October 19, 2016

To: Department of the Interior (DOI) Glen Canyon Leadership Team for the High Flow Experimental Protocol (HFE Protocol) and Non-Native Fish Control (NNFC)

From: DOI Glen Canyon Technical Team

Re: Final Recommendation to Implement a Fall 2016 High Flow Experiment at Glen Canyon Dam

I. Introduction

The DOI Glen Canyon Dam Technical Team (Team) has worked over the past month to evaluate existing data in determining this recommendation for a high flow experiment (HFE) to be conducted at Glen Canyon Dam in November 2016 and is recommending that the Leadership Team conditionally approve a fall 2016 HFE. This controlled high flow release would be the fourth HFE conducted under the HFE Protocol.

The purpose of this memorandum is to transmit this recommendation to the Glen Canyon Dam Leadership Team in accordance with the May 23, 2012, Secretarial Directive on the Implementation of Research to Improve Conditions in the Colorado River in Grand Canyon National Park and Glen Canyon National Recreation Area. The Team includes technical representatives from the National Park Service (NPS), the Fish and Wildlife Service (FWS), the Bureau of Indian Affairs (BIA), the United States Geological Survey (USGS) and its Grand Canyon Monitoring and Research Center (GCMRC), and the Bureau of Reclamation (Reclamation), Western Area Power Administration (WAPA), the seven Basin States (States) and the Upper Colorado River Commission (UCRC).

The Team has met several times in recent weeks. Resource and communications specialists have been coordinating with the Team as necessary. The Team incorporated the latest data from agency experts and considered multiple issues, as summarized below, in making this final recommendation. In particular, the Team considered the presence of green sunfish in a backwater slough in Glen Canyon, the 2016 green sunfish risk assessment, and the planned chemical ammonia treatment of the population prior to the proposed November 7, 2016 start date for an HFE. This final recommendation also incorporated technical information and operating experience developed as a result of implementing the 2012, 2013 and 2014 HFEs.

The Team conditionally recommends that an HFE at Glen Canyon Dam be conducted beginning November 7, 2016 with a peak magnitude of approximately 36,000 cubic feet per second (cfs) for 96 hours, as explained below, after 1) by Friday, October 21, GCMRC and NPS personnel confirm ammonia has provided effective treatment for green sunfish in the upper pond and 2) DOI commits to prioritizing the development and implementation of non-native species monitoring and mitigation to be in place within the next year.

II. HFE Protocol

As explained in the Development and Implementation of a Protocol for High-Flow Experimental Releases from Glen Canyon Dam, Arizona, 2011 through 2020 Environmental Assessment (HFE EA; Reclamation 2011), the HFE Protocol is experimental in nature and is designed to achieve a better understanding of whether, how, and when to incorporate high releases into future dam operations in a manner that effectively conserves natural resources that are intimately connected to the distribution, size, and characteristics of sediment deposits. The HFE Protocol establishes a decision-making framework consisting of three components: (1) planning and budgeting, (2) modeling, and (3) decision and implementation.

Although HFEs are included in the recently completed Glen Canyon Dam Long-Term Experimental and Management Plan (LTEMP) Final Environmental Impact Statement (FEIS), a Record of Decision for the LTEMP has not yet been issued. Therefore, consideration of a fall 2016 HFE is implemented under the 2011 HFE EA and the 2012 HFE Protocol Finding of No Significant Impact (FONSI; Bureau of Reclamation 2012a).

The 2012 HFE Protocol uses predictive models to make recommendations for specific 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 was used to predict the mass of sand that would be transported by an HFE and to estimate if a proposed HFE would transport more or less sand than had been delivered from the Paria River to the Colorado River during the fall accounting period (July 1 to November 30). Only HFEs 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 Protocol includes a review of the model output that may modify the recommended HFE to benefit relevant resources.

Throughout the summer and fall, Reclamation regularly updated its modeling estimates based on cumulative sediment inputs. The modeled HFE shape was based on past years' input from scientists at GCMRC designed meet the twin objectives of providing the greatest resource benefit and developing scientific information that will help better inform future decision making.

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

Sand Budget Model

Because sand transport can be reliably predicted, a sand transport/budget model (Wright et al., 2010) was used to determine the largest and longest HFE that could be conducted that still yielded a positive sand balance in Marble Canyon for the accounting period, (given the mass of sand delivered by the Paria River since July 1 of any given year). Model runs iteratively cycled

through the different HFE types to determine the largest HFE types that did not result in a negative sand balance. Following several storm events in the Paria River watershed, September 2016 model results predicted there was sufficient sediment for implementation of an HFE under the Protocol.

The sediment modeling component uses the sand transport/budget numerical model developed by the GCMRC. Model results reliably matched measured conditions in upper Marble Canyon, which is the river segment between Lees Ferry and River Mile (RM) 30.

Model Inputs

Model predictions require estimation of the following:

- Antecedent conditions
- Hydrographs including the potential HFE
- Sand input from the Paria River

Antecedent Conditions

The antecedent conditions required for the sand budget model are bed thickness, in meters, and median particle size, in millimeters. The most recent values represented May 2002 bed conditions. These values were updated to June 2016 by running the sand budget model for the period from 2002 to 2016 and using the results of that simulation as the antecedent conditions of the 2016 HFE model simulations.

Hydrology Input

Hydrology inputs were provided as hourly releases from Glen Canyon Dam in cubic feet per second (cfs). During the modeled period (July 1 – November 30), a combination of historic and future hourly releases were used as the hydrology inputs.

Sand Input

Sand inputs to the sand budget model were provided as hourly loads in kilograms per second (kg/sec). During the modeled period, observed sand loads were used as input up to the date of the simulation. From the simulation date forward, zero future sand input was assumed through the end of the modeled period.

Sand inputs were measured and estimated by GCMRC. Data were made available in real-time to Reclamation through the Paria River USGS/GCMRC water quality website (www.gcmrc.gov/discharge_qw_sediment/station/GCDAMP/09382000#). Estimates of sand inflow were regularly adjusted by GCMRC as field samples were processed in the USGS/GCMRC laboratory.

Paria River sand input data is increased in the model to account for inputs from other tributaries in Upper Marble Canyon. Although inputs from these tributaries are monitored and measured, estimates are not available in real-time. The historic average of these inputs is equal to approximately 10% of the Paria River loads, and is always a very small proportion of the amount delivered by the Paria River. Thus, for modeling purposes, Paria River sand input values are increased by 10% to account for these contributions from the lesser tributaries.

