January 29, 2021

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

From: LTEMP Planning/Implementation Team

Re: Final Recommendation to Implement a Spring Disturbance Flow at Glen Canyon Dam in March 2021

## I. Introduction

The LTEMP Planning/Implementation Team (PI Team) recommends, by consensus, that a spring disturbance flow be implemented at Glen Canyon Dam beginning March 15 and ending March 26, 2021.

Under the 2016 LTEMP Record of Decision (ROD), High Flow Experiments (HFEs) are the primary type of flows that cause disturbance to the Colorado River ecosystem downstream of Glen Canyon Dam. Past studies have indicated that impacts to natural processes and other biological resources would be maximized with spring-timed HFEs, while building of beaches and sand bars would be maximized with fall-timed HFEs. To fill the knowledge gap left by infrequent Sediment-Triggered Spring HFEs, Adaptive Management Work Group (AMWG) subcommittees worked to develop a spring disturbance flow hydrograph that includes a high spring release within the normal operating constraints of the 2016 LTEMP Record of Decision (i.e. 25,000 cubic feet per second).

The proposed spring disturbance flow capitalizes on a unique low flow of 4,000 cubic feet per second for 5 days, which is needed to conduct maintenance on the apron of Glen Canyon Dam. This low flow disturbance would be followed by a high flow disturbance that will culminate in a discharge of approximately 20,150 cubic feet per second for 82 hours. Although the LTEMP ROD permits releases of up to 25,000 cubic feet per second under normal operations, powerplant capacity is currently constrained due to hydrologic conditions and maintenance outages. The proposed combination of desiccation at low flows followed by scour at high flows is hypothesized to disturb benthic habitats to a much greater extent than either the low or high flows alone. Technical experts at the U.S. Geological Survey's (USGS) Grand Canyon Monitoring and Research Center (GCMRC) and Western Area Power Administration (WAPA) have coordinated design of the recommended experiment to optimize benefits for the aquatic ecosystem throughout Glen, Marble, and Grand Canyons (the Canyon) while minimizing negative impacts to hydropower.

The purpose of this memorandum is to transmit this recommendation to the Glen Canyon Leadership Team for Implementation of Experiments (Leadership Team) under the LTEMP and to the Department of the Interior (Department) in accordance with the LTEMP Record of Decision (ROD). The PI Team includes technical representatives from the National Park Service (NPS), the U.S. Fish and Wildlife Service (FWS), the Bureau of Indian Affairs (BIA), USGS-GCMRC, the Bureau of Reclamation (Reclamation), WAPA, the Arizona Game and Fish

Department (AGFD), and one liaison from each of the seven Colorado River Basin States (States) and the Upper Colorado River Commission (UCRC). The PI Team evaluated the latest data from agency experts and considered multiple issues, as summarized below, to develop this final recommendation to implement the spring disturbance flow.

## II. LTEMP Process for Implementing Experiments

The 2016 LTEMP ROD provides the framework for implementing flow experiments at Glen Canyon Dam when resource conditions warrant. The purpose of LTEMP experiments is to leverage adaptive management to better protect, mitigate adverse effects, 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 (GCDAMP) ensures the best science and data are available for making decisions related to flow experiments. While not an "experiment" or "experimental treatment" as those terms are used in the LTEMP (i.e. a research-driven flow that is 1) outside the range of normal operations allowed by the LTEMP ROD, and 2) specifically evaluated and proposed for implementation in the preferred alternative of LTEMP Final Environmental Impact Statement), the spring disturbance flow was developed and evaluated by the AMWG within the adaptive management framework of the LTEMP. Because of its usefulness, the LTEMP communication and consultation process was adopted here for considering if conditions warrant implementing a spring disturbance flow.

Under the LTEMP ROD, the Department may conduct flow experiments at Glen Canyon Dam when resource conditions warrant and if it is determined that there will not be unacceptable adverse impacts to other resources. The process for recommending experiments under the LTEMP, which has been used for past experiments and has been followed here, involves outreach to GCDAMP partners through regular meetings and additional notification to Tribes inviting consultation. The process also involves coordination with the PI Team to plan for implementation, evaluate the status of resources, and make the technical recommendation to conduct an experiment. The PI Team presents its recommendation to the Leadership Team, which makes a recommendation to the Department. The Secretary of the Interior (Secretary) retains decision making authority as to whether to implement an experiment. The Secretary's Designee to the AMWG is the chair of the Leadership Team and often communicates the Department's decision regarding implementation.

## III. Recommendation: Spring Disturbance Flow

The proposed spring disturbance flow includes a combination of desiccation at low flows followed by scour at high flows. This combination of low and high flows is hypothesized to disturb benthic habitats to a much greater extent than either the low or high flows alone (Kennedy and others 2020). Disturbance of benthic habitats in spring may drive aquatic ecosystem responses like increased algae and insect production, thereby increasing aquatic insect prey available for endangered humpback chub (*Gila cypha*), non-native rainbow trout (*Oncorhynchus mykiss*), an important sportfish, as well as other wildlife that inhabit the Canyon like birds and bats. The spring disturbance flow may disadvantage brown trout (*Salmo trutta*) in Glen Canyon by reducing survival of emerging fry; potential methods to address this nonnative are of interest owing to recent increases in brown trout abundance in Lees Ferry and the threat this piscivore represents to humpback chub and other native fishes downstream in Grand Canyon. The spring disturbance flow may also provide new scientific information that can be used in future decision making.

