the Grand Canyon and high flows from May-Sept may also contribute to dispersal, so the risk to humpback chub is similar with or without a Spring HFE.**

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).

A high flow in mid-April could produce a negative effect on brown trout. Below are temperature-based estimates of brown trout fry emergence in Glen Canyon based on recorded temperatures for Accumulated Thermal Unit (ATU) calculations and assuming spawning peaks December 1. By approximately April 15, most of the fry are predicted to have emerged but would still be quite small in size and vulnerable to displacement from high flows. High flows can reduce trout recruitment rates in small streams, but it is unclear if that pattern holds true in large river systems.

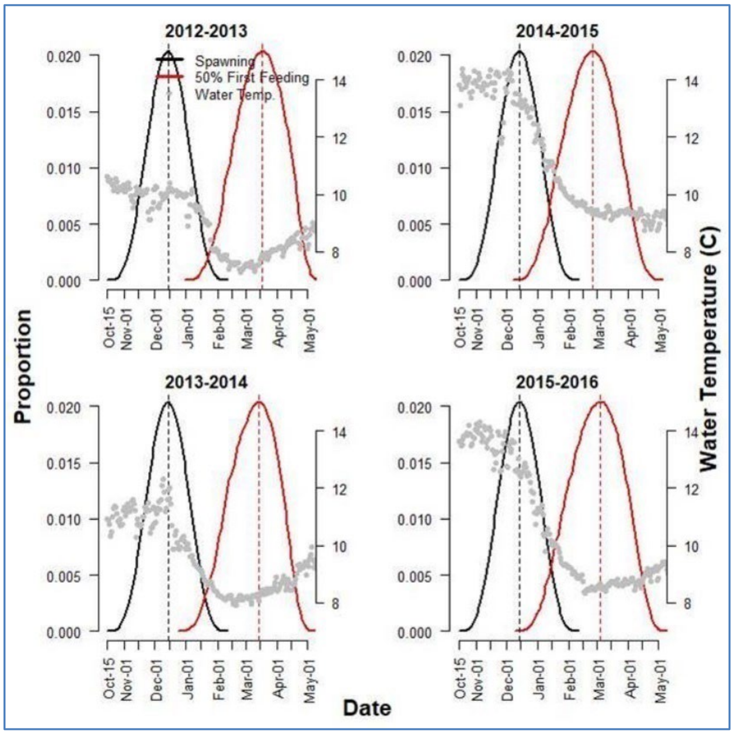

Figure 5. Temperature based estimates of brown trout fry emergence in Glen Canyon based on recorded temperatures for Accumulated Thermal Unit (ATU) calculations and assuming spawning peaks Dec 1. By ~ Apr 15. From Josh Korman, personal communication.

The HFE may impact fishing in April during the high flows, but fishing would return to normal after the HFE. Although a spring 2023 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. **No unacceptable exacerbation of risk to brown trout is expected and no unacceptable risks are anticipated.**

Nonnative Invasive Species – Smallmouth Bass (Micropterus 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 AZGFD in the Lees Ferry reach has averaged 0-3 fish per year until 2022. A fall 2022 USGS trip captured 30 young of year smallmouth bass (58-93 mm fork length (FL)), and 20+ young of year detected in the slough that 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. Further sampling by NPS and others in fall 2022 detected and removed over 300 young of year smallmouth bass in 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 smallmouth bass captured last fall were 58 to 122 mm FL (average 80 mm). There is little information available on the effects of spring floods on this size range of smallmouth bass. 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 smallmouth bass movement study in the Yampa River noted that smallmouth bass can move great distances upstream and downstream, thus smallmouth bass may be likely to move downstream regardless of a Spring HFE (Hawkins et al. 2009).

Some literature suggests that a flood prior to spawning may improve smallmouth bass reproductive success by clearing spawning gravel (Brown et al. 2009). This presents some concern that an HFE prior to smallmouth bass spawning in the Glen Canyon Dam tailwater could remove fine particulates from gravel and cobble substrates and increase the suitability of smallmouth bass spawning substrate, especially upstream of the Paria River in the Lees Ferry reach and in the -12 mile slough. Smallmouth bass did likely find spawning suitable in 2022 without any recent HFE occurring, however, so this may not be a limiting factor and further gravel bed condition improvement may not affect their reproductive potential. High flows expected from April-September are likely to also remove fine particles from spawning gravels, so the effect of an HFE is not expected to increase the risk of smallmouth bass spawning. **A spring 2023 HFE does not pose unacceptable risk to exacerbating the spawning, migration, and/or establishment of smallmouth bass below Glen Canyon Dam.**

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 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. 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 above sea level, 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 survey of the forebay with gill nets in early March 2023 captured only 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 to the dam capture small numbers of juvenile green sunfish and bluegill down to almost the penstock depths (Barrett Freissen, Utah State University, personal communication). 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 (Mike Horn, Bureau of Reclamation, personal communication). **A 2023 spring HFE does not pose unacceptable risks to endangered and/or native fishes.**

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). Periodic HFEs likely assist in preventing vegetation encroachment, largely by disadvantaging flood-intolerant species. An April HFE may promote seedling germination of some riparian plant species, but seedlings will likely be eroded by later high flows and desiccated above the daily high-water line. Nonetheless, possible impacts of HFEs will be assessed through analysis of annually collected long-term monitoring data. **A spring HFE is unlikely to significantly impact riparian vegetation resources over the long term and no unacceptable risks are anticipated.**