In real time, GCMRC provides estimates of the mass of sand delivered by the Paria River. Monthly, GCMRC provides estimates of the mass of sand that remains on the channel bed and in eddies in Marble Canyon. Initially, estimates are $\pm$40%, because they are only based on modeling predictions. However, the uncertainty in these estimates progressively is reduced, because laboratory analysis of physical samples allows calibration of the model predictions. The range of uncertainty in estimates is reported by GCMRC as an upper and lower bound. For purposes of estimating the amount of newly delivered sand that is available for downstream transport and building of eddy sandbars, Reclamation used GCMRC's lower bound estimate. Thus, Reclamation's assessment of the amount of sand that is available for transport by the HFE is the minimum amount about which the GCMRC has a very high degree of confidence (i.e., a conservative estimate). Although the uncertainty associated with GCMRC's estimate of the actual amount of sand available for transport will inevitably be reduced, use of the lower bound during the HFE planning process ensures that there is minimal risk that the HFE will entrain more sand than is actually available to be transported. Subsequent to the 2012, 2013, and 2014 HFEs, analyses demonstrated that each controlled flood actually transported much less sand than was available to build new eddy sandbars or be transported downstream.

Therefore, while the use of the lower bound during the initial planning process may be appropriate, for some future HFEs, the Technical Team may wish to evaluate whether other decision criteria should be considered in recommendations concerning the magnitude and duration of future HFEs.

The sand mass balance for Upper Marble Canyon, where virtually all of the available sand is presently stored, was estimated by GCMRC and provided to Reclamation. The latest estimates available were for the period July 1 to October 14, 2016 (the last update available for this Technical Team report and recommendation). The estimates for the lower and upper bounds were, respectively, 639,000 and 995,000 metric tons.

HFE Types

Appendix E of the HFE EA listed 13 modeled HFE types ranging from a peak magnitude of 31,500 to 45,000 cfs and ranging in peak duration from 1 to 96 hours. Although the HFE Protocol model evaluates performance of 13 possible types of HFEs, the HFE Protocol decision and implementation phase allows for modifications based on resource conditions and predicted benefits to resources. Thus the HFE Protocol allows for HFEs from 1 to 96 hours in duration, up to 45,000 cfs in magnitude, and ramp rates of up to 4,000 cfs/hour increasing and 1,500 cfs/hour decreasing as defined in the HFE Protocol Finding of No Significant Impact (FONSI; Bureau of Reclamation 2012a) and the operating criteria for Glen Canyon Dam (62 FR 9447).

The modeling for this HFE used a peak magnitude of 36,000 cfs rather than 45,000 cfs due to expected maintenance at Glen Canyon Dam and other limitations due to reservoir head and power regulation. To assist with creating additional generation at Glen Canyon Dam, WAPA offered to move power reserves off of Glen Canyon Dam during a potential fall 2016 HFE, thus decreasing the normal 67 megawatts (MW) of regulation/reserve requirement to 40 MW and increasing the maximum possible peak magnitude of a potential HFE. Based on current reservoir and power plant conditions, the 13 HFE types modeled this year ranged from 21,000 cfs (estimated current power plant capacity) to 36,000 cfs (estimated current power plant capacity plus full bypass) (Table 1).

Table 1. The 13 HFE types tested in model runs.

HFE No.	**Peak Magnitude (cfs)**	**Peak Duration (hrs)**
1	36,000	96
2	36,000	72
3	36,000	60
4	36,000	48
5	36,000	36
6	36,000	24
7	36,000	12
8	36,000	1
9	33,000	1
10	30,000	1
11	27,000	1
12	24,000	1
13	21,000	1

All modeled HFEs assumed a ramp-up rate of 4,000 cfs/hr from base flow to power plant capacity, a rate of one bypass tube (3,750 cfs) every hour up to peak magnitude, and a ramp-down rate of 1,500 cfs/hr to base flow. These ramp rates are in accordance with the HFE Protocol EA and FONSI, 1995 EIS, 1996 Record of Decision, and the Operating Criteria for Glen Canyon Dam (62 FR 9447).

HFE Model Results

The model simulation for the lower bound estimate for Paria River sand input and the HFE hydrograph completed October 14, 2016 estimated 639,000 metric tons of sand supply in all of Marble Canyon (i.e. the Upper and Lower parts) on November 6, 2016 prior to the start of a potential HFE and an estimated 143,000 metric tons on November 30, 2016 following a potential HFE and at the end of the accounting period.

Sand budget model results through October 14, 2016, determined an HFE with a peak magnitude of 36,000 cfs and a peak duration of 96 hours.

HFE Recommendation

GRMRC and Reclamation recommend that the HFE:

- Ramp-up from base releases at 4,000 cfs/hr at approximately 6:00 am on Monday, November 7, 2016 (all times Mountain Standard Time) until reaching powerplant capacity (~21,000 cfs)
- Open first bypass tube at 9:00 am November 7th
- Ramp-up from powerplant capacity to full bypass (~36,000 cfs) at one full bypass tube (~3,750 cfs) per hour in 4 hrs
- Stay at peak release (~36,000 cfs) for 96 hrs
- Ramp-down from peak release to base releases at 1,500 cfs/hr

These recommendations result in the following release schedule at Glen Canyon Dam

- Begin ramp-up from 9,000 cfs at 6:00 am on November 7 (Monday)
- Reach powerplant capacity at approximately 8:00 am on November 7
- Open bypass tubes at approximately 9:00 am November 7
- Reach full bypass at 12:00 noon on November 7
- Begin ramp-down from bypass at 12:00 noon on November 11 (Friday)
- Complete HFE (back to 9,000 cfs) at 3:00 am on November 12 (Saturday)

This recommendation ensures that monitoring to increase scientific knowledge is a priority and places a high priority on USGS/GCMRC's field collection of samples at RM87. Automated pump samplers would collect at least 2 samples during hydrograph rise. Based on the assumed travel time of the HFE release wave, and to ensure the safety of sampling crews as discussed further below, daylight conditions will be available for sampling at all sites.

III. Assessment of Resources

In making this recommendation, the Team completed an assessment of key resources that may be impacted or affected by a 2016 HFE based on the most recent information, and in particular, information collected since the fall 2012, 2013 and 2014 HFEs. This assessment focuses on recent findings and key resources and an evaluation of these resources relative to the proposed timing, duration, and magnitude of the potential fall 2016 HFE as described above using the best available science.

Three HFEs have been conducted under the HFE Protocol: a fall 2012 HFE November 18-23 2012 with a maximum magnitude of approximately 44,700 cfs for 24 hours followed by a slow down-ramp rate of 200 cfs per hour for 30 hours, a fall 2013 HFE November 11-16, 2013 with a maximum magnitude of approximately 37,500 cfs for 96 hours, and a fall 2014 November 10-15, 2014 with a maximum magnitude of approximately 37,500 cfs for 96 hours. The following resource assessment summarizes the results of these first three HFEs, in relation to prior HFE tests, and in developing a recommendation for a 2016 HFE.

The Team refers to Reclamation (2011) and Melis (2011) for more complete summaries of resource effects from HFEs. The following key resources were considered:

- Sediment Resources
  - In-channel sediment storage
  - Sandbar campable area
  - High-elevation sand deposits

- Cultural Resources
  - Archaeological site condition and stability
  - Access to archaeological sites by tribes

- Biological Resources
  - Aquatic food base
  - Lees Ferry trout population
  - Lees Ferry fishery recreation experience quality
  - Endangered humpback chub and other fish abundance
  - Riparian vegetation
  - Endangered Kanab ambersnail

- Hydropower and water delivery
  - Water quality
  - Water delivery
  - Dam maintenance
  - Hydropower production and marketable capacity

In our 2015 resource assessment, we found key information, specifically the presence of green sunfish in a backwater slough in Glen Canyon, that indicated a fall 2015 HFE could have potential adverse effects. This information led the Team to recommend that no HFE take place in fall 2015. In November 2015, green sunfish were eradicated from a pond and slough at RM -12 with a piscicide treatment of rotenone in partnership with Arizona Game and Fish Department (AGFD), NPS, GCMRC, FWS, and others. In 2016, after two sampling trips in which no green sunfish were found, they were found to have reinvaded the pond at RM -12 and had begun reproducing. Subsequent removal efforts have produced only a few adults (2 or 3) but thousands of young green sunfish from 8 to 50 mm long. Concerns related to this new green sunfish invasion as well as several additional issues that warranted further consideration are described in this section.

Sediment Resources: See discussion in Section II for current sediment conditions relative to the HFE Protocol. Responses to the first three HFEs under the HFE Protocol in 2012, 2013, and 2014 were similar to previous HFEs. All resulted in substantial deposition followed by erosion of about half the new deposits within 6 months. Response immediately after the 2014 HFE based on digital camera images of sandbars from Lees Ferry to Diamond Creek indicated that there was a substantial gain (deposition) for 22 sandbars (58% of sites), no substantial change for 11 sandbars (29% of sites), and substantial loss (erosion) for 5 sandbars (13% of sites). Annual topographic surveys of sandbars were conducted between September 23 and October 9, 2015. Data from these surveys indicate that sandbars in Marble Canyon were smaller compared to fall 2014 observations, but still larger than in fall 2012. Sandbar size in eastern Grand Canyon has

changed little since 2012, but has increased in western Grand Canyon including over the interval from fall 2014 to fall 2015.

The aggregate sand mass balance conditions since inception of the HFE Protocol, i.e. for the period between July 1, 2012, and September 30, 2016 for the different segments of the Colorado River (from http://www.gcmrc.gov/discharge_qw_sediment/reaches/GCDAMP) are:

Upper Marble Canyon: + 2.40 million metric tons (the range of this estimate is between +0.52 and + 4.20 million metric tons)

Lower Marble Canyon: + 1.00 million metric tons (the range of this estimate is between +0.54 and + 1.50 million metric tons)

Thus, there was more sand in the Colorado River corridor in Marble Canyon on September 30, 2016, than there was on July 1, 2012 when the HFE Protocol was first implemented.

Cultural Resources: Reclamation (2011) determined that the HFE Protocol could, through multiple HFEs, potentially affect historic properties and the effect would be adverse per 36 CFR 800.5(2)(iv). Reclamation also found that adverse effects to sacred sites could result from the HFE Protocol, primarily from limitation of access of tribes to sacred sites during the period of HFE releases. Reclamation completed the HFE Protocol Memorandum of Agreement (MOA; Reclamation 2012b) with affected tribes and other parties to address these effects. Effects of HFEs to cultural resources are primarily from erosion and redistribution of sediment. Inundation can directly adversely affect sites through erosion, but deposition may help protect sites directly or by providing sources of sand that can bury historic properties via aeolian transport (Reclamation 2011, East et al., 2016). HFEs also may affect access of tribes to historic properties and alter visitation patterns to historic properties (Reclamation 2011).

GCMRC monitoring has shown that recent HFEs have eroded terraces that contain archaeological sites in Glen Canyon NRA. GCMRC research and monitoring has also shown that aeolian dunefields ("high elevation sand deposits") which contain archaeological sites throughout Marble and Grand Canyons are resupplied with sand blown by wind from sandbars that are re-built or maintained by HFEs. The wind transport of sand from sandbars appears to occur over multiple years following an individual HFE and may not outpace erosion of the dunefields and archaeological sites. However, preliminary results from monitoring conducted during 2016 show that several archaeological sites have recently 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.

The MOA has a stipulation, Stipulation 2c, that requires a meeting be conducted with the parties after each HFE event, to review the effects of the HFE, and use the results of the meeting to inform monitoring for future HFEs, and to design and implement any measures necessary to prevent or control adverse effects of future HFEs. Reclamation held an HFE Workshop on February 27, 2015 in Salt Lake City, Utah, and that meeting also served as the HFE MOA meeting to review the results of the 2014 HFE. No adverse effects to historic properties from the 2012, 2013, or 2014 HFEs were identified.

The MOA also includes a stipulation, Stipulation 2b, that requires all the parties be notified at least 30-days in advance of any planned HFEs, and consult with tribes to resolve any conflicts with tribal access to or uses of the Colorado River. DOI began notifying the parties of the potential for an HFE in early September, and the parties were also officially notified of a potential HFE in fall 2015 on September 30, 2015 via letter.

Biological Resources: HFEs can affect aquatic biological resources in Glen, Marble, and Grand Canyons as well as Lake Mead by changing the physical template of the ecosystem. HFEs scour the river bed, primarily in Glen Canyon, removing algae and aquatic plants and animals, which alters the distribution and abundance of aquatic animals, particularly in benthic habitats, and can result in changes to the aquatic food base for fish (Kennedy and Ralston 2011).

Controlled floods have been released from Glen Canyon Dam on the Colorado River six times since 1996. Research conducted around the March 2008 flood demonstrated that this pulse disturbance reduced biomass and cover of aquatic macrophytes, and restructured invertebrate assemblages by favoring fast-growing insect taxa (midges and blackflies) that prefer bare substrates and disadvantaging non-native and non-insect taxa such as mudsnails that prefer macrophyte beds (Cross et al. 2011). These shifts in the invertebrate assemblage and increases in drift concentrations led to dramatic increases in rainbow trout biomass. In the years after this controlled flood (2009-2012), aquatic macrophytes returned, large bodied mudsnails came to dominate, and fast-growing midges and blackflies declined (GCMRC unpublished data).

Controlled floods were again conducted in November 2012, 2013, and 2014, but long-term drift monitoring indicates these fall-timed floods did not restructure invertebrate assemblages, likely due to the seasonal scouring potential of aquatic macrophytes (GCMRC unpublished data). Specifically, primary production monitoring indicates that although these fall-timed floods temporarily reduce macrophyte cover (i.e., lower primary production) these negative effects are not persistent, and macrophyte biomass and production recovers the following spring thereby providing low-velocity habitat that favors mudsnail production. The 2008 spring-timed floods appeared to have a persistent and long-term effect (i.e., >1 yr) on macrophyte production, because this disturbance occurred at the onset of the growing season. Fall-timed floods occur at the end of the growing season at a time when macrophytes are already in the process of shunting biomass and preparing to overwinter. Thus, the timing, rather than simply the magnitude, of controlled floods on the Colorado River appears to affect food web response. In addition, the proposed hourly releases for the days prior to and after the November 2016 HFE (6,500 to 9,000 cfs) may also help address concerns expressed by the Lees Ferry recreational angling community regarding the effects of HFEs on the character, composition, and quantity of the aquatic food base. This is because these flows will reduce the area of exposed cobble bars in Glen Canyon which may affect the condition of aquatic food base (GCMRC unpublished data).

Investigations into the effects of HFEs on key fish species, namely nonnative rainbow trout and native humpback chub, indicate these events do not appear to affect young fish of either species through displacement to downstream habitats or increased mortality (Kennedy and Ralston 2011). For example, trout in Glen Canyon moved very little over intervals that included the 2012, 2013, and 2014 HFEs (Korman et al. 2015). Furthermore, juvenile humpback chub

survivorship in the mainstem Colorado River at the Little Colorado River confluence was actually higher over the 2012-2013 and 2013-2014 periods that included HFEs relative to 2011-2012 interval that did not include an HFE (GCMRC unpublished data) indicating that HFEs do not affect juvenile survival in this reach of the Colorado River. Other fish species present in Glen or Grand Canyons may, however, respond differently. A recent risk assessment of green sunfish in Glen Canyon (Ward 2015) concluded that HFEs pose a risk to spread this invasive species from Glen Canyon to downstream areas in Grand Canyon. This was the main reason a HFE was not conducted in the fall of 2015. Green sunfish are prolific, with a single female capable of producing up to 10,000 eggs. They are also voracious predators of native fish and their eggs. Biologists with the AGFD, NPS, GCMRC, and Reclamation determined that the establishment of a spawning population of green sunfish downstream of Glen Canyon Dam poses an unacceptable threat to native fish including the humpback chub. The re-infestation of green sunfish in the late summer and fall of 2016 has prompted additional mechanical removal efforts and a planned experimental ammonia treatment to chemically eradicate green sunfish from the pond at RM -12 prior to a 2016 HFE.

HFEs may improve spawning habitat for rainbow trout in Glen Canyon by scouring fine sediment and cleaning gravel beds used for spawning. HFEs also suspend and redistribute sediment to higher elevations resulting in changes in aquatic habitat, for example the creation of backwaters (Kennedy and Ralston 2011) as well as deposition along shorelines and gravel bars that allow for aquatic vascular plants to become established (GCMRC unpublished data). HFEs also change the water quality in the river and in Lake Mead downstream by increasing turbidity and altering water quality, in particular, temperature, dissolved oxygen, and specific conductance (Reclamation 2011, Southern Nevada Water Authority unpublished data).

Rainbow trout densities decreased in Glen and Marble Canyons from 2012 to 2015, but populations in these reaches are increasing again due to higher juvenile production in 2015 and 2016. Whereas densities just above and below the Little Colorado River confluence increased between 2012 and 2014 due to downstream movement. By late 2014 trout density in this area declined suddenly and has remained low through 2016 (Korman et al. 2016, GCMRC unpublished data). Typically growth rates for rainbow trout in Glen Canyon vary seasonally with high growth in spring and summer and low growth in fall and winter. Annual rainbow trout growth declined substantially between 2012 and 2014, particularly over spring and summer periods. Growth began increasing in January 2015 following three consecutive years with fall HFEs (GCMRC unpublished data), indicating that changes in growth rates were due to non-HFE factors (e.g., changing trout biomass, variation in nutrient inputs). Growth rates over fall intervals with HFEs were slightly negative (2012, 2014) or slightly positive (2013). The same interval in 2015, however, showed higher trout growth (GCMRC unpublished data). This suggests a weak negative HFE effect on trout growth that appears to be temporary as shown by elevated growth beginning in the December (2012, 2013) or January (2015) following an HFE. Although a dramatic decline in the Glen Canyon rainbow trout population did coincide with the fall 2012, 2013, or 2014 HFEs, increases in juvenile production and growth rates following the 2014 HFE suggest factors other than fall HFEs are driving trout population dynamics in this reach.

Monitoring indicates that rainbow trout in Glen Canyon moved very little during the intervals that included the fall 2012, 2013, and 2014 HFEs. Approximately 90% of age-0 rainbow trout were recaptured within 0.25 miles of their initial release locations (Korman et al. 2016). There is some evidence, based on year class structure, of local rainbow trout recruitment in Marble Canyon; although it is unclear that this has been caused directly by HFEs. Downstream movement and recruitment of rainbow trout appears to be less related to displacement from HFEs and more likely due to changes in the population dynamics in Glen Canyon and possibly Marble Canyon. Dispersal of age-0 rainbow trout appears more likely related to periods when adult rainbow trout exhibit good spawning condition followed by high juvenile densities with increased growth and survival as observed in 2011 and 2016 (Yard et al. 2016; GCMRC unpublished data).

Brown trout catches at the Little Colorado River confluence have remained low since implementation of the HFE protocol. Brown trout are a highly piscivorous species known to eat 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 survival rates, however this effect is uncertain and may be weak relative to other drivers of humpback chub dynamics (i.e., temperature, juvenile recruitment, and potentially food availability). In contrast to observations near the Little Colorado River, brown trout abundance has increased in Glen Canyon over the last five years and is a cause for concern. This species is known to be a fall-spawner that has successfully spawned and recruited during past HFEs (GCMRC unpublished data); therefore, it remains uncertain whether the proposed 2016 HFE will have any disrupting effect on its reproductive activities. It is also unclear if brown trout may be benefitting from fall HFEs. Continuation of the trout monitoring program now in place will provide an assessment of the effects from a 2016 HFE, if it occurs.

The adult humpback chub population in the Little Colorado River aggregation is stable and above the threshold of 7,000 adults identified in the Biological Opinion for the HFE Protocol and Nonnative Fish Control EAs (GCMRC unpublished data). HFEs have had no measurable direct effects, positive or negative, on humpback chub or other native fish, although their populations have increased significantly over the last decade, a period that included HFEs in 2004, 2008, 2012, 2013 and 2014, as well as increased water temperatures (Kennedy and Ralston 2011, GCMRC unpublished data). HFEs may indirectly affect humpback chub through increases in rainbow trout populations, which can prey on and compete with young humpback chub. While increases in rainbow trout abundance have been observed following the spring flows of 2008 which included an HFE in March, no positive trout response has been observed following fall HFEs in 2012, 2013 or 2014 (GCMRC unpublished data). Based on provisional unpublished data, humpback chub were not directly affected by the 2012, 2013, and 2014 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. The spring abundance estimate for adult (> 200 mm) humpback chub in the Little Colorado River was lower in 2015 and 2016 relative to 2014 values (USFWS unpublished data). While this data may show a slight population decline, it is within the FWS acceptable threshold of 7000 adults 2 out of 3 years. The fluctuation may be a natural population fluctuation. This evidence indicates that the relative condition (a ratio of length to weight and general indicator of fish health) of humpback chub in the Colorado River near the confluence of the Little Colorado River has been low since 2014 (GCMRC

unpublished data). It is possible that low spring catches in the LCR are due to adults with low condition values choosing to forego spawning as a result of less energy available for fish to devote to reproduction. Humpback chub are known to skip spawn (Yackulic et al. 2014). A complete analysis of humpback chub data from monitoring trips in September and October 2016 was not available in time to be considered in this report, but preliminary results suggest catches of various size classes of humpback chub were moderate in both the Colorado River and Little Colorado River (USFWS and GCMRC unpublished data) suggesting that there are no issues of concern relative to a fall 2016 HFE.

A small reproducing population of endangered razorback sucker occurs downstream in Lake Mead, and recent monitoring data indicated that razorback sucker occupy and spawn in western Grand Canyon. A single adult was caught in October 2012 near Spencer Canyon in the riverine part of Lake Mead that is within western Grand Canyon. Two adults, one untagged and one sonic tagged, were captured in the same area in 2013 (Arizona Game and Fish Department (AGFD) unpublished data). Sonic-tagged adults have also been remotely detected as far upstream as Pipe Creek (River Mile 90). Razorback sucker larvae were captured just upstream of Lava Falls in 2014 and 2015. In 2016, the study was expanded upstream, and preliminary data indicate larvae were collected as far upstream as below Havasu Creek (Biowest Inc.,/ASIR, Inc., unpublished data). Changes in flows due to a fall HFE are unlikely to have any significant effect to razorback suckers. While a spring HFE could have some effect to sensitive razorback sucker life stages (spawning adults, larval fish, etc.) a fall HFE would not have this effect, as spawning does not occur during this timeframe.

As described in the 2011 U.S. Fish and Wildlife Service biological opinion, endangered Kanab ambersnail would be adversely affected by HFEs (U.S. Fish and Wildlife Service 2011). HFEs will scour snail habitat resulting in loss of some snails at Vasey's Paradise. FWS found in its 2011 biological opinion that this loss of snails and snail habitat would not jeopardize the continued existence of the Kanab ambersnail. A recent report by the USGS found that Kanab ambersnails are part of a much more widespread species of snail and may not qualify as an endangered species (Culver et al. 2013).

Whirling disease, a serious disease of trout species, was detected in Glen Canyon in 2011 by AGFD. Although there is no data on how HFEs affect whirling disease, GCMRC completed an assessment of the potential for HFEs to spread whirling disease in 2012 that concluded HFEs pose little risk of spreading whirling disease, and that HFEs may reduce the prevalence of the disease by removing tubificid worms from sediments in Glen Canyon (tubificid worms are hosts to this myxosporean parasite). The AGFD has not specifically monitored for the disease in Marble and Grand Canyons. However annual monitoring of rainbow trout in Glen, Marble, and Grand Canyons did not detect symptoms of the disease in 2014, 2015, or 2016 since the 2013 and 2014 HFEs.

In August 2016, nonnative green sunfish were again discovered primarily in the small isolated pool at the upstream end of the backwater slough on river left at RM -12 in Glen Canyon (AGFD unpublished data). The pool is about 1/3 acre in size and is located just upstream of the larger backwater slough. These water bodies are separate at lower flows, but become connected at flows of approximately 20,000 cfs. The island bar that creates the backwater slough appears to

be the result of large rock falls from the canyon rim on river left. The hydraulic connection of the pool at the upstream end of the slough, begins when river flows are somewhere between 20,000 and 30,000 cfs.

Five electrofishing efforts in the main slough have revealed that relatively few green sunfish are present this year, and few appear to have escaped the isolated upstream pool. Agency biologists agreed that elimination of this invasive species from the isolated pool is necessary and urgent due to the risk of negative interactions with native fish, particularly the humpback chub. Ten subsequent removal trips from August to October 2016 using electrofishing, seining and minnow trapping have removed over 4,000 green sunfish but have failed to completely eliminate the population inhabiting the isolated pool (Trammell 2016, GCMRC unpublished data).

While mechanical removal has been able to reduce green sunfish numbers, elimination of the fish in the upper slough is greatly preferred, to minimize the risk of downstream establishment of green sunfish as much as possible. Aside from mechanical approaches, potential methods to eradicate green sunfish from the upper slough include chemical treatments such as piscicides or carbon dioxide. As outlined in a risk assessment completed in 2015, chemical treatments provide the greatest likelihood of success (Ward 2015). Because fewer green sunfish (<20 in 2016 versus thousands in 2015) and no reproductively mature adults have been found in the main slough, treatment of that location is not necessary this year. Permitting a rotenone treatment as occurred in 2015 was not possible within the necessary time frame, consequently other chemical treatments options have been explored, primarily an experimental treatment of ammonia (ammonium hydroxide).

Ammonia tested as a new piscicide has been shown to be effective at removing invasive fishes common in the southwestern United States (Ward et al. 2013), but is not yet a registered piscicide. NPS has obtained a permit from the State of Arizona DEQ to apply ammonia to the isolated pool for the purpose of eradicating the green sunfish in that location. Ammonium hydroxide (29%, Univar Chemical) will be added to the isolated backwater at the Lees Ferry slough at dosage rate of 0.5 ml ammonia hydroxide per 3.78 L of water, following protocols outlined in Ward et al. 2013. Up to 94L (25 gallons) of ammonia will be added to the pond to achieve initial calculated ammonia concentrations of 38 ppm. Ammonia will be poured directly from enclosed containers into the pond without mixing. Sentinel green sunfish in baskets and two passes of electrofishing in the days following treatment will be used to verify that a complete fish kill has occurred. Water quality will then be monitored weekly until the HFE occurs to determine the persistent concentration of the ammonia which is expected to break down in to constituent nitrites in 7 to 14 days. The high volume of water delivered by the HFE will dilute any remaining ammonia in the upper slough to a non-toxic level immediately and any small amount remaining will break down quickly with little to no effect on downstream aquatic life. The slough will be administratively closed for a week after the treatment.

The risk of dispersal of this invasive species must be taken into account as the HFE is considered, since this species is adapted to using floods as a means of dispersing to new habitats and colonizing them. Bathymetric maps of the slough area and preliminary results from flow modeling indicate the area becomes a flowing side channel at flows between 20,000 and 30,000 cubic feet per second (cfs), while the minimum flows for HFEs are 31,500 cfs. Eradication of

green sunfish from Glen Canyon before any HFE is necessary to eliminate the risk of dispersal and subsequent establishment of this harmful nonnative in the Colorado River or any of its tributaries in Grand Canyon.

Hydropower and Water Delivery: Throughout the HFE planning process Reclamation and WAPA have coordinated to ensure that the maximum possible release from the dam could be achieved. While there are a number of unknown factors that might impact the maximum release rate that can be made during the HFE, Reclamation anticipates that a release of approximately 36,000 cfs will be achievable.

The best estimate for total release from Glen Canyon Dam for a HFE in November 2016 is 36,000 cfs (21,000 cfs through the powerplant and 15,000 cfs of bypass). This estimate is based on the most recent unit testing completed in October 2016, a maintenance assumption that six of the eight units at Glen Canyon Powerplant would be available November 7-12, 2016, and an approximate 100% gate opening on the available six units. In addition, this estimate assumes that 40MW (approximately 1,100 cfs) of system regulation will be maintained at Glen Canyon.

WAPA completed an analysis of the potential financial costs to WAPA as a result of running the fall 2016 HFE. WAPA estimates that the HFE described in this document will have a financial impact on firm power customers of about $1.40 million due to additional power purchases to replace generation due to implementation of the HFE. WAPA has completed an analysis of the financial costs of running the experimental flows during the fall 2014 HFE. WAPA estimates that the 2014 HFE cost approximately $2.1 million ($1.1 million for 2012 and $2.6 million for 2013). The financial implications of the HFE occurs over several months. Initially there tends to be a financial gain in November due to the increased generation, but this is offset by a financial loss that occurs in December through May from water that is needed to support the experimental releases in November. In addition, water that is bypassed (or spilled) does not generate any power and thus represents lost revenue. The Technical Team was able to schedule the HFE to start on Monday, November 7, which resulted in better conditions for WAPA to market hydropower generated by the HFE and resulted in a cost savings compared with scheduling the HFE over a weekend day or holiday.

The release volume required in November for the proposed 2016 HFE is approximately 745,000 acre feet. The October 24-Month Study projected 600,000 acre feet release volume in November, therefore it is necessary to reallocate approximately 145,000 acre feet from months later in the 2017 water year. Approximately 125,000 acre feet of water would be bypassed during the proposed HFE. WAPA and Reclamation will coordinate on the scheduled reallocation of monthly release volumes with the goal of protecting minimum MLFF monthly thresholds whenever practicable as described in the EA as well as maximizing the economic value of hydropower. The most probable annual release for water year 2017 under the 2007 Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lakes Powell and Mead (2007 Interim Guidelines, Bureau of Reclamation 2007a and 2007b) is projected to be 9.0 maf, with all months projected to be above these thresholds regardless of the HFE release. If inflows in water year 2017 are very low, the annual release could be as low as 8.23 maf, in which case some monthly volumes could be below the MLFF monthly thresholds. Hourly releases for the days prior to and after the proposed HFE in November are anticipated to

fluctuate between 6,500 to 9,000 cfs. This fluctuation level was estimated by WAPA to result in a cost savings of approximately $0.1 million compared to lower fluctuating releases of 5,000 cfs to 8,000 cfs.

Releases from Glen Canyon Dam in November may fluctuate beyond the scheduled releases due to system regulation requirements. Throughout the entire month of November, Glen Canyon Dam will maintain 40MW of system regulation. These instantaneous release adjustments stabilize the electrical generation and transmission system. The 40MW translates to a range of approximately 1,100 cfs above or below the hourly scheduled release rate. Maintaining regulation is necessary to comply with federal regulations concerning the electric grid and for safe operation of the hydropower facility.

Reclamation confirmed through modeling that there will be no effect on the annual release volume from Lake Powell in compliance with the 2007 Interim Guidelines from conducting the modeled fall 2016 HFE. Reclamation currently projects the annual release volume for water year 2016 will be 9.0 million acre feet under the minimum and most probable hydrology inflow scenarios and 11.9 million acre feet under the maximum probable hydrology inflow scenario. An HFE in November 2016 would not affect the annual release volume from Lake Powell nor the Operational Tier in accordance with the 2007 Interim Guidelines. In the HFE FONSI, Reclamation also committed to consulting with the Basin States prior to conducting an HFE as to the issue of compliance with the 2007 Interim Guidelines. In fall 2016 representatives from the Basin States and the UCRC participated in the HFE Technical Team, consulting with Reclamation and reviewing information relevant to the 2007 Interim Guidelines in consideration of a decision to conduct a fall 2016 HFE. These HFE Technical Team participants also reviewed additional information about the HFE (e.g., modeling information, resource assessments).

The Pueblo of Zuni, in a letter dated September 20, 2012 expressed concern that successive iterations of HFEs under the HFE Protocol could have cumulative negative impacts on power generation and a resultant effect on raising the cost of purchasing power for individual rate payers, and that this is especially of concern to economically disadvantaged minority communities such as Zuni. The Pueblo of Zuni requested that Reclamation provide a detailed description on how the economic effects of successive HFEs on power rate payers will be monitored. Reclamation is working with WAPA to carefully assess this issue and provide for post-HFE monitoring that will analyze, to the extent possible, effects to ratepayers from HFEs conducted under the HFE Protocol. At this time, WAPA does not anticipate that the cost of HFEs will cause near-term changes in power rates.

IV. SAFETY CONSIDERATIONS

As identified in the HFE Protocol EA and FONSI, 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 proposed 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 proposed 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.

Day raft trips from Glen Canyon Dam to Lees Ferry, conducted under contract by Colorado River Discovery (CRD), 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. NPS will notify CRD of a potential HFE so that the company can prepare to move boats and associated infrastructure out of the river to the Lees Ferry launch ramp. Revenue losses for the period of time associated with a six-day HFE are estimated at $14,000 to $16,000, with and additional costs of $600 for NPS amenities revenues, and $1,620 concession franchise fees, incurred by the primary concessionaire on the Glen Canyon reach, CRD. They will be affected and notified of the loss of revenue. CRD's license agreement with NPS and Reclamation acknowledges the potential for operations that can disrupt business. For the 2016 HFE, the projected largest volume day for business in this period according to CRD, Saturday November 12, will not be affected by the HFE.

Reclamation and NPS coordinate to address safety and security issues related to HFEs. Additionally, the three park service units affected, Glen Canyon National Recreation Area (GLCA), Grand Canyon National Park (GRCA) and Lake Mead National Recreation Area (LAKE) will work together to collaboratively plan necessary actions for the 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 will maintain frequent communication and information sharing leading up to and during the HFE.

If an HFE is approved by the Leadership Team, GRCA, GLCA, and LAKE will identify and communicate with 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. Given that an HFE is likely to occur, active planning is underway to provide alternative trip dates for trips potentially affected by an HFE. All permit holders will be 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 will be alerted to potential campsite inundation areas.

If an HFE is approved by the Leadership Team, GLCA will communicate with the holders of commercial use authorizations for commercial services (primarily fishing guides) 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. Information about the pending HFE and safety considerations will be provided to recreational users at Lees Ferry in coordination with the Technical Team Communications group. Information will also be provided via public media, the GLCA website and on-site NPS staff. A fact sheet explaining potential impacts to park visitors will be developed and distributed to potentially affected visitors. Notifications will be provided at Lees Ferry and Phantom Ranch and the fact sheet will be available at these locations, as well as the GRCA Backcountry Information

Center and primary visitor center. Given that an HFE is likely, a press release, and notifications to Colorado River permit holders within GRCA, GLCA and LAKE is underway.

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. 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”). USGS crews will have been deployed to locations in the days before the high flow release and will be supported by motorized rafts, and boats and cableways. They will be making critical measurements of discharge, suspended sediment transport, and organic drift. 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 the 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 USGS personnel will be done during daylight hours in order to maximize the safety of field personnel.

V. COMMUNICATIONS PLAN

This HFE, if conducted, presents an excellent opportunity to explain to the public the purpose of the HFE Protocol and expected beneficial impacts. The communications/public affairs aspect of this HFE will not include a public/media event at Glen Canyon Dam, but will include communications product development and media coordination.

Reclamation’s Upper Colorado Region Public Affairs Office in primary coordination with National Park Service and U.S. Geological Survey public affairs contacts and DOI is leading development of communications product development. Should the Leadership Team decide to conduct an HFE, an initial media advisory will be sent to alert media representatives and the public of the HFE, its summary 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 Secretary's office. Social media outlets will also be used to communicate with the public leading up to and during the event--including to share imagery of the HFE.

VI. POST HFE-REPORTING AND FEEDBACK

Reclamation committed in the HFE EA and FONSI to provide reports on effects of HFEs conducted in a given year. If the Leadership Team decides to conduct a fall 2016 HFE, the Technical Team will coordinate to report initial findings at the 2016 Glen Canyon Dam Adaptive Management Program (GCDAMP) Annual Reporting Meeting in January, 2017 in Phoenix.

Members of the Technical Team will schedule additional meetings as necessary and will also report ongoing findings at meetings of the GCDAMP Technical Work Group and Adaptive Management Work Group. Reclamation also has a commitment to provide an annual monitoring report to the FWS Arizona Ecological Services Office (AESO) in compliance with the 2011 Biological Opinion; this report will also include a summary of effects of HFEs conducted under the protocol. Also, under the HFE Protocol MOA, Reclamation will conduct a reporting meeting with the signatories to that agreement, describing the effects of the HFE. Reclamation will use

the monitoring information and feedback from AESO and the MOA signatories to inform monitoring for future HFEs, and to design and implement any measures necessary to address any adverse effects that may occur due to future HFEs.

There are two similar commitments in the HFE Protocol FONSI that Reclamation addressed in 2015, after the 2014 HFE. The first commitment was to undertake a review in 2014 of the first two years of implementation of the HFE Protocol through a workshop with scientists to assess what has been learned. This commitment is part of the FWS 2011 Biological Opinion on the HFE Protocol. The second commitment, from the HFE Protocol FONSI, was to conduct a comprehensive review of the HFE Protocol after multiple events (at least 3) have occurred, with GCDAMP stakeholders, to document and standardize planning tools and information sharing approaches as part of the implementation of the HFE Protocol. As a result of consultation with FWS, Reclamation combined these two commitments and conducted a workshop on February 27, 2015, in Salt Lake City, Utah, with GCDAMP stakeholders and MOA signatories to evaluate the results of the first three HFEs, and completed and submitted to FWS a draft written report of the biological opinion reporting results in 2015. Due to significant changes in staff, this draft report on the biological opinion has not yet been finalized, however, Reclamation and FWS staff have been in communication and anticipate finalizing the report in 2016.

In addition, GCMRC developed a science plan for the HFE Protocol that describes a program of monitoring and research activities that support ongoing information needs associated with implementation of the HFE Protocol. The approach described in this science plan relies on water quality, sediment, aquatic biology, and other resource monitoring and research projects funded in the GCDAMP Fiscal Year (FY) 2015-17 Triennial Budget and Work Plan (TWP, Reclamation and GCMRC 2014). These projects will inform the effect of future HFEs on the downstream resources of Glen, Marble, and Grand Canyons. These projects from the TWP are further discussed below.

Project 2, Streamflow, Water Quality, and Sediment Transport in the Colorado River Ecosystem, and Project 3, Sandbars and Sediment Storage Dynamics: Long-term Monitoring and Research at the Site, Reach, and Ecosystem Scales, are essential components to implementation of the HFE Protocol 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. Project 2 is the measurement program needed to document the HFE Protocol. Project 3 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 significant accomplishment of these programs in FY13–14 was the development of web-based interfaces to serve sediment transport and water quality data, calculate fine sediment mass balances, and to serve photographs of approximately 50 sandbars located from Lees Ferry to Diamond Creek. The latter data allow stakeholders to evaluate the effects of controlled floods implemented under the HFE Protocol.

As described in the HFE Protocol EA, the HFE planned for fall 2016 would not be an isolated event, but as 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 approximately every 4 years. These activities are described in detail in the TWP. 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 and fall 2017.

GCMRC scientists have installed digital cameras that capture 5 images every day at 43 sandbar monitoring sites throughout Marble and Grand Canyon 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. They will also be used to assess the rate of post-HFE sandbar erosion. GCMRC scientists tested the effectiveness of this monitoring method based on images collected at 22 sites, from Lees Ferry to Diamond Creek, for the 2008 HFE. The assessment of sandbar gains and losses based on a categorical ranking of changes from the images agreed with the changes detected by detailed topographic surveys at 86% of the sites. 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 2015 HFE relative to the previous HFEs. NPS will also be providing post-HFE monitoring of sandbars using photography.

All of the long-term sandbar monitoring sites, located between Lees Ferry and Diamond Creek, were surveyed between September 22 and October 9, 2015. This assessment of the size and distribution of HFE deposits approximately 11 months following the 2014 HFE provide the most informative assessment of sandbar-building effectiveness. These measurements, now being analyzed, will indicate the degree to which deposits created by the fall 2014 HFE provide enhanced sandbars for use in the following summer recreation season and whether the HFE Protocol is resulting in cumulative increases in sandbar size.

Project 4, Connectivity along the Fluvial-Aeolian-Hillslope Continuum: Quantifying the Relative Importance of River-related Factors that Influence Upland Geomorphology and Archaeological Site Stability (called Project J in the FY13–14 Work Plan; East et al., 2016) is focused on monitoring and research concerning geomorphic and weather processes that affect cultural resources above the active channel of the Colorado River. This project seeks to address longstanding issues associated with monitoring of landscape change near archaeological sites and other culturally significant properties. The project directly supports evaluation of the HFE Protocol effects to cultural resources by measuring deposition and erosion of river-derived sediment (sandbars) and consequent aeolian sand transport and efficacy of these processes in *in situ* preservation and impacts of archaeological sites.

Projects 5 (Food base Monitoring and Research), 6 (Mainstem Colorado River humpback chub aggregations and fish community dynamics), 7 (Population Ecology of Humpback Chub in and around the Little Colorado River), 8 (Management Actions to Increase Abundance and Distribution of Native Fishes in Grand), 9 (Understanding the Factors Determining Recruitment,

Population Size, Growth, and Movement of Rainbow Trout in Glen and Marble Canyons), and 10 (Where does the Glen Canyon Dam rainbow trout tailwater fishery end?- Integrating Fish and Channel Mapping Data below Glen Canyon Dam) concern the fishes of the Colorado River and its tributaries, the food base on which those fish depend, and the habitats in which the food base and fishes occur. Project 5 is a new stand-alone effort designed to continue monitoring of the aquatic food base and to conduct research to resolve questions about the current condition of the aquatic invertebrate community in Glen Canyon. Many of the research and monitoring projects on native and nonnative fish in the mainstem Colorado River are included in Project 6. Project 7 is a research project intended to resolve uncertainties about humpback chub and their life history in the Little Colorado River and near its confluence with the mainstem Colorado River. Management actions focused on benefitting native fish and funded by the GCDAMP are included in Project 8, as is a proposed review of the fisheries program by an external protocol evaluation panel (PEP). Project 9 concerns the rainbow trout fishery of Glen Canyon as well as the factors influencing the distribution and movement of rainbow trout in Marble Canyon. Project 10 focuses on improving understanding of the relationships between physical habitat in Glen Canyon and Marble Canyon and rainbow trout recruitment and distribution. These projects work in concert to maintain long-term monitoring data sets of key aquatic resources in the Colorado River ecosystem while also looking to minimize redundancy and increase efficiency and to continue addressing persistent scientific uncertainties that have plagued management of the aquatic ecosystem. These projects work directly to evaluate the HFE Protocol through a set of monitoring and research efforts designed to evaluate the effect of HFEs on the physical habitat of the aquatic ecosystem, the aquatic food base, and concomitant changes in the nonnative fishery (predominantly rainbow trout in Glen and Marble canyons), the native fishery downstream, including endangered humpback chub, and the interactions between the native and nonnative fishery, in particular the effect of predation and competition from rainbow trout on humpback chub.

In addition to the projects described above, it is recognized that additional monitoring for potentially harmful nonnative fishes is needed as is the implementation of mitigation actions to be taken in the event these species are detected. Reclamation, NPS, GCMRC, and other partner agencies will prioritize these efforts and work together on monitoring and actions regarding potentially harmful nonnative fishes with the goal of implementing actions within 12 months.

VII. CONSULTATION

Reclamation and GCMRC presented much of the information in this report that was available at that time to the Adaptive Management Work Group (AMWG) at its August 23-24, 2016 meeting. Notification of a potential for a fall 2016 HFE was emailed to GCDAMP stakeholders on September 26, 2016. Representatives of the Colorado River Basin states participated in the development of this recommendation and concur with it. Reclamation also intends to present the findings and recommendation of this report to the Technical Work Group (TWG) on October 18-19, 2016. On September 30, 2016, the required 30-day advance notification was given to the MOA signatories, including the tribes, of the potential for an HFE in November 2016.

VIII. CONCLUSION

Determining whether to recommend an HFE required coordination of many details and effective communication among technical staff of multiple agencies. The Team members relied heavily on the staff in each of the agencies in making this recommendation. The Team has thoroughly evaluated the issues discussed above, and has taken into consideration the information and analysis included in the HFE Protocol EA and FONSI. The Team's recommendation to proceed with implementation of the HFE is based on the careful assessment of resources, especially that of the green sunfish, and best available science. In particular, the Team is recommending that HFE be conducted (with the caveats noted above) in fall 2016 because the sediment conditions are favorable and because there is a very high degree of confidence that the planned treatment of green sunfish will be successful in eradicating the fish in the Glen Canyon slough prior to an HFE. The success of this important initiative is in large part due to the commitment of the Team to ensuring that the HFE Protocol is a success.

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