*Purpose and Goal*

The primary driver of the low flow portion of the proposed hydrograph (4,000 cfs for 5 days) is to allow a Reclamation dive team to safely complete necessary maintenance on the apron immediately downstream of Glen Canyon Dam. The research purpose of the spring disturbance flow is to determine whether this type of operation can trigger beneficial aquatic ecosystem responses such as higher algae and insect production, similar to what was observed following the March 2008 HFE. Aquatic insects are the cornerstone of Colorado River food webs and they fuel growth of humpback chub, rainbow trout, and other desired fish and wildlife species downstream of Glen Canyon Dam. By initiating a disturbance that more closely matches the seasonal timing of pre-dam floods compared to recent fall HFEs, the spring disturbance flow is expected to enhance natural processes that sustain Colorado River food webs. The spring disturbance flow was conceived collaboratively by the Flow Ad Hoc Group (FLAHG), a subcommittee of the GCDAMP Technical Work Group (TWG), and GCMRC in response to a charge from the AMWG "…to evaluate opportunities for conducting higher spring releases that may benefit high value resources of concern to the GCDAMP (recreational beaches, aquatic food base, rainbow trout fishery, hydropower, humpback chub and other native fish, cultural resources, and vegetation), fill critical data gaps, and reduce scientific uncertainties."

*Flow Design and Description*

GRMRC and Reclamation recommend that the release schedule for the spring disturbance flow should:

- Begin ramping down at 6:00 am on Monday, March 15, reaching 4,000 cfs at 8:00 am.
- Apron repair releases (4,000 cfs): 8:00 am on Monday, March 15 to 7:59 am on Saturday, March 20.
    - Required maintenance will be conducted during this time.
- Daily up ramps:
    - to 7,550 cfs beginning at 8:00 am on Saturday, March 20,
    - to 13,850 cfs beginning at 7:00 am on Sunday March 21, and
    - to approximately 20,150 cfs beginning at 7:00 am on Monday, March 22.
- Powerplant capacity release (approximately 20,150 cfs): 8:00 am on Monday, March 22 to 5:59 pm on Thursday, March 25.
- Down ramp: to 13,850 cfs beginning at 6:00 pm on Thursday, March 25.
- Completion of spring disturbance flow (back to normal operations): 9:00 am on Friday, March 26.

All ramp rates and daily fluctuation ranges will stay within ROD constraints of 4,000 cfs per hour up ramp, 2,500 cfs per hour down ramp, and a daily fluctuation factor of 6,300 cfs/day (0.9 x 700,000 acre-feet).

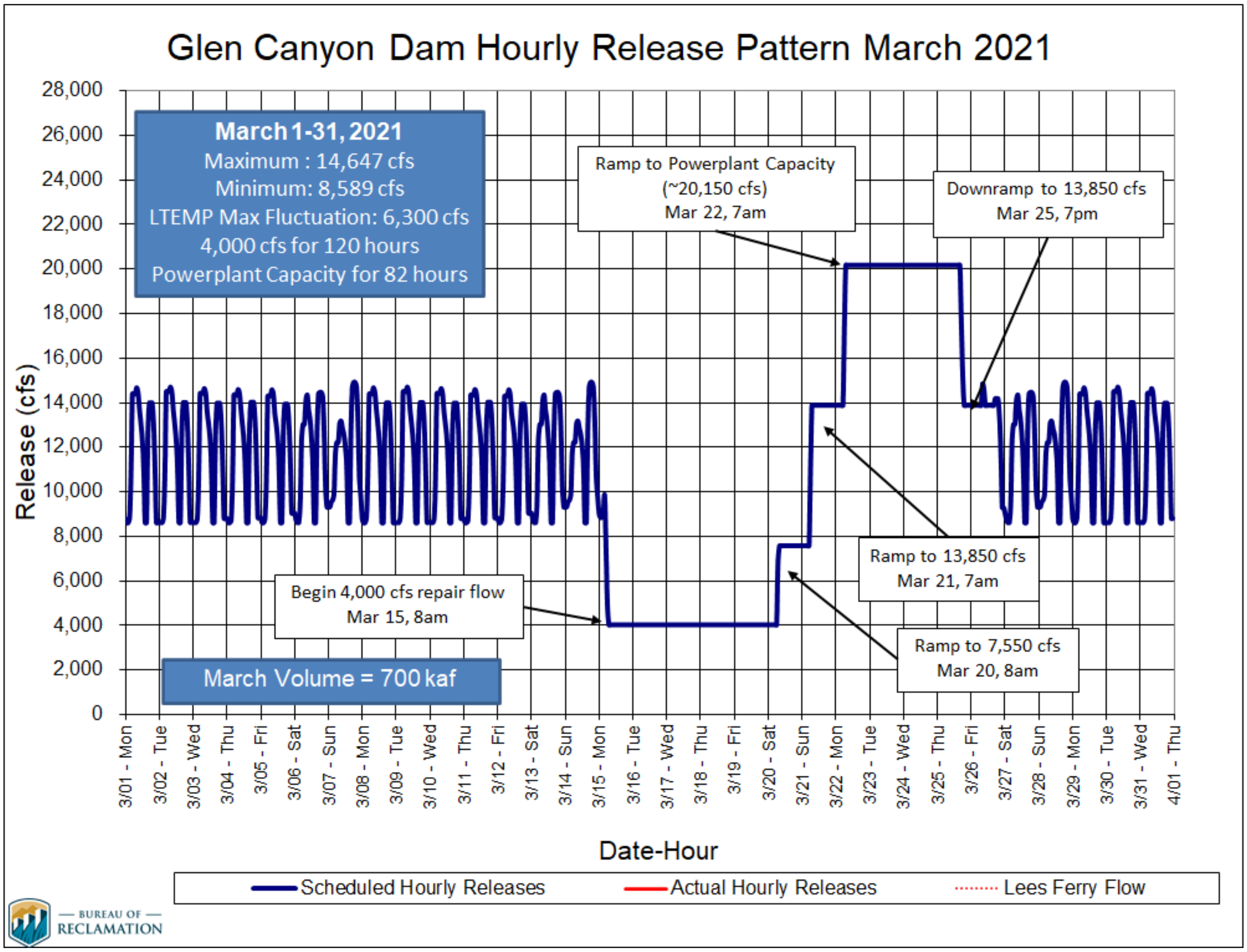


Figure 1. Spring disturbance flow hydrograph that is recommended for implementation in March 2021.

*Water delivery*

The recommended spring disturbance flow will not result in changes to the monthly or annual release volumes from Glen Canyon Dam and Lake Powell, in compliance with the 2016 LTEMP and the 2007 Interim Guidelines. Reclamation currently projects the annual release volume for water year 2021 will be 8.23 million acre-feet, which is under the minimum and most probable inflow scenarios.

## IV. 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 (VanderKooi and others 2017). This approach relies on water quality, sediment, aquatic biology, and other resource monitoring and research projects funded in the GCDAMP Fiscal Year (FY) 2021-23 Triennial Budget and Work Plan (Reclamation and GCMRC TWP, U.S. Department of the Interior, 2020). These projects funded in the TWP provide valuable long-term data that will help quantify effects of the spring disturbance flow on the downstream resources of Glen, Marble, and Grand Canyons.

GCMRC also developed a stand-alone, interdisciplinary project as an addendum to the FY2021-23 Triennial Budget and Work Plan (Project O) outlining research and monitoring activities that could be conducted if a spring disturbance flow is authorized and implemented. Project O aims to quantify the effect of the spring disturbance flow on high value resources of concern to the GCDAMP (recreational beaches, aquatic food base, rainbow trout fishery, hydropower, humpback chub and other native fish, cultural resources, and vegetation). Project O is included as an attachment to this document for readers that are interested in more detailed description of the research and monitoring activities that have been proposed by GCMRC to track ecosystem response to the spring disturbance flow.

Owing to limited time between a final decision by DOI and the implementation date, proposed monitoring (O.7) that would intensively study movement of sonic tagged native fish in response to the spring disturbance flow cannot be conducted. Nonetheless, there are still opportunities for understanding native fish movement in relation to the spring disturbance flow using existing monitoring data that will be collected as part of the TWP; GCMRC and collaborators will analyze other native fish data collected within the WY 2021 workplan (e.g., LCR-MUX data and mark-recapture data) to glean insights concerning native fish movement patterns during the spring disturbance flow.

*COVID-19 contingencies*

The evolving COVID-19 pandemic and response may affect GCMRC's ability to fully implement Project O and monitor the spring disturbance flow as planned. Employee health and safety remains the highest priority during the ongoing pandemic. GCMRC has developed and implemented COVID-19 safety protocols to reduce risk of infection and ensure staff safety. GCMRC leadership will actively monitor conditions and will modify or cancel any planned activities as needed to ensure the health and safety of all staff.

## V. Assessment of Resources

Following procedures in the LTEMP ROD, the PI Team completed an assessment of key resources that may be impacted or affected by a spring disturbance flow in making this recommendation. This assessment relies heavily on the recently completed "Predicted Effects of a spring disturbance flow on LTEMP Resources" report by the FLAHG (https://www.usbr.gov/uc/progact/amp/amwg/2020-11-17-amwg-meeting/20201117-PredictedEffectsSpringDisturbanceFlowLTEMPResources-508-UCRO.pdf). This analysis and document describe the predicted effects of the spring disturbance flow on the 11 Resource Goals identified in the LTEMP, as determined by technical experts at GCMRC and cooperating agencies. Based on this evaluation, the PI Team did not find any evidence that would indicate a spring disturbance flow conducted March 15th to 26th, 2021 would have sufficient potential adverse effects to other resources that would lead to a recommendation to not conduct the flow. Below are qualitative narratives describing predicted effects of the proposed spring disturbance flow on each of the 11 LTEMP resources.

*Archaeological and Cultural Resources*

No major adverse impacts to archaeological or cultural resources are anticipated if the spring disturbance flow is implemented. For cultural resources other than archaeological sites, such as traditional cultural places (TCPs), the predicted effects from the spring disturbance flow are expected to be minor, considering that the upper limit of the hydrograph is still within normal dam operations. However, considering that these kinds of resources encompass a wide variety of TCPs, which include ancestral archaeological sites but may also include springs, landforms, shrines, plant and mineral gathering areas, and many others, the actual effects may vary widely. It must be understood that the different participant tribes in the GCDAMP do not necessarily view these places from the same perspective, and the way that effects are ultimately perceived may vary as well. It also must be pointed out that the distinction of "Archaeological and Cultural Resources" from "Tribal Resources" does not mesh well with the perspectives of the tribal stakeholders in the GCDAMP, who view all of these as an inextricably intertwined whole and the entire landscape within the Colorado River ecosystem as a holistic and sentient entity. Reclamation determined that the spring disturbance flow may have an effect, but is not likely to have an adverse effect, on a National Register-eligible traditional cultural property (the Colorado River through Grand Canyon). In accordance with Stipulation I.A.2 (c) in the 2017 cultural Programmatic Agreement (PA) for the LTEMP, notification of the determination was emailed to Tribes and Parties to the PA on January 22, 2021.

The low flow portion of the hydrograph may temporarily increase aeolian transport of sand from the river channel to archaeological sites in dunefields by increasing the amount of exposed sand available for aeolian transport by as much as 400% (Kasprak and others in review, Kasprak and others 2018, Sankey and others 2018). However, the duration of the low flow is short and so effects on aeolian transport are expected to be minor. Although the high flow portion of the hydrograph will decrease the supply of sand available for aeolian transport, the duration of high flows is also short, so any reductions in aeolian transport are expected to be temporary and minor.

*Natural Processes*

For the purposes of this document, we evaluate how the spring disturbance flow will affect two key natural processes (algae production, insect production), which were identified by GCMRC scientists as representative of the LTEMP goal. Although algae production may not have historically been an important natural process sustaining river food webs (Kennedy and others 2013), in the post-dam river, algae constitutes the base of the food web in Glen, Marble, and Grand Canyon (Stevens and others 1997, Cross and others 2013). Continuous monitoring of algae production at multiple sites using dissolved oxygen sensors began in 2011 and has allowed scientists to estimate algae production on daily time scales (Hall and others 2015). Aquatic insects are the primary prey consumed by native and desired non-native fishes in the post-dam river (Kennedy and others 2013) and insects are also thought to have represented a cornerstone of pre-dam food webs (Kennedy and others 2016). Monitoring insect production in the drift has occurred continuously since 2008 (Kennedy and others 2014) while citizen science light trapping has occurred since 2012 (Kennedy and others 2016).

The spring disturbance flow will likely alter rates of algae production (technically measured as gross primary productivity (GPP)) and these effects will vary by river segment. In the Glen Canyon segment, the spring disturbance flow should lower overall GPP owing to desiccation and scour of rooted aquatic vegetation during the low and high flow portions of the hydrograph, respectively. Although total GPP is expected to be lower in Glen Canyon, the availability of newly cleaned gravel substrates is expected to increase production of fast-growing and palatable diatoms, which should in turn lead to increased production of aquatic insects (Project O.1), similar to what was documented during the 2008 Spring HFE (Cross and others 2011).

In Grand Canyon, cobble bars and shallow edge habitats are hot spots for GPP and insect production, and deeper pools are generally unproductive (Stevens and others 1997, Cross and others 2013, Hall and others 2015). The spring disturbance flow is expected to desiccate and scour cobble bars and other edge habitats, leading to declines in GPP over the short term. This disturbance is predicted to also favor fast growing and palatable diatoms and disadvantage the unpalatable blue-green algae (i.e., Oscillatoria spp.) that can sometimes proliferate in the intertidal zone in Grand Canyon (Stevens and others 1997). Blue-green algae do not fuel invertebrate growth (Stevens and others 1997, Wellard-Kelly and others 2014), so this predicted shift in composition of primary producers towards palatable diatoms is expected to increase insect production over the long-term (see Project O.1). For aquatic insects, black flies may show a particularly strong positive response to the spring disturbance flow owing to improvements in habitat quality associated with scouring cobbles and cleaning substrates; black fly densities are greatest on clean cobble bars and they exhibited a nearly 400% increase in production following the 2008 spring HFE (Cross and others 2011).

Phosphorus concentrations may be an important modifier of ecosystem responses to the spring disturbance flow hydrograph. The spring disturbance flow has the potential to increase concentrations of soluble phosphorus over the short-term owing to desiccation and subsequent mineralization of organically bound phosphorus during low flow, followed by phosphorus release during the high flow. This phenomenon of phosphorus release immediately following drying and desiccation of edge habitats has been documented across diverse sediment types (Kinsman-Costello and others 2016). Whether this pulse of soluble phosphorus occurs during a spring disturbance flow test may depend on overall background sediment phosphorous concentrations along the river margins that will be exposed to desiccation during low flows. If phosphorous concentrations are elevated during the spring disturbance flow, either because of the mechanisms described above or owing to high soluble phosphorus releases from the dam, this would also be expected to favor fast-growing diatoms during the recovery phase that follows a disturbance. Turbidity during the months following the spring disturbance flow will also be an important modifier of ecosystem response, with low turbidity conditions expected to favor fast-growing diatom and insect production while elevated turbidity conditions may slow these processes.

*Humpback Chub*

No major adverse impacts to humpback chub are anticipated if the spring disturbance flow is tested. The low and high flows of the spring disturbance flow, while unusual relative to base dam operations, are minor compared to the extreme low and high flows the river historically experienced. This means wide-spread stranding and displacement of humpback chub is unlikely during testing of this spring disturbance flow. Effects of the spring disturbance flow on humpback chub would likely be positive and through indirect pathways such as increased GPP and/or increased aquatic insect productions, given the proposed timing of the action in early spring.

Humpback chub might also benefit from a spring disturbance flow via reductions in the abundance of nonnative brown trout, which prey upon humpback chub. Other studies suggest flows similar to the spring disturbance flow are capable of reducing brown trout recruitment if they occur during sensitive incubation and emergence periods for brown trout (e.g., Lobón-Cerviá 2009). The exact timing of incubation and emergence of brown trout in Glen Canyon is poorly understood, but anecdotal observations and expert opinion suggest incubation and emergence may be occurring from January-March, which means a test of the spring disturbance flow hydrograph in mid-March could lower brown trout recruitment.

*Hydropower and Energy*

This hydropower analysis evaluates the impact of adjusting releases to accommodate a possible spring disturbance flow proposed while staying within the scheduled monthly volume for March 2021. This analysis uses the hourly market prices to value the electrical energy produced by Glen Canyon Dam. Two release scenarios were evaluated: one involving rescheduling water that would have been released during the apron repair evenly across the remaining days of the month and following normal hydropower operations, and a second involving rescheduling the water that would have been released during the apron repair as a block release for a spring disturbance flow. The hydropower impacts of the apron repair and rescheduling water to either the rest of the month or as a block release for a spring disturbance flow are negative but very small relative to net generation value for the month. The impact of doing the apron repair low flow alone results in an estimated cost of $8,453 in a month where the net generation value is approximately $7.6 million. The small size of this cost is primarily due to a low differential in on-peak and off-peak power prices that are typical for months with lower power demand (i.e., “shoulder months”, such as March). Adding a spring disturbance flow after the apron repair yielded an additional estimated cost of $4,475. Finally, as a sensitivity analysis, we also evaluated a range of spring peak durations (i.e., 34, 58, 82, and 106 hours) to evaluate how the duration of the spring disturbance flow affected hydropower, and overall impacts to hydropower remained small across all these durations when modeled with forecasted power prices for March 2021.

Water releases from Glen Canyon Dam during the 2021 spring disturbance flow may be affected by electrical disturbances of the electrical system. Electrical system operations for these disturbances are required by Reclamation and WAPA under law, contracts, and other agreements. Changes in water releases at Glen Canyon Dam to assist in recovery from electrical system disturbances are of two types, regulation and contingency reserves; 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 Colorado River Storage Project (CRSP) powerplant capable of the immediate responses required for regulation. The regulation responses can either slightly increase or decrease Glen Canyon Dam water releases and can be as much as ±1,100 cfs (40 mw) for up to 1 hour and 59 minutes. WAPA will be able move contingency reserves from Glen Canyon Dam to the Aspinall units during the 2021 spring disturbance flow which will allow for the highest release possible from the facility given the current maintenance constraints.

An additional consideration for impacts during the March 2021 apron repair and spring disturbance flow is WAPA's potential entry into the Western Energy Imbalance Service market (WEIS) on March 1, 2021. The scale of potential impact is unknown; however, it should be noted that the need for increased coordination of operations during this time will be even more important to mitigate unintentional deviations from the planned electrical output of Glen Canyon powerplant. These deviations, depending on the magnitude, have the potential to cause significant financial penalties to WAPA.

WAPA estimates that the Colorado River Basin Fund will end the 2021 fiscal year with a balance of $102 million. This is below WAPA's target for an end of year balance which puts WAPA at an increased level of financial risk. However, WAPA's evaluation of all factors and projected cost of this spring disturbance flow does not indicate a level of risk preventing a spring disturbance flow in water year 2021.

*Other Native Fish Species*

This assessment of potential impacts of a spring disturbance flow on other native fish species was limited to species of conservation concern (i.e., razorback sucker-*Xyrauchen texanus*, flannelmouth sucker-*Catostomus latipinnis*, and bluehead sucker-*Catostomus discobolus*). No major adverse impacts to other native fish species are anticipated if the spring disturbance flow is tested. The overall range of flows being tested in the spring disturbance flow is relatively minor compared to pre-dam flow regimes under which native fish evolved, so direct effects of stranding and downstream displacement on other native fish are unlikely. It is possible the low flows associated with the spring disturbance flow could desiccate spawning habitat or incubating eggs of razorback sucker if the flow occurs in March; back-calculations of hatch dates from larval razorback sucker collected in 2014 and 2015 indicate peak spawning in mid-March in those years (Gilbert and others in review). However, razorback sucker have a protracted spawning window, so short-term desiccation of eggs during the 5 day low flow would only affect a small proportion of total razorback sucker eggs. However, larval catch rates of razorback sucker have been low in recent years, and no juveniles have been detected in recent years even though annual surveys are conducted.

Spring high flows could stimulate the food base for native fish species in Grand Canyon, leading to higher overall native fish production, although flow effects on the food base may be muted in western Grand Canyon where native fish are most common, similar to what was observed in the 2008 spring HFE (Cross and others 2013). The spring disturbance flow may disfavor production of brown trout, which could indirectly benefit native fish species in Grand Canyon through reduction in predation by nonnative brown trout. Other studies have suggested that flows similar to the spring disturbance flow that occur during critical incubation and emergence periods reduce brown trout recruitment (e.g., Lobón-Cerviá 2009) owing to loss of habitat and reduced prey availability for newly emerged brown trout fry. Minimizing brown trout abundance in the Grand Canyon is an important program goal, because brown trout are a threat to the maintenance and conservation of native fishes (Healy and others 2020).

*Recreational Experience*

No major adverse impacts to recreational experience are anticipated if the spring disturbance flow is implemented, however some minor impacts to recreational experience are expected and will vary by recreation type. River corridor access will not be affected by the spring disturbance flow. For flatwater boating in the Glen Canyon reach, the spring disturbance flow is anticipated to have no impact based on the findings of Bishop and others (1987). For whitewater boating, the spring disturbance flow is anticipated to negatively impact navigation and time on river during the five days of low flow and increase the risk of boats getting stuck or stranded on submerged or emergent rocks.

The maximum discharge of the spring disturbance flow will benefit whitewater boating. Whitewater boaters have strong preferences for flows of this magnitude (i.e., ~20,000 cfs) and discharges will be similar to those during summer months (Bishop and others 1987, Neher and others 2017). The action is not expected to increase sediment deposition or total sandbar volume, but the low flow will increase camp-able area temporarily, and the pulse flow may ‘refresh’ camps that have been disturbed by gully erosion and other factors.

It is anticipated that the low flow of the spring disturbance flow will have a strong negative effect on angler access in Glen Canyon by creating navigational risks. However, fishing, especially that focused on harvesting brown trout under the Incentivized Harvest program, may improve as low flows reduce drifting invertebrate prey, potentially enhancing the attractiveness of artificial lures used by anglers. These effects on fishing, either positive or negative, will be of limited duration.

The spring disturbance flow may benefit the recreational experience goal through improvements in navigation in western Grand Canyon. Poor navigation has been identified as an issue of concern by the Hualapai Tribe for many years, as the Tribe operates a river running enterprise in this reach of the river. Navigation risk and shallow channel depths in this reach impacts recreation resources for the Tribe and other non-tribal river recreation. Both tribal and non-tribal river trips have noted safety concerns due to hidden sandbars lying just below the water surface.

*Sediment*

No major impacts to sandbar resources are anticipated if the spring disturbance flow is implemented. Because the maximum discharge of the spring hydrograph is approximately 20,150 cfs, which is similar to normal peak discharges during winter and summer months, and the 82 hours at peak discharge is relatively short, the spring disturbance flow is expected to have weak impacts on sandbar volume, sand storage, and campsite area. Sandbar volume and campsite area could experience small increases, small decreases, or no net change. The direction of the response is uncertain and will vary by reach and depend on antecedent sediment conditions. Some campsites may benefit from small amounts of deposition during the spring disturbance flow, which will not substantially change sandbar area but will improve campsite condition by smoothing out minor features such as gullies. Minor negative impacts to sandbar resources will likely occur during the spring disturbance flow owing to slight decreases in sand storage in eddies overall, because rates of sediment transport will be elevated during the approximately 20,150 cfs pulse flow. However, the impact that 82 hours of elevated sand transport has on sand storage will likely be minor and vary by river segment, with some segments possibly experiencing zero net change or even increasing sand storage during the spring disturbance flow test.

A sand transport/budget model (Wright et al. 2010) was used to estimate the marginal impact of the spring disturbance flow on the sand mass balance in upper Marble Canyon compared to normal operations. The model was run on January 27, 2021 and estimated the sand mass balance for the entire spring accounting period (December 1 to June 30) using projected dam operations data for this 7-month interval and using sediment input data from December 1, 2020 to January 27, 2021 (i.e., the date the model was run). Assuming no additional inputs of sand from the Paria River from January 27 until the end of the accounting period on June 30, the conservative lower bound estimate for sand mass balance over this 7-month interval is -161,200 metric tons under normal operations and -187,200 metric tons under the spring disturbance flow. Thus, assuming no additional sediment inputs, the effect of the spring disturbance flow hydrograph on sand mass balance in upper Marble Canyon is an estimated 26,000 metric tons of additional sand export.

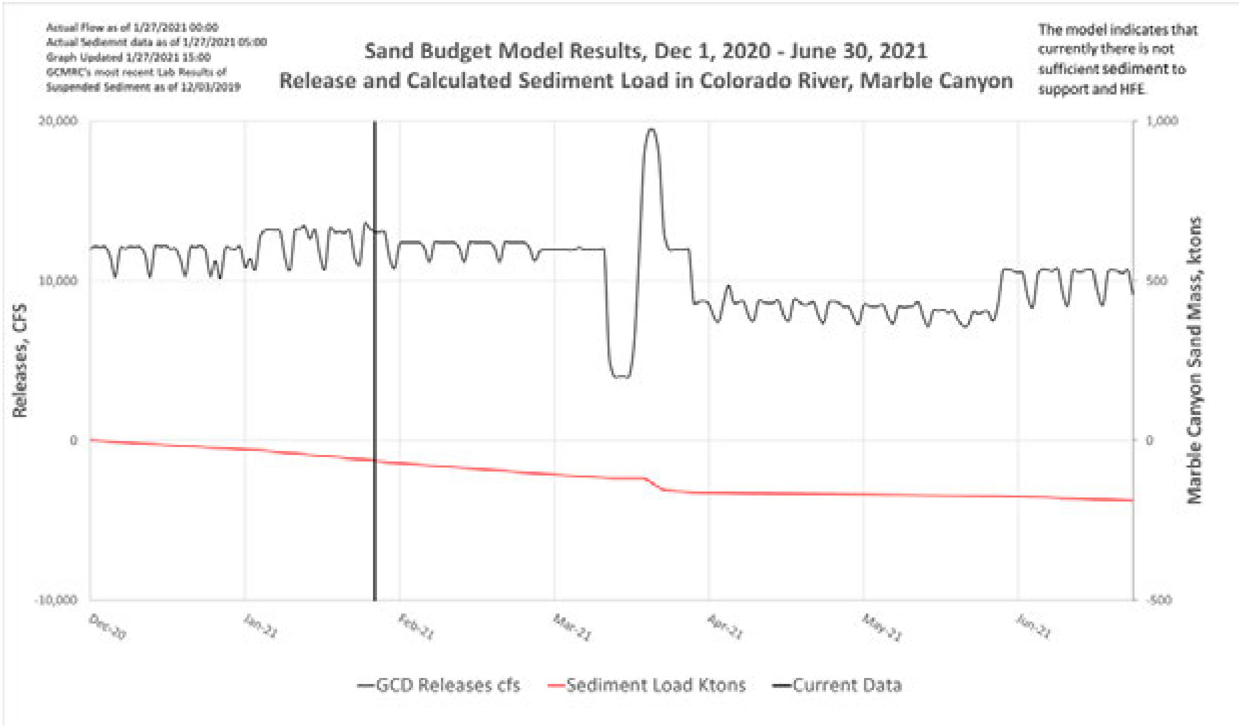


Figure 2. Sand budget model results from January 27, 2021. The spring disturbance flow is projected to export an additional 26,000 metric tons relative to normal operations.

*Tribal Resources*

The LTEMP FEIS considers Tribal Resources as two intertwined domains: "(1) traditional cultural places (TCPs)—those elements with fixed and defined locations, and (2) traditional cultural resources—resources that are either widely scattered or mobile, such as riparian vegetation, birds, mammals, and fishes" (FEIS 4-251). The latter domain essentially falls within the general category of the river corridor's ecosystem, as measured by the health of the ecosystem, as well as the health of the river's spiritual nature. It must be pointed out that the distinction of "Tribal Resources" from "Archaeological and Cultural Resources" does not mesh well with the perspectives of the tribal stakeholders in the GCDAMP, who view all of these as an inextricably intertwined whole and the entire landscape within the Colorado River ecosystem as a holistic and sentient entity.

As the proposed upper end of the spring disturbance flow is within normal dam operations, it is not expected to result in any additional direct impacts to archaeological sites or TCPs that would not occur under these normal conditions. Although sediment transport and sandbar building is expected to be relatively minimal compared to HFEs, some sediment could be deposited on lower beach and bank areas near ancestral archaeological sites and temporarily stabilize or enhance existing conditions, with some sand redepositing through aeolian transport further upslope, potentially providing sediment for covering certain archaeological sites in optimal locations. However, as the kinds of TCPs vary widely and their significance to the various participant tribes in the GCDAMP varies as well, the specific impacts are difficult to predict without further observations by tribal monitoring trips.

As discussed previously, it is expected that high flow releases in the spring, even though very limited in comparison to pre-dam conditions, would more closely emulate pre-dam natural flow regimes, resulting in responses by plant and animal communities along the river that are predicted to enhance the ecosystem by promoting spring reproductive and growth patterns that existed before the dam to some extent. In this regard, the proposed hydrograph may have the potential to "increase the health of the ecosystem in Glen, Marble, and Grand Canyons (see Tribal Resource Goal 4.9.1.1 in the FEIS; also Philips and Jackson 1997, Dongoske and Seowtewa 2011, Joe 2014, Bullets 2015, Yeatts 2018). This would be expected to be true for both plant and animal species, and aquatic and riparian species in particular. Direct evidence of the important role of spring high flows in enhancing health of the Colorado River ecosystem is seen in annual trends in frog populations, which appear to have increased in years with high spring flows (Larry Stevens, Grand Canyon Wildlands Council, personal communication to Peter Bungart).

*Rainbow Trout Fishery*

The spring disturbance flow has the potential to moderately positively affect the rainbow trout fishery in Lees Ferry, but the strength of that effect will likely depend on the response of the food base to the proposed flow. The low flow associated with apron repair work will dewater approximately 20-25% of the channel Glen Canyon-wide and up to ~50% of the cobble bars closest to the dam relative to typical maximum flows in March (Kennedy and others 2020). This dewatering has the potential to kill emerging rooted macrophytes or macroalgae (e.g., Benenati and others 1998). Scouring and cleaning of cobble bars should facilitate re-growth of fast-growing diatom assemblages that are more palatable to invertebrate consumers, similar to what occurred after the Spring HFEs of 1996 and 2008 (e.g., Webb and others 1999; Cross and others 2013; Korman and others 2011). Further, the spring disturbance flow might improve the quality of spawning gravels for rainbow trout through scouring of fine sediment and improvements in the rearing and feeding environment for juvenile rainbow trout that emerge two months or more after the flow (e.g., Korman and others 2011).

*Nonnative Invasive Species*

No major adverse impacts to Nonnative Invasive Species are anticipated if the spring disturbance flow is tested. Green sunfish may take advantage of the high flow portion of the spring disturbance flow and colonize areas like the -12 mile slough, but this colonization occurs annually and would likely occur in the summer anyway, when summer peaking flows will be similar to the spring disturbance flow peak discharge. To mitigate potential colonization of green sunfish during periods of elevated flows, the NPS has enhanced the screens and netting between the Upper and Lower Slough to minimize opportunities for adult green sunfish to enter the warmer, off-channel, waters of the Upper Slough.

The spring disturbance flow may disadvantage brown trout owing to reduced survival of emerging fry. High flows in late winter or early spring are known to disadvantage brown trout, because this coincides with the period of fry emergence, when young fish are seeking food and territory (Runge and others 2018). It is possible that the low flow portion of the spring disturbance flow may dry out some brown trout redds and/or strand some brown trout fry. However, the down-ramp rate during the proposed spring disturbance flow hydrograph is experienced by brown trout on a daily-basis during routine load-following flows, so stranding of brown trout during the spring disturbance flow is likely to be minor.

*Riparian Vegetation*

No major adverse impacts to Riparian Vegetation are anticipated if the spring disturbance flow is tested. The 4,000 cfs low flows could temporarily desiccate riparian and obligate wetland plant species that are strongly dependent on river flows, such as sedges, rushes, and many willows, potentially reducing their survival (Gorla and others 2015); however, given the short duration of the low flow (five days) in early springtime, major negative impacts are unlikely. Drought-tolerant riparian species (*Tamarix* spp., for example) are unlikely to be affected by the low flows.

The high flow portion of the spring disturbance flow will provide water to riparian plants established farther away from the river during the time of year that they start to grow. For many species this may temporarily growth (Ralston 2010). However, since the high flow portion of the spring disturbance flow is similar to high flows during summer peaking operations, plant growth is not anticipated to be measurably higher over the long term.

High flows can improve germination and establishment of both native and nonnative plants, but the proposed March timing of the spring disturbance flow is prior to seed release for many species. For example, herbarium records suggest that cottonwood (*Populus fremontii*) are typically in seed in April or May in the Grand Canyon region while coyote willow (*Salix exigua*) and Goodding's willow (*Salix gooddingii*) are in seed later still, from May to September. Thus, a March test of the spring disturbance flow hydrograph is unlikely to improve germination or establish of these native species. Additionally, previous studies indicate a short-duration March high flow is unlikely to contribute to the establishment of *Tamarix* spp., an invasive and nonnative species (Ralston 2010, Mortenson and others 2012).

## VI. Safety Considerations

Potential, but minimal effects on public health and safety could occur in conjunction with the spring disturbance flow, primarily impacting recreational river users. The minimum flows necessary to conduct apron maintenance are lower than the range experienced by recreational users since the mid-1990s. However, March implementation will minimize adverse impacts of the low flows to recreational river users by avoiding the start of the commercial river trip motor season in April. Reclamation and NPS will coordinate to ensure that safety measures are implemented and will provide public notice about the timing and purpose of the unusual flows. The three affected National Park Service units (Glen Canyon, Grand Canyon, and Lake Mead) have coordinated communications plans, medical plans, and resource capabilities for search and rescue responses. Flow and stage change information will be provided via public media, the individual park websites, and by on-site NPS staff at Lees Ferry and Phantom Ranch.

## VII. Communications Plan

A communications plan including key messages, media advisory, and press release will be developed to support communications and public engagement related to the spring disturbance flow. There will not be a media event at Glen Canyon Dam associated with the spring disturbance flow.

Reclamation's Upper Colorado Basin – Interior Region 7 Public Affairs Office, in coordination with NPS, USGS, and WAPA public affairs contacts will lead communications plan development. If the spring disturbance flow is approved, a detailed news release will be issued to media representatives and the public on or near the flow implementation start date. Social media outlets will also be used to communicate with the public leading up to and during the event.

## VIII. Monitoring and Coordination During Experiment Implementation

Members of the PI Team will continue to meet regularly throughout the implementation of the spring disturbance flow. This will occur through the regularly scheduled monthly Glen Canyon Dam operations coordination calls. Scientists conducting field surveys during the flow and agency technical experts will report back on data collected and preliminary results to the Department and the GCDAMP at regularly scheduled meetings. Glen Canyon Dam operations will be adjusted accordingly in the event of unexpected impacts from the spring disturbance flow.

## IX. Post-Experiment Reporting and Feedback

The PI Team will coordinate to report findings at the GCDAMP Annual Reporting Meeting in January 2022. In addition, the PI Team will report ongoing findings at meetings of the GCDAMP Technical Work Group (TWG) and Adaptive Management Work Group (AMWG). Reclamation will include a summary of the effects of the spring disturbance flow in the annual report to the FWS Arizona Ecological Services Office (AESO) submitted in compliance with the 2016 Biological Opinion for the LTEMP. Reclamation and GCMRC will use the monitoring information and feedback from AESO and GCDAMP stakeholders to inform monitoring for future experiments.

## X. Planning for Future Experiments

The low flow portion of the proposed hydrograph will allow Reclamation to safely complete necessary maintenance; additional planning and compliance efforts would be required to consider future implementation of a spring disturbance flow solely for research purposes. The PI Team will meet in early 2022 to review the implementation and results of any 2021 activities, and to begin coordination on the evaluation of resources and potential experiments that may be conducted in 2022. Results of the spring disturbance flow may inform planning and implementation for future LTEMP experiments, such as a Spring HFE. In accordance with the 2016 LTEMP ROD, 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.

**XI. Consultation**

Over the past year, there have been numerous opportunities for Parties to the 2017 cultural Programmatic Agreement (PA) for the LTEMP to engage in development, planning, and implementation of the proposed spring disturbance flow. Reclamation and GCMRC presented much of the information in this report at AMWG, TWG, and ad hoc group meetings in 2020, and at the GCDAMP Annual Reporting Meeting. Representatives of the seven Colorado River Basin States, the Upper Colorado River Commission, and the Arizona Game and Fish Department participated in the development of this recommendation and concur with its implementation.

On January 12, 2021, a 30-day advance notification of the potential for a spring disturbance flow to be implemented beginning March 15, 2021 and an offer for consultation was emailed to Tribes and Parties to the 2017 cultural Programmatic Agreement for the LTEMP. As of January 29, 2021, no requests for consultation have been received. A follow-up notification will be sent electronically to the Programmatic Agreement signatories, including Tribes, following the Department's decision regarding the proposed spring disturbance flow.

**XII. Conclusion**

Determining whether to recommend the spring disturbance flow required coordination of many details and effective communication among technical staff of multiple agencies. The PI Team has thoroughly evaluated the issues discussed above and has taken into consideration the information and analysis included in the LTEMP EIS and ROD. The PI Team has reached a consensus recommendation to proceed with implementation of the spring disturbance flow based on the careful assessment of resources and best available science.

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