Water Delivery - Monthly, Daily, and Hourly Releases

The 72-hour HFE considered by the PI Team would take place during a time of high April monthly release volumes and would be considered a within-month experiment. 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 2023 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 was initially set to 7.00 maf, and in April 2023 Reclamation would 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 March 2023 24MS projected a balancing annual release volume of 7.83 maf.
- Because of increased snowpack throughout March in the upper basin and subsequent increase in the spring inflow projections from 125% of average to 177% of average over March (3.3 maf), it is likely the balancing annual release volume from Glen Canyon Dam during WY2023 will be 9.5 maf.
- The additional 2.2 maf of water releases, including the 523 kaf DROA volume shifted from the months of December through April to the months of May through September, necessitates significant increases in monthly release volumes. It is likely that the releases May through September will be close to power plant capacity with six units available.
- The timing of an April HFE will further assist sand budget management through distribution prior to the significant increase in monthly release volumes from June through September.

The best estimate for total release from Glen Canyon Dam for a HFE in Spring 2023 is 39,500 cfs (powerplant capacity of 25,500 cfs plus 14,000 cfs bypass). This estimate is based on the most recent unit testing completed in August 2022, a maintenance assumption that eight units at Glen Canyon Powerplant would be available in late April 2023, and an approximately 100% gate opening on the available eight units. In addition, this estimate assumes that 40 mw (approximately 1,300 cfs) of system regulation will be maintained at Glen Canyon, while 30 MW (approximately 1,100 cfs) of reserves will be transferred to another hydropower plant during the experiment.

The release volume required in April for the potential 72-hour HFE is approximately 279,000 acre-feet. This experiment is proposed to be conducted as a within-month occurrence in April 2023, thus no water will be borrowed from other months in WY2023. As this experiment will occur within-month, there will only be a temporary drop in Lake Powell elevation, estimated at 4.5 feet. As this experiment will occur within-month, there will only be a temporary drop in Lake Powell elevation, estimated at 4.5 feet. Additionally, as the HFE is scheduled toward the end of the month, the reduced releases pre-HFE accommodate the 4.5 elevation drop prior to reaching May 1, causing no unacceptable risk to Lake Powell elevations.

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 set at 8,000 cfs/day. Hourly releases for the days prior to and after the potential HFE in April are anticipated to fluctuate between 8,033 to 14,631 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 spring 2023 HFE does not pose unacceptable risk to Lake Powell elevations. Remaining WY2023 hydrology confidence is high and accommodating of a Spring HFE.**

Water Quality

The bypass tubes withdraw water from deeper in the reservoir than the penstocks. 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. Turnover in Lake Powell reservoir can occur from mid-October to November and in March 2023, the reservoir temperature is mixed from 5 meters below the surface to the bottom (hypolimnion) of the reservoir between 8 and 7.4 deg C respectively. A significant change in the hypolimnion temperature or dissolved oxygen levels between March and April is not expected, with mainly surface reservoir warming expected. So a spring HFE is not expected to have any meaningful change in the existing discharge water temperature. Later in the season, with an increased Lake Powell water surface elevation and a removal of some of the hypolymnetic cooler water during the HFE, there might be a slight increase in the temperature of the penstock discharge water.

There is a parcel of hypoxic water (~ 2.5 mg/L) at the river outlet elevation in the forebay, while the dissolved oxygen concentration of the penstock water is 7.5 mg/L. Opening the river outlet tubes for a spring HFE will oxygenate hypoxic water via aeration and may have the added benefit of mixing oxygen downward to alleviate the metalimnion and hypolimnion low oxygen (Hueftle and Stevens 2001). We do not anticipate that the 2023 proposed spring HFE will negatively affect water temperatures or dissolved oxygen during the HFE or in the ensuing months compared to not performing an HFE. A spring 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, low phosphorus).

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 (LMNRA) 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 LMNRA 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.

Safety Considerations: Research and Monitoring

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.

VII. 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 spring 2023 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.

VIII. Monitoring and Coordination During Implementation

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.

IX. Post Experiment Reporting and Planning

The PI Team would coordinate to report initial findings at the 2023 GCDAMP Annual Reporting Meeting, scheduled for January 2024 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 9.5 maf releases will lead to higher sand export compared to typical 8.23 maf release patterns.
- The PI Team would meet in early 2024 to review the implementation and results of all 2023 experimental activities, and to begin coordination on the evaluation of resources and potential experiments that may be conducted in 2024.
- 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.

X. GCDAMP and LTEMP PA Consultation

Notification of the potential for a LTEMP sediment-triggered Spring HFE was communicated to GCDAMP stakeholders at the GCDAMP Annual Reporting Meeting in January 2023, though the specific concept of this April HFE has not yet been communicated to stakeholders. A follow-up informational webinar will be held with GCDAMP stakeholders as an opportunity to ask questions and provide feedback before implementation. Representatives from the Basin States participated in the development of this recommendation. Reclamation and GCMRC will present the findings to the TWG on October 12-13, 2023.

On February 22, 2023, 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. As of March, 30, 2023, 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.

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