U.S. Department of the Interior

Record of Decision for the Glen Canyon Dam Long-Term Experimental and Management Plan Final Environmental Impact Statement

December 2016

U.S. Department of the Interior

Bureau of Reclamation
Upper Colorado Region
Salt Lake City, Utah

National Park Service
Intermountain Region
Lakewood, Colorado

Record of Decision
Glen Canyon Dam Long-Term Experimental and Management Plan

1. SUMMARY OF ACTION

The U.S. Department of the Interior (DOI), through the Bureau of Reclamation, Upper Colorado Region (Reclamation) and the National Park Service (NPS) have jointly published a Final Environmental Impact Statement (FEIS) for the Glen Canyon Dam Long-Term Experimental and Management Plan (LTEMP). Reclamation and NPS are joint-lead agencies for the LTEMP EIS because of their roles in operating Glen Canyon Dam (Reclamation's role) and managing the resources of Glen Canyon National Recreation Area (GCNRA), Grand Canyon National Park (GCNP), and Lake Mead National Recreation Area (LMNRA) (NPS's role). As joint leads, both agencies were equally involved in the development of all aspects of the LTEMP FEIS. There were 15 Cooperating Agencies for the FEIS, which included the Bureau of Indian Affairs (BIA), U.S. Fish and Wildlife Service (FWS), Western Area Power Administration (WAPA), Arizona Game and Fish Department (AZGFD), Colorado River Board of California, Colorado River Commission of Nevada, Upper Colorado River Commission, Salt River Project, Utah Associated Municipal Power Systems, Havasupai Tribe, Hopi Tribe, Hualapai Tribe, Kaibab Band of Paiute Indians, Navajo Nation, and the Pueblo of Zuni. Throughout the process, the U.S. Geological Survey (USGS) Grand Canyon Monitoring and Research Center (GCMRC) provided technical advice and managed peer review processes.

The proposed Federal action considered in the LTEMP FEIS is the development and implementation of a structured, long-term experimental and management plan for operations of Glen Canyon Dam. The LTEMP will provide a framework for adaptively managing Glen Canyon Dam operations and other management and experimental actions over the next 20 years, consistent with the Grand Canyon Protection Act (GCPA) and other provisions of applicable Federal law. The LTEMP identified specific options for dam operations (including hourly, daily, and monthly release patterns), non-flow actions, and appropriate experimental and management actions that meet the GCPA's requirements, and maintain or improve hydropower production to the greatest extent practicable, consistent with improvement of downstream resources, including those of importance to American Indian tribes. Under the LTEMP, water will continue to be delivered in a manner that is fully consistent with and subject to the Colorado River Compact, the Upper Colorado River Basin Compact, the Water Treaty of 1944 with Mexico, the decree of the Supreme Court in *Arizona v. California*, and the provisions of the Colorado River Storage Project Act of 1956 (CRSPA) and the Colorado River Basin Project Act of 1968 that govern allocation, appropriation, development, and exportation of the waters of the Colorado River Basin, and consistent with applicable determinations of annual water release volumes from Glen Canyon Dam made pursuant to the Long-Range Operating Criteria (LROC) for Colorado River Basin Reservoirs, which are currently implemented through the 2007 Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead.

The area potentially affected by the LTEMP includes Lake Powell, Glen Canyon Dam, and the Colorado River downstream to Lake Mead. More specifically, the scope primarily encompasses the Colorado River Ecosystem (CRE), which includes the Colorado River mainstream corridor and interacting resources in associated riparian and terrace zones, located primarily from the forebay of Glen Canyon Dam to the western boundary of GCNP. The CRE specifically consists of the area where dam operations impact physical, biological, recreational, cultural, and other resources. This section of the river runs through Glen, Marble, and Grand Canyons in Coconino and Mohave Counties in northwestern Arizona. Although the FEIS focuses primarily on the CRE, the affected area varies by resources and extends outside of the immediate river corridor for some resources and cumulative impacts. For resources such as socioeconomics, air quality, and hydropower, the affected region is larger and includes areas potentially affected by indirect impacts of the LTEMP.

The FEIS and this Record of Decision (ROD) have been prepared in accordance with the National Environmental Policy Act (NEPA), the Council on Environmental Quality's NEPA regulations (Title 40, *Code of Federal Regulations*, Parts 1500 to 1508 [40 CFR 1500–1508]), and DOI regulations (43 CFR 46). The decision made here is based on the FEIS filed with the U.S. Environmental Protection Agency (EPA) (FES 12-01) on October 7, 2016, and noticed by the EPA in the *Federal Register* on October 14, 2016.

For this ROD, DOI selected Alternative D without modification, which was identified in the LTEMP FEIS as both the preferred and the environmentally preferred alternative. This alternative will use the monthly release volumes as specified in Table 1. Within a year, monthly operations may be increased or decreased based on factors referenced in Sections 1.2 and 1.3 of Attachment B of this ROD. Alternative D best meets the purpose and need and the broadest set of objectives and resource goals of the LTEMP. Alternative D provides the best balance of performance among downstream resources to comply with the GCPA to protect, mitigate adverse impacts to, and improve the natural and cultural resources and visitor use in the GCNP and GCNRA park units while continuing to comply with GCPA 1802 (b) applicable laws.

TABLE 1 Monthly Release Volumes of the Selected Alternative

	Monthly Release Volume (thousand ac-ft)[a]									
Total Annual	7,000	7,480	8,230	9,000	9,500	10,500	11,000	12,000	13,000	14,000
October	480	480	643	643	643	643	643	643	643	643
November	500	500	642	642	642	642	642	642	642	642
December	600	600	716	716	716	716	716	716	716	716
January	664	723	763	857	919	1,041	1,102	1,225	1,347	1,470
February	587	639	675	758	813	921	975	1,083	1,192	1,300
March	620	675	713	801	858	973	1,030	1,144	1,259	1,373
April	552	601	635	713	764	866	917	1,019	1,121	1,223
May	550	599	632	710	761	862	913	1,014	1,116	1,217
June	577	628	663	745	798	905	958	1,064	1,171	1,277
July	652	709	749	842	902	1,022	1,082	1,202	1,322	1,443
August	696	758	800	899	963	1,091	1,156	1,284	1,413	1,537
September	522	568	600	674	722	819	867	963	1,059	1,160

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[a] Within a year, monthly operations may be increased or decreased based on factors referenced in Section 1.2 and 1.3 in Attachment B of this ROD.

2. PURPOSE AND NEED

The purpose of the proposed action is to provide a comprehensive framework for adaptively managing Glen Canyon Dam over the next 20 years consistent with the GCPA and other provisions of applicable Federal law. The proposed action will help determine specific dam operations and actions that could be implemented to improve conditions and continue to meet the GCPA's requirements and to minimize—consistent with law—adverse impacts on the downstream natural, recreational, and cultural resources in the two park units, including resources of importance to American Indian Tribes.

The need for the proposed action stems from the need to use scientific information developed since the 1996 ROD to better inform DOI decisions on dam operations and other management and experimental actions so that the Secretary of the Interior may continue to meet statutory responsibilities for protecting downstream resources for future generations, conserving species listed under the Endangered Species Act (ESA), avoiding or mitigating impacts on *National Register of Historic Places* (NRHP)-eligible properties, and protecting the interests of American Indian Tribes, while meeting obligations for water delivery and the generation of hydroelectric power.

3. ALTERNATIVES CONSIDERED

The FEIS assesses the potential environmental effects of seven alternatives to meet the purpose and need of the proposed action: The No-Action Alternative (Alternative A), and six action alternatives (Alternatives B, C, D, E, F, and G), which are summarized below (see LTEMP FEIS, Section 2.2).

Alternative A (No-Action Alternative): Alternative A represents continued operation of Glen Canyon Dam as guided by the 1996 ROD for operations of Glen Canyon Dam, that is, Modified Low Fluctuating Flow (MLFF), as modified by recent DOI decisions, including those specified in the 2007 ROD on Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lakes Powell and Mead (Interim Guidelines) (until 2026); the High-Flow Experiment Environmental Assessment (HFE EA); and the Nonnative Fish Control EA (both expiring in 2020).

Alternative B: The objective of Alternative B is to increase hydropower generation while limiting impacts on other resources and relying on flow and non-flow actions to the extent possible to mitigate impacts of higher fluctuations. Compared to the No-Action Alternative, Alternative B would increase within-day fluctuations and include experimental hydropower improvement flows, but would retain the monthly water release pattern of Alternative A. Alternative B focuses on non-flow actions and experiments to address sediment resources, nonnative fish control, and on native and nonnative fish communities.

Alternative C: The objective of Alternative C is to adaptively operate Glen Canyon Dam to achieve a balance of resource objectives with priorities placed on humpback chub, sediment, and minimizing impacts on hydropower. Compared to the No-Action Alternative, Alternative C would decrease within-day fluctuations, reduce water releases in the late summer and fall, and provide more even releases in other months. Alternative C features a number of condition dependent flow and non-flow actions that would be triggered by resource conditions.

Alternative D (Selected Alternative): Alternative D was identified as both the preferred alternative and the environmentally preferred alternative in the LTEMP FEIS. The objective of Alternative D is to adaptively operate Glen Canyon Dam to best meet the resource goals of the LTEMP. Compared to the No-Action Alternative, Alternative D would have comparable within-day fluctuations, but a more even monthly release pattern. Alternative D features a number of condition-dependent flow and non-flow actions that would be triggered by resource conditions.

Alternative E: The objective of Alternative E is to provide for recovery of the humpback chub while protecting other important resources, including sediment, the rainbow trout fishery at Lees Ferry, aquatic food base, and hydropower resources. Compared to the No-Action Alternative, Alternative E would increase within-day fluctuations, reduce water releases in the late summer and fall, and provide more even releases in other months. Alternative E features a number of condition dependent flow and non-flow actions that would be triggered by resource conditions.

Alternative F: The objective of Alternative F is to provide seasonally adjusted steady flows that follow a more natural pattern of high spring, and low summer, fall, and winter flows while limiting sediment transport and providing for warming in summer months. In keeping with this objective, Alternative F does not feature some of the flow and non-flow actions of the other alternatives.

Alternative G: The objective of Alternative G is to maximize the conservation of sediment, in order to maintain and increase sandbar size. Under Alternative G, flows would be delivered in a steady pattern throughout the year, with no monthly differences in flow other than those needed to adjust operations in response to changes in forecast and other operating requirements such as equalization. Alternative G features a number of condition dependent flows in the spring and early summer, but low flows in other times of the year.

3.1 Environmentally Preferred Alternative

The preferred alternative, Alternative D, is the environmentally preferred alternative, based on its relative impacts (compared to other alternatives) on the full range of environmental resources. Alternative D is expected to result in an improvement in conditions for humpback chub, trout, and the aquatic food base; have the least impact on vegetation, wetlands, and terrestrial wildlife; improve sandbar building potential and conserve sediment; sustain or improve conditions for reservoir and river recreation; improve preservation of cultural resources; respect and enhance Tribal resources and values; and have limited impacts on hydropower resources.

4. DECISION AND RATIONALE FOR THE DECISION

The DOI selected Alternative D, identified in the FEIS as both the preferred alternative and the environmentally preferred alternative, without modification. For the reasons discussed below, Alternative D best meets the purpose and need of the proposed action. As presented in the Biological Opinion (BO) developed by the FWS (see Attachment E of this ROD), implementation of Alternative D will not jeopardize the continued existence of threatened or endangered species in the action area, and will not result in adverse modification of critical habitat of these species. A full description of Alternative D is described in Attachment B of this ROD.

The decision to select Alternative D was made after carefully weighing economic, social, and technical considerations, as well as the potentially significant environmental effects analyzed in the FEIS, and after reviewing comments and concerns of agencies, tribes, public and private organizations, and individuals. The decisionmaking process included internal and public scoping; qualitative and quantitative evaluations of impacts using modeling, literature review, and structured decision analysis; extensive coordination and meetings with cooperating agencies, stakeholders, and tribes; and public review and comment on the Draft EIS (DEIS). The DOI considered economic and technical considerations, agency statutory missions, objectives and resource goals, and applicable national policy. Sections 1.4, 1.9, 2.5, and 4.17 of the FEIS address these topics.

4.1 LTEMP Purpose, Need, Objectives, and Resource Goals

As stated in Chapter 1 of the LTEMP FEIS, the reasons for conducting this EIS process included a wealth of new scientific information developed over 20 or more years which offered new approaches to address key issues such as the loss of sandbars and beaches and related effects on habitat, endangered fish, including temperature and food base concerns, nonnative fish interactions, cultural resource protection, riparian vegetation condition; and many other issues. This LTEMP EIS process provided the opportunity to develop new approaches, experiments, and tools to better comply with GCPA 1802 (a) requirements to protect, mitigate adverse impacts to, and improve downstream resources and recreation while still complying with the 1802 (b) applicable laws. The intent was to develop a 20-year framework for adaptive management that incorporated this new science and to use the new approaches, experiments, and tools as the main focus of the Glen Canyon Dam Adaptive Management Program (GCDAMP). The DOI determined that developing a comprehensive EIS process would also be more efficient than conducting a series of smaller analyses and compliance efforts to update individual experiments to reflect the latest scientific understanding.

In developing the LTEMP EIS, DOI identified eight primary objectives of operating Glen Canyon Dam under the LTEMP, as well as 11 more specific goals to improve resources within the Colorado River Ecosystem through experimental and management actions. These objectives and resource goals were considered in the formulation and development of alternatives in this

EIS, and the decision to select Alternative D in this ROD. The LTEMP objectives addressed were (1) compliance with water allocation laws, regulations, and guidelines; (2) water delivery; (3) scope of flow and non-flow actions; (4) hydropower generation and capacity; (5) tribal interests; (6) use of the latest scientific findings; (7) adaptive management; and (8) compliance with Federal laws. The resource goals addressed were (1) archaeological and cultural resources; (2) natural processes; (3) humpback chub; (4) hydropower and energy; (5) other native fish; (6) recreational experience; (7) sediment; (8) tribal resources; (9) rainbow trout fishery; (10) nonnative invasive species; and (11) riparian vegetation. The full text of the objectives and resource goals is provided in Attachment A of this ROD. For the purposes of the EIS analysis, specific metrics were developed to objectively determine the relative performance of alternatives with regard to effects on resources; these are listed in Appendix B of the LTEMP FEIS.

4.2 Development of Alternative D

The DOI initiated a robust process of scoping and alternative development in July 2011. This included public meetings in 6 cities for the solicitation of formal scoping comments as is required by NEPA. The DOI also went beyond NEPA requirements and made available the preliminary goals and objectives and preliminary alternative concepts to the cooperating agencies, tribes, members of the Glen Canyon Adaptive Management Work Group (AMWG), and the general public for comment at a public workshop in April of 2012. Additional alternative proposals were accepted from cooperating agencies, tribes, stakeholders, and the general public through July 2, 2012. A series of subject matter expert work groups (including GCMRC and cooperating agencies) was held to refine the range of alternatives, seven of which (including the No-Action Alternative) were fully developed and carried forward. Modeling metrics and approaches that reflected the best available science were developed with GCMRC and other subject matter experts. Those modeling metrics and approaches were shared with cooperating agencies, tribes, and the AMWG stakeholders a number of times for review and input. The DOI revised several aspects of metrics and approaches in response to comments. The DOI also conducted an extensive modeling effort from 2013 to 2014, and the results were presented in March of 2014 to cooperating agencies, tribes, and other AMWG stakeholders for review and feedback.

The DOI determined that two alternatives—Alternatives C and E—performed well on the goals and objectives, and that a new "hybrid" alternative could be crafted utilizing the best characteristics of these alternatives. The DOI conducted a series of meetings to discuss the characteristics and the performance of the alternatives, and performed structured decision analysis processes with cooperating agencies, tribes, and stakeholders. The DOI also conducted technical meetings with GCMRC and other subject matter experts to better understand the drivers of performance. Those discussions and considerations led to the development of a new "hybrid" alternative, Alternative D, which combined and modified those characteristics that improved performance and reduced impacts to better meet the purpose, need, and objectives of the LTEMP EIS. Alternative D performed well for downstream resource goals, such as improving humpback chub population, building sandbars and beaches, while still preserving the sand mass balance, performing best on vegetation condition, and minimizing effects on hydropower value and capacity.

The DOI identified this new hybrid alternative as the preferred alternative in the DEIS. Based on comments and feedback on the DEIS, adjustments were made to Alternative D to further improve the performance and to address concerns raised by cooperating agencies and tribes (see Sections 2.2.4, 2.5, and 4.1 of the FEIS). These adjustments improved the performance of Alternative D for hydropower value and capacity while largely preserving the benefits to downstream resources for sediment, endangered fish, vegetation, and many other resources. In addition, the approach to mechanical removal of nonnative fish was refined based on consultations with tribes and the FWS, making it an action that would be implemented only after other conservation measures were attempted. These refinements still retained the many resource benefits of Alternative D.

Alternative D has a base hydrological pattern that incorporates a few improvements over the No-Action Alternative. Monthly release volumes are more evenly distributed throughout the year (see Table 1), which improves sediment conservation without affecting the annual release volume or the 2007 interim guidelines' operating tiers. The August release volume is the highest monthly release, which allows for greater hydropower production during the peak demand month (mainly due to air-conditioning use). The September and October release volumes are lower than under the No-Action Alternative, which allows for improved sediment conservation prior to a fall HFE. The daily release fluctuation level is very similar to the No-Action Alternative level, maintaining the 8,000 cfs maximum daily fluctuation restriction, which retains sediment conservation benefits as well as recreation and safety benefits. Alternative D uses a proportional formula for calculating the fluctuations and increases the down-ramp rate, which provides more operational efficiency and flexibility.

Alternative D also includes many new experiments to improve downstream resources within an adaptive management framework. To address humpback chub and other endangered and native fish populations, several tools are included. Trout management flows (TMFs) help manage trout populations in Glen Canyon and maintain a healthy fishery while also reducing downstream migration of trout to minimize competition with and predation on endangered fish. Macroinvertebrate production flows (MPFs) provide potential improvements to the food base that could benefit endangered fish and other aquatic species. Mechanical removal of nonnative fish is a tool that can be employed when needed to protect endangered fish. Low summer flows (LSFs) are a tool that may be tested in the second 10 years of the LTEMP period and used if needed to increase water temperatures to improve conditions for humpback chub and other native fish in the Colorado River mainstem. Building on the 2012 HFE Protocol, Alternative D includes spring and fall HFEs, which are intended to occur frequently to maintain and improve beaches, sandbars, and associated habitat. Two new types of HFEs included in this alternative are extended-duration fall HFEs (>96 hr), designed to extend HFE benefits in very high sediment years, and proactive spring flows designed to "park' sediment before summer flows in high annual volume years. Experimental non-flow vegetation treatments mitigate impacts from dam operations within the CRE. Together, these features and experiments work within an adaptive management framework and incorporate the best available science to protect, mitigate adverse impacts to, and improve downstream resources while continuing to comply with GCPA 1802(b) applicable laws.

4.3 Performance of Alternative D

No single alternative performed the best for all of the LTEMP objectives and resource goals; however, Alternative D performed well on each of the major resource areas as described below (also see Table 2-14 of the FEIS).

For water resources, Alternative D will not affect annual operating tiers. Annual reservoir elevations only differ from the No-Action Alternative as a result of changes in evaporation and bank storage. Alternative D has more evenly distributed monthly release volumes and mean daily flows in the river (to improve sediment conservation), and within-day flow fluctuations which are similar to the No-Action Alternative in most months (up to a maximum within-day change of 8,000 cfs).

For sediment resources, Alternative D improves sandbar building potential by 152 percent, compared to the No-Action Alternative, and it conserves the most sand (higher sand mass balance) of any of the action alternatives. Alternative D is expected to protect and improve sandbars and beaches and related downstream resources.

For aquatic ecology, Alternative D is expected to result in slightly higher humpback chub abundance and slightly higher productivity of the aquatic food base compared to the No-Action Alternative. Experimental MPFs (only featured in this alternative) may further increase productivity and diversity of the food base. Habitat quality and stability for native fish and other aquatic species are expected to be slightly better than under the No-Action Alternative. Alternative D is expected to maintain trout abundance at a level similar to the No-Action Alternative by implementing TMFs frequently and mechanical removal when necessary.

For vegetation, Alternative D is expected to improve vegetation conditions more than any other alternative. These improvements will include more native plant community cover, higher native plant diversity, a lower ratio of native to nonnative plants, less arrowweed, and more wetland as compared to the No-Action Alternative. Alternative D also includes experimental non-flow vegetation treatments that are expected to improve vegetation through the removal of nonnative plants and replanting of native plants in select areas along the river.

For wildlife, Alternative D will result in negligible impacts on most terrestrial wildlife species. Alternative D will produce greater nearshore habitat stability and will benefit species that eat insects or use nearshore areas. Alternative D will retain the most wetland habitat of any alternative.

For cultural resources, Alternative D will result in indirect potential benefits for archaeological sites in the Grand Canyon due to an increase in the availability of sand that will protect site stability; and a slight decrease in time off-river which will decrease the potential for inadvertent or intentional damage to sites. In addition, the experimental vegetation treatments will improve wind transport of sand in a few select sites to protect archaeological resources.

In terms of resources important to tribes, Alternative D will result in (1) an increase in the amount of sand available for protection of cultural resource sites, (2) the best retention of wetlands, and (3) the best retention of riparian plant diversity; other alternatives would increase wetland loss and/or reduce plant diversity. Alternative D includes trout management actions (TMFs and mechanical trout removal). Some tribes have stated concerns regarding these tools because they result in a taking of life in the Canyons. Therefore, DOI has incorporated steps to (1) consult with tribes prior to mechanical removal, (2) ensure mechanical removal is only used when necessary, and (3) consider beneficial uses before nonnative fish are removed.

For recreation, Alternative D will maintain or improve camping beaches in the Grand Canyon and retain navigability for river rafters similar to the No-Action Alternative. It will retain similar numbers of large trout and trout catch rates in Lees Ferry in comparison to the No-Action Alternative. It will result in more lost rafting visitor days in Glen Canyon when HFEs are implemented than the No-Action Alternative. Alternative D is expected to retain the economic activity for most forms of river recreation except angling, with temporary declines only in Lees Ferry during HFEs. Since annual release volumes are not affected by the LTEMP, Alternative D will result in only slight changes in reservoir elevations during some months and could result in very slight reductions in use values[1] and economic activity (−0.4%) associated with Lake Powell recreation and slight improvements (+0.3%) with Lake Mead recreation.

In terms of hydropower, Alternative D is expected to result in a 1.1 percent decrease in average daily generation (MWh) and a 6.7 percent decrease in firm capacity (MW) when compared to the No-Action Alternative. In terms of cost, Alternative D results in a 0.13 percent increase in the cost of generation and a 0.85 percent increase in the cost of capacity, for a combined 0.17 percent increase in total cost to meet electric demand over the 20-year LTEMP period. Alternative D has the second lowest cost of the action alternatives. Alternative D would result in a small increase in average retail electric rate (0.39%) and average monthly residential electricity bill ($0.38) in the year of maximum rate impact compared to the No-Action Alternative.

For socioeconomics, several aspects of recreation economics and hydropower rate-payer economics were considered. For environmental justice, the same factors were evaluated to assess the effects to minority or low income populations. Alternative D will result in only slight changes in reservoir elevations during some months since annual volumes are not affected by the LTEMP. Thus, Alternative D could result in very slight reductions in use values and economic activity (−0.4%) associated with Lake Powell recreation and slight improvements (+0.3%) to Lake Mead recreation. One modeling result shows declines in use values associated with most forms of river recreation; however, the number of river rafters annually through the Grand Canyon would not decrease, camping beaches are expected to improve, and navigability and other factors are maintained similar to the No-Action Alternative. Under Alternative D, no change is expected in economic activity for most forms of river recreation except a temporary decrease in angling during HFEs. Economic activity is expected to increase from capacity expansion (up to 4.5%), and economic activity is expected to decrease slightly from higher residential electric bills (<0.1%). No disproportionately high and adverse impacts on minority or low-income populations are expected under Alternative D. Under Alternatives D, financial impacts on tribal customers related to electricity sales are expected to be slightly higher

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1 Use value is defined as the economic benefit associated with the physical use of a resource, usually measured by the consumer surplus or net economic value associated with such use.

(<$1.00/MWh) than those on non-tribal customers relative to the No-Action Alternative. In addition, Alternative D would have the highest non-use value of alternatives, with an annual increase in non-use value of $4,486 million at the national level.

In terms of air quality and climate change, Alternative D would produce no change in sulfur dioxide (SO_2) emissions, a negligible increase in nitrogen oxide (NO_x) emissions, and no change in visibility. Alternative D would result in a very slight (0.042%) increase in greenhouse gas (GHG) emissions (including methane) relative to the No-Action Alternative. When DOI considered climate change scenarios, Alternative D still performed well relative to other alternatives under drier hydrological conditions (see FEIS Section 4.16, and Appendix C for discussion).

4.4 Summary of Rationale for the Decision

There was no single alternative that performed best on each of the 8 objectives and 11 resource goals. The DOI, therefore, selected the alternative with the best overall performance among the goals and objectives that fully comply with the GCPA 1802 (a) requirements to protect, mitigate adverse impacts to, and improve downstream resources and maintain their long-term sustainability while also continuing to comply with GPCA 1802 (b) applicable laws. The alternative selected for implementation is Alternative D.

Specific performance benefits of Alternative D include expected improvements to conditions for humpback chub, trout, and the aquatic food base; the least impact on vegetation, wetlands, and terrestrial wildlife; improvements to sandbar building potential and sediment conservation; maintaining or improving conditions for reservoir and river recreation; improving preservation of cultural resources; respecting and enhancing tribal resources and values; and limiting impacts on hydropower resources. Specific to hydropower, it was determined (after the initial results analysis was complete) that combining elements of Alternatives C and E into a new alternative, Alternative D, would allow for increased hydropower and sediment conservation performance without sacrificing performance for other resources such as fish, vegetation, cultural resources, and others. Alternative D was also further modified based on comments from cooperating agencies and the public between the DEIS and FEIS and following those modifications, Alternative D performed second best on hydropower goals and objectives of the action alternatives and only increased the combined cost of generation and capacity by 0.17 percent. Therefore, with the selection of Alternative D, DOI has limited hydropower generation, capacity, and flexibility only to the extent necessary.

Alternative D performed well compared to other alternatives. The No-Action Alternative would continue to maintain the existing condition of most resources. However, it did not incorporate the last 20 years of learning. In particular, it had more limited fish management actions, no vegetation treatment, and performed poorly for sediment conservation due to the HFE protocol expiring partway through the analysis period. Alternative B performed the best for the hydropower objective with a slight improvement (0.4%) in the cost of generation and capacity. However, as described in Chapter 4 of the FEIS, Alternative B did not perform as well for sediment conservation, recreation, other objectives and resource goals, or for the long-term sustainability of downstream resources. Alternatives C and E performed well for multiple resources, but Alternative C did not perform as well on hydropower, and Alternative E did not perform as well on sediment conservation. Alternatives F and G performed well on potential sandbar building but not on other resource goals and objectives, including vegetation and fish.

Alternative D will use an adaptive management and experimental framework to refine existing information regarding the effects of dam operations and management actions on affected resources. Information gathered through the adaptive management and experimental process may be used to adjust operations and non-flow actions to further improve downstream resources within the range of flexibility described in the LTEMP FEIS for the actions of the selected Alternative D. Significant changes beyond the scope of the FEIS may require additional NEPA analysis.

Alternative D was identified as the preferred alternative in the DEIS, and DOI received letters of support for Alternative D from a broad range of stakeholders, including WAPA, the Basin States, the National Parks Conservation Association, the Grand Canyon Trust, Grand Canyon River Guides, the Navajo Nation, and many members of the public. However, DOI also received comments that identified other alternatives as preferable, including Alternative B (increased hydropower), the No-Action Alternative, or one of the alternatives considered but dismissed because they did not meet the purpose and need of the proposed action (e.g., Fill Mead First or decommissioning of Glen Canyon Dam).

Alternative D best meets the purpose and need, and meets the broadest set of objectives and resource goals of the LTEMP while providing the best balance of downstream resource improvements to comply with the GCPA.

5. SUMMARY OF COMMENTS ON THE FINAL EIS

During the 30-day period after the EPA published its Notice of Availability of the LTEMP FEIS in the *Federal Register*, 10 comment letters were received from agencies and stakeholders. In addition, more than 850 form letters were received; these campaign letters raised four points also included in the letter from Save the Colorado. No new issues were raised that would require further analysis in a supplemental EIS. Substantive issues that were raised in the comments and the joint-lead agencies' responses are presented in Attachment D of this ROD.

6. ENVIRONMENTAL COMMITMENTS

The following mitigation, monitoring, and enforcement commitments will be implemented as integral parts of the decision as a means of avoiding or minimizing adverse effects. All practicable means to avoid or minimize environmental harm from the alternative selected have been adopted in its design or are part of the measures below.

6.1 Glen Canyon Dam Adaptive Management Program (GCDAMP)

a. Purpose and Continuation of the GCDAMP

The GCDAMP was established under the authority of the 1992 GCPA and initiated with the 1996 ROD. The purpose of the GCDAMP is to provide an organization and process for cooperative integration of dam operations, downstream resource protection and management, and monitoring and research information for the purposes of protecting and improving the values for which the GCNRA and GCNP were established. The GCDAMP program will continue with this purpose under the selected preferred alternative. The Secretary of Interior retains sole discretion to decide how best to accomplish operations and experiments in any given year pursuant to the ROD and other binding obligations. As part of the GCDAMP, DOI bureaus, including Reclamation, USGS, NPS, FWS, and BIA, will continue to inform the Secretary and his/her designee on policies, scientific matters related to the GCDAMP, and the overall priorities and direction of the GCDAMP. The DOI bureau managers will continue to meet regularly to resolve questions of policies, priorities, and direction among the bureaus. Meetings among DOI managers will be part of the GCDAMP, which is independent of the AMWG. The WAPA may also be invited to participate in "Federal family" GCDAMP meetings as has occurred in recent years.

b. Priorities and Funding of the GCDAMP

The GCDAMP priorities are set by the GCPA of 1992, the LTEMP FEIS, and ROD, and related mitigation requirements for endangered species and cultural resources. The GCDAMP priorities include the management and experimental actions; mitigation and environmental commitments; and research and monitoring identified in the LTEMP FEIS and ROD, and these will be the highest priorities for GCDAMP over the term of the LTEMP. The GCDAMP activities that are eligible for funding from power revenues are those actions related to dam operations or the mitigation of dam operations within the CRE. These will be funded in compliance with Section 204 of Public Law (PL) 106-377. Appropriated funds or other sources of funding may also be used for GCDAMP activities as specified in Section 1808 of the GCPA and Section 204 of PL 106-377.

c. The GCDAMP Guiding Documents

The DOI will work in consultation with the AMWG to update GCDAMP guiding documents (e.g., GCDAMP strategic plan, vision, mission, and charters) to reflect and be fully consistent with the priorities expressed in the FEIS and in this ROD. The goals and objectives in Section 1.4 of the LTEMP FEIS will be carried forward as the goals in the GCDAMP guiding documents. Processes and documents will be evaluated and streamlined or combined as necessary. The DOI, in consultation with the AMWG, will develop monitoring metrics for the goals and objectives using those in Appendix C of the FEIS as a starting point.

d. Communication and Consultation

The GCD AMP will follow the process specified in Sections 1.3 and 1.4, in Attachment B of this ROD, to provide a series of meetings with different purposes throughout the year to allow for an appropriate level of communication and coordination regarding proposed experiments and resource conditions.

e. The USGS Grand Canyon Monitoring and Research Center

The GCMRC will continue as one of the elements of GCDAMP, consistent with and for the purposes of the 1992 GCPA. The GCMRC will continue to function as a long-term monitoring and research center as was envisioned with its establishment in 1995 to provide scientific advice to GCDAMP, including the Secretary of the Interior, his/her designee, DOI managers, and AMWG. The Assistant Secretary for Water and Science or his/her designee, the Director of USGS or his/her designee, the Commissioner of Reclamation and his/her designee, and the Director of the NPS and his/her designee shall continue to provide policy and programmatic guidance to the GCMRC Chief and review the policies and protocols that govern the operations of GCMRC at least every 5 years. The GCRMC leads the coordination of the monitoring and research of the CRE and facilitates communication and information exchange between GCDAMP, including scientists, DOI, AMWG, Technical Working Group (TWG), and the Science Advisors Program. The GCMRC will be independent from any single stakeholder within the AMWG. The GCMRC will continue conducting monitoring and research activities as guided by the LTEMP FEIS and ROD priorities and commitments. The administrative responsibilities of GCMRC will continue to include managing resource data, reporting monitoring and research results, administering contracts and developing annual research and monitoring reports, and providing technical resource advice related to the GCPA.

f. The GCDAMP Science Advisors Program

The Science Advisors Program (SAP) will continue as part of GCDAMP to provide independent scientific review and recommendations regarding monitoring and research, integration, and management of natural, cultural, and recreational resources affected by Glen Canyon Dam operations. The SAP will be composed of qualified individuals not otherwise participating in the long-term monitoring and research studies. The SAP will establish review panels as directed by DOI and in consultation with GCDAMP, including the Tribes and AMWG to conduct periodic reviews. The SAP and review panels convened thereunder are advisory and not decision-making bodies.

g. Adaptive Management Working Group

- **Continuation of the AMWG**
  The Federal Advisory Committee known as the AMWG will continue to function as part of the GCDAMP in its advisory capacity. The Secretary of Interior's Designee will chair AMWG. The AMWG will continue to be composed of the representatives

from the stakeholders, tribes, organizations, and institutions as envisioned under Section 1804 (c) and 1805 (c) of the GCPA.

- **Roles and Functions of the AMWG**
  The AMWG charter will be updated to reflect these advisory roles and functions:

  - Establish AMWG operating procedures.

  - Advise GCDAMP and the Secretary of Interior or their designee consistent with GCPA Section 1804 (c) and1805 (c), regarding GCDAMP priorities and policies, proposed changes to the criteria and operating plans for Glen Canyon Dam, and the implementation of resource management objectives, research studies, and environmental or cultural commitments to comply with GCPA and the priorities of the LTEMP FEIS and ROD.

  - Review and provide input on the report identified in GCPA Section 1804 (c)(2) to the Secretary, Congress, and Governors of the Colorado River Basin States. The report will include discussion of dam operations, the operation of GCDAMP, status of resources, and measures taken to protect, mitigate adverse impacts to, and improve the resources defined in the GPCA.

  - Participate in an annual review of long-term monitoring data to provide advice on the status of resources, whether the LTEMP FEIS goals and objectives are being met, and on the proposed experiments in a given year.

  - Facilitate input and coordination of information from stakeholders to assist in meeting consultation requirements under Section 1804 (c) of the GCPA.

  - Review and provide input on GCDAMP monitoring and reports of program activities undertaken to comply with applicable laws, including permitting requirements.

h. Technical Working Group

The TWG will continue to function as a subcomponent of AMWG. It will continue to be composed of technical representatives of the AMWG Federal Advisory Committee Act (FACA) committee member organizations that have special technical expertise related to the downstream resources addressed by GCPA. It will address technical rather than policy issues. The TWG's main function is to provide technical assistance to the AMWG, and its responsibility is limited to carrying out only specific assignments within the scope of AMWG's responsibility, as directed by AMWG.

i. The LTEMP Scientific Monitoring Plan

The DOI, through GCMRC, will prepare a scientific monitoring plan for LTEMP. This plan will be reviewed every 3 years and may be updated as needed. This is intended to be a framework that will delineate what monitoring will be needed to document resource status, to collect data for determining whether experiments identified in the preferred alternative of the LTEMP FEIS had the intended effects, and to monitor for potential unacceptable adverse effects. It will only be used to provide a framework for the scientific support needed to complete the monitoring and experimentation specified in the LTEMP FEIS and ROD. Specifics on research and monitoring activities, including detailed study plans and budgets, will be described in GCDAMP budget process, currently implemented through the triennial work plan and budget. A draft of LTEMP scientific monitoring plan has been provided to TWG. This LTEMP scientific monitoring plan will be finalized by GCMRC within 30 days of the signing of this ROD.

6.2 Protection, Mitigation, and Monitoring of Cultural Resources

Cultural resources, in general, include archeological resources, historic and prehistoric structures, cultural landscapes, traditional cultural properties (TCPs), ethnographic resources, and museum collections. These may include locations and objects that are important to American Indian tribes for maintaining their culture. There are a number of ways in which dam operations may affect cultural resources, including the periodicity of inundation and exposure, changing vegetation cover, streambank erosion, slumping, and influencing the availability of sediment. The GCPA, NEPA, and National Historic Preservation Act (NHPA) have varying responsibilities to address these cultural resources and the responsibilities to protect, mitigate, and monitor cultural resources that may be affected by the actions in the selected alternative.

Section 106 of the NHPA focuses on a specific set of cultural resources known as "historic properties" (properties that are eligible for or listed on the NRHP) rather than GCPA and NEPA's focus on a broader range of cultural resources. Specifically, NHPA requires consultation on the potential for an "undertaking" (here, Glen Canyon Dam operations and non-flow actions identified in the LTEMP) to affect "historic properties" within a designated "area of potential effect (APE)."

The scope of the NEPA analysis is confined to the area defined in Section 1 of this ROD as the CRE and does not extend rim to rim of the Canyons. For the purposes of NEPA and for this LTEMP ROD, the physical effects within CRE are the focus.

For NHPA purposes, the APE must take into consideration the effects on TCPs that are determined to be eligible for listing on the NRHP. Several tribes participating in the NHPA consultation process have stated that the Canyons as a whole are a place of great cultural importance. Both the Hopi and Zuni Tribes have documented a rim to rim TCP that meets the criteria for eligibility to the NRHP within the Grand Canyon and have submitted this documentation to the Arizona State Historic Preservation Office (SHPO) and DOI agencies. Several other tribes have also expressed a desire to conduct determinations of eligibility for TCPs that extend rim to rim under NHPA. The DOI, with Reclamation as the lead agency for Section 106 compliance, recognizes the potential for adverse effects on contributing elements of the documented TCP within the CRE2 from direct or indirect physical effects of dam operations and related mitigation and science activities.

Several existing documents address historic properties under NHPA, including a 1994 Programmatic Agreement (PA) entitled "Programmatic Agreement among The Bureau of Reclamation, Advisory Council on Historic Preservation, National Park Service, Arizona State Historic Preservation Officer, Havasupai Tribe, Hopi Tribe, Hualapai Tribe, Kaibab Paiute Tribe, Navajo Nation, San Juan Southern Paiute Tribe, Shivwits Paiute Indian Tribe and Zuni Pueblo Regarding Operations of the Glen Canyon Dam" (1994 PA), the 2012 "Memorandum of Agreement: Glen Canyon Dam High Flow Experimental Protocol" and the 2012 "Non-Native Fish Control in the Colorado River below Glen Canyon Dam Memoranda of Agreement." A new PA and a new or amended nonnative fish agreement are being developed, and upon execution, these new agreements will replace the previous agreements. Until this new PA is in place, Reclamation will comply with the existing Section 106 agreement documents.

One of the elements of the PA that will be developed is a Historic Preservation Plan (HPP). The HPP will include tribal perspectives, long-term management goals, a monitoring plan, the process for documentation of TCPs, and communication protocols, including cultural sensitivity training. The HPP will also identify the historic properties within CRE that may be adversely affected by dam operations that may require mitigation. The HPP will also specify the cycle for monitoring the historic properties within CRE. The monitoring, science, and potential mitigation activities that are tied to dam operations within CRE would be eligible for funding with GCDAMP hydropower funds, as stated in Section 6.1(b) of this ROD. Other cultural resource commitments that cannot be directly tied to dam operations will be addressed through other funding sources or processes.

6.3 Endangered Species Act Compliance

In compliance with ESA, Reclamation submitted a draft Biological Assessment (BA) to FWS on August 16, 2016, and requested formal consultation on the preferred alternative. In the final BA, submitted on September 27, 2016, Reclamation determined the preferred alternative may affect, and is likely to adversely affect, the humpback chub (*Gila cypha*) and the razorback sucker (*Xyrauchen texanus*) and their designated critical habitat due to potential harm and/or harassment resulting from changes in (1) flows, (2) nonnative trout and other species, and (3) water temperatures that are largely driven by reservoir elevation. The fish may also benefit from both flow (e.g., TMFs) and non-flow options (e.g., mechanical removal) and adaptive and experimental actions that minimize impacts on humpback chub and razorback sucker and support the recovery of the species. The proposed action may affect, and is likely to adversely affect, the Kanab ambersnail (*Oxyloma haydeni kanabensis*), because there is potential that habitat would be inundated during HFEs. The proposed action may affect, but is not likely to adversely affect the Yuma Ridgway's rail (*Rallus obsoletus Yumanensis)* and the southwestern willow flycatcher (*Empidonax traillii extimus*), because the proposed action will not occur in areas occupied by these species or will result in insignificant or discountable effects on these species and their

2 Whenever the CRE is referred to within this ROD, it refers to the specific definition of the CRE provided in Section 1 of this ROD.

critical habitat. The FWS concurred with this determination by memo dated November 8, 2016, and issued its BO for the preferred alternative by memo dated November 28, 2016.

In the BO, FWS determined that the adverse effects and associated incidental take from implementation of the LTEMP are not expected to negatively affect humpback chub, razorback sucker, or Kanab ambersnail recovery or further diminish the conservation contribution of critical habitat to the recovery of these species. Further, the BO states that the LTEMP selected action incorporates sufficient conservation measures that reasonably and prudently minimize the effects of incidental take of humpback chub, razorback suckers, and Kanab ambersnails. All reasonable measures to minimize take have been incorporated into the project description; therefore, no reasonable and prudent measures were included in FWS incidental take statement. For the humpback chub, FWS stated that the proposed conservation measures are at least as strong, and likely stronger, than any reasonable and prudent measures FWS would require.

Reclamation has included the following conservation measures for listed species in the action area as part of its proposed action. Further planning and compliance may be needed to implement components of the new conservation measures below. Full details can be found in the BO (Attachment E of this ROD).

Humpback Chub

Ongoing actions:

- Reclamation will continue to support translocations of humpback chub into tributaries of the Colorado River.

- Reclamation will continue to fund a spring and fall population estimate annually, or at a different frequency as deemed appropriate in consultation with FWS, using a mark recapture based model for the Little Colorado River or the most appropriate model developed for the current collecting techniques and data.

- Reclamation will continue to fund control or removal of nonnative fish in tributaries prior to chub translocations depending on the existing fish community in each tributary.

- Reclamation will continue to fund the maintenance of a humpback chub refuge population at a Federal hatchery or other appropriate facility to assist in annual maintenance.

- Reclamation will continue to support efforts to ensure that a stable or upward trend of humpback chub aggregations can be achieved by continuing to conduct monitoring, evaluating drivers of the existing aggregations, and exploring means to expand the populations.

- Reclamation will support disease and parasite monitoring in humpback chub and other fishes in the mainstem Colorado.

New actions:

- Reclamation will collaborate with the FWS, GCMRC, NPS, and the Havasupai Tribe to conduct preliminary surveys and a feasibility study for translocation of humpback chub into Upper Havasu Creek (above Beaver Falls).

- Reclamation will, in cooperation with the FWS, NPS, GCMRC, and AZGFD, explore and evaluate other tributaries for potential translocations.

Razorback Sucker

Ongoing actions:

- Reclamation will continue to fund larval and small-bodied fish monitoring in order to determine habitat use and distribution of different life stages, determine the extent of hybridization, and assess the effects of TMFs and other dam operations on razorback suckers.

Actions to Benefit All Native Aquatic Species

Ongoing actions:

- Reclamation, in collaboration with the NPS and FWS, and in consultation with AZGFD, will investigate the possibility of renovating Bright Angel and Shinumo Creeks with a chemical piscicide, or other tools, with appropriate planning, compliance, and tribal consultation.

- Reclamation will continue to fund efforts of the GCMRC and NPS to remove brown trout (and other nonnative species) from Bright Angel Creek and the Bright Angel Creek Inflow reach of the Colorado River, and from other areas where new or expanded spawning populations develop, consistent with the NPS Comprehensive Fisheries Management Plan (CFMP). After 5 years of removal efforts are completed (in 2017), an analysis of success would be conducted.

New actions

- Reclamation will explore the efficacy of a temperature control device at the dam to respond to potential extremes in hydrological conditions due to climate conditions that could result in nonnative fish establishment.

- Reclamation will pursue means of preventing the passage of deleterious invasive nonnative fish through Glen Canyon Dam.

- Reclamation will assist in funding the completion of planning and compliance to alter the backwater slough at River Mile (RM) 12 (commonly referred to as "Upper Slough"), making it unsuitable or inaccessible to warm water nonnative species.

- Reclamation will support the completion of planning and compliance of a plan for implementing rapid response control efforts for newly establishing or existing deleterious invasive nonnative species within and contiguous to the action area.

- Reclamation will consider experimental use of TMFs to inhibit brown trout spawning and recruitment in Glen Canyon, or other mainstem locations.

Southwestern Willow Flycatcher and Yuma Ridgway's Rail

- Reclamation would partially assist in funding NPS to conduct Yuma Ridgway's rail surveys once every 3 years for the life of the LTEMP.

- Reclamation would partially assist in funding NPS to conduct southwestern willow-flycatcher surveys once every 2 years for the life of the LTEMP.

6.4 Experimental Vegetation Treatment and Mitigation

As part of LTEMP, experimental riparian vegetation treatment was included as mitigation for dam operations within CRE. Vegetation treatment actions on NPS managed lands will be implemented by NPS consistent with NPS *Management Policies* (NPS 2006) and will occur only within the CRE in areas that are influenced by dam operations. The NPS will work with tribal partners and GCMRC to experimentally implement and evaluate a number of vegetation control and native replanting activities on the riparian vegetation within the Colorado River Ecosystem in GCNP and GCNRA. These activities would include ongoing monitoring and removal of selected nonnative plants, species in the corridor, systematic removal of nonnative vegetation at targeted sites, and native replanting at targeted sites and subreaches, which may include complete removal of tamarisk (both live and dead) and revegetation with native vegetation. Treatments would fall into two broad categories, including the control of nonnative plant species and revegetation with native plant species. Principal elements of this experimental riparian vegetation proposal include:

- Control nonnative plant species affected by dam operations, including tamarisk and other highly invasive species;
- Develop native plant materials for replanting through partnerships and the use of regional greenhouses;
- Replant native plant species to priority sites along the river corridor, including native species of interest to tribes;
- Remove vegetation encroaching on campsites; and
- Manage vegetation to assist with cultural site protection.

6.5 Commitments to Tribes

- Traditionally Associated Tribes[3] shall be notified at least 30 days in advance of planned experimental flows (including HFEs, TMFs, MPFs, and LSFs).
- The DOI is committed to finding beneficial uses with Traditionally Associated Tribes for nonnative fish that are mechanically removed as part of the LTEMP actions to the extent practicable.
- The DOI recognizes the opportunities for cooperative and collaborative partnerships with tribes in the management of Federal lands and resources related to the LTEMP as stated in Secretarial Order No. 3342.

7. IMPLEMENTATION

The Glen Canyon Dam LTEMP base operations shall be phased in through interim operations between January 1, 2017, and September 30, 2017. Beginning January 1, 2017, interim operations shall implement LTEMP general monthly release volume pattern. The LTEMP operations will not affect or change the total annual release volume stated in the Annual Operating Plan for Colorado River Reservoirs. The LTEMP ramp rates and daily fluctuations shall be phased in no later than October 1, 2017. The LTEMP experimental flows and non-flow experiments shall be implemented after September 30, 2017, to allow for agreements, planning, and budgeting to be adjusted for the new LTEMP priorities and operations. Spring HFEs shall be implemented when conditions warrant, as described in the FEIS beginning September 30, 2019. The LSF experiments may be implemented no sooner than October 1, 2027. Research and monitoring projects already approved in the 2015–2017 triennial work plan and budget shall continue until September 30, 2017.

As part of the adaptive management process, DOI will conduct a comprehensive review after October 1, 2027, to evaluate what has been learned from the experimental studies and an

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3 "Traditionally Associated Tribes" refers to the Havasupai Tribe, Hopi Tribe, Hualapai Tribe, Kaibab Paiute Tribe, Navajo Nation, San Juan Southern Paiute Tribe, Shivwits Paiute Indian Tribe, and the Pueblo of Zuni.

evaluation of resource conditions after 10 years of LTEMP operational experience. If after this review it is determined that there is significant new scientific information and a compelling need to conduct new experiments or modify existing experiments for the improvement of resources, then new experiments outside of what was analyzed and selected in this NEPA process could be considered. Additional NEPA processes related to these experiments may need to be completed as appropriate.

As stated in Section 2.2.4 in Attachment B of this ROD, DOI will convene a scientific panel that includes independent experts prior to the first potential use of LSFs to synthesize the best available scientific information related to LSFs. The panel may meet periodically to update the information, as needed. This information will be shared as part of the AMWG annual reporting process.

8. DISCLAIMER

Nothing in this ROD is intended to interpret specific provisions of the Law of the River, including, but not limited to, the provisions of the Colorado River Compact (45 Stat. 1057); the Upper Colorado River Basin Compact (63 Stat. 31); the Utilization of Water of the Colorado and Tijuana Rivers and of the Rio Grande; Treaty between the United States of America and Mexico (Treaty Series 994, 59 Stat. 1219); the United States/Mexico agreement in Minute 242 of August 30, 1973 (Treaty Series 7708; 24 UST 1968); the Decree entered by the Supreme Court of the United States *Arizona v. California, et. al.* (376 U.S. 340), as amended and supplemented; the Boulder Canyon Project Act (45 Stat. 1057); the Boulder Canyon Adjustment Act (54 Stat. 774; 43 U.S.C. 618a); the Colorado River Storage Project Act (70 Stat. 105; 43 U.S.C. 620); or the Colorado River Basin Project Act (82 Stat. 885; 43 U.S.C. 1501). Nor is this ROD intended to interpret specific provisions pertaining to laws governing the administration of GCNP, GCNRA, LMNRA or WAPA.

Approved:

Sally Jewell
Secretary of the Interior

Dec. 15, 2016
Date

Attachments

- **A. Objectives and Resource Goals of the LTEMP**
- **B. Description of the Selected Alternative (Alternative D)**
- **C. High-Flow Experiment Protocol for the Selected Alternative (Alternative D)**
- **D. Responses to Comments on the FEIS**
- **E. U.S. Fish and Wildlife Service Biological Opinion for the Glen Canyon Dam Long-Term Experimental and Management Plan**
- **F. Statement of Non-Impairment Determination for the Selected Alternative**

ATTACHMENT A:

OBJECTIVES AND RESOURCE GOALS OF THE LTEMP

The DOI has identified several primary objectives of operating Glen Canyon Dam under the LTEMP, as well as more specific goals to improve resources within the Colorado River Ecosystem through experimental and management actions. These objectives and resource goals were considered in the formulation and development of alternatives in the FEIS.

The following is a list of the objectives of the LTEMP:

- Develop an operating plan for Glen Canyon Dam in accordance with the GCPA to protect, mitigate adverse impacts to, and improve the values for which GCNP and GCNRA were established, including, but not limited to, natural and cultural resources and visitor use, and to do so in such a manner as is fully consistent with and subject to the Colorado River Compact, the Upper Colorado River Basin Compact, the Water Treaty of 1944 with Mexico, the decree of the U.S. Supreme Court in *Arizona v. California*, and the provisions of CRSPA and the Colorado River Basin Project Act of 1968 that govern the allocation, appropriation, development, and exportation of the waters of the Colorado River Basin (see Section 1.9.4 of the FEIS) and in conformance with the Criteria for Coordinated Long-Range Operations of Colorado River Reservoirs which are currently implemented by the 2007 Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead.

- Ensure the LTEMP does not affect water delivery to the communities and agriculture that depend on Colorado River water consistent with applicable determinations of annual water release volumes from Glen Canyon Dam made pursuant to the LROC for Colorado River Basin Reservoirs, which are currently implemented through the 2007 Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead.

- Consider potential future modifications to Glen Canyon Dam operations and other flow and non-flow actions to protect and improve downstream resources.

- Maintain or increase Glen Canyon Dam electric energy generation, load following capability, and ramp rate capability, and minimize emissions and costs to the greatest extent practicable, consistent with improvement and long-term sustainability of downstream resources.

- Respect the interests and perspectives of American Indian Tribes.

- Make use of the latest relevant scientific studies, especially those conducted since 1996.

- Determine the appropriate experimental framework that allows for a range of programs and actions, including ongoing and necessary research, monitoring, studies, and management actions in keeping with the adaptive management process.

- Ensure Glen Canyon Dam operations and non-flow actions under the LTEMP are consistent with the GCPA, ESA, NHPA, CRSPA, and other applicable federal laws.

Reclamation and NPS developed resource goals considering public input and desired future conditions (DFCs) previously adopted by the Adaptive Management Work Group (AMWG). The following resource goals were identified:

1. *Archaeological and Cultural Resources*. Maintain the integrity of potentially affected NRHP-eligible or listed historic properties in place, where possible, with preservation methods employed on a site-specific basis.

2. *Natural Processes*. Restore, to the extent practicable, ecological patterns and processes within their range of natural variability, including the natural abundance, diversity, and genetic and ecological integrity of the plant and animal species native to those ecosystems.

3. *Humpback Chub*. Meet humpback chub recovery goals, including maintaining a self-sustaining population, spawning habitat, and aggregations in the Colorado River and its tributaries below the Glen Canyon Dam.

4. *Hydropower and Energy*. Maintain or increase Glen Canyon Dam electric energy generation, load following capability, and ramp rate capability, and minimize emissions and costs to the greatest extent practicable, consistent with improvement and long-term sustainability of downstream resources.

5. *Other Native Fish*. Maintain self-sustaining native fish species populations and their habitats in their natural ranges on the Colorado River and its tributaries.

6. *Recreational Experience*. Maintain and improve the quality of recreational experiences for the users of the Colorado River Ecosystem. Recreation includes, but is not limited to, flatwater and whitewater boating, river corridor camping, and angling in Glen Canyon.

7. *Sediment*. Increase and retain fine sediment volume, area, and distribution in the Glen, Marble, and Grand Canyon reaches above the elevation of the average base flow for ecological, cultural, and recreational purposes.

8. *Tribal Resources*. Maintain the diverse values and resources of traditionally associated Tribes along the Colorado River corridor through Glen, Marble, and Grand Canyons.

9. *Rainbow Trout Fishery*. Achieve a healthy high-quality recreational rainbow trout fishery in GCNRA and reduce or eliminate downstream trout migration consistent with NPS fish management and ESA compliance.

10. *Nonnative Invasive Species*. Minimize or reduce the presence and expansion of aquatic nonnative invasive species.

11. *Riparian Vegetation*. Maintain native vegetation and wildlife habitat, in various stages of maturity, such that they are diverse, healthy, productive, self-sustaining, and ecologically appropriate.

Overlying these goals is the understanding that operations under LTEMP will continue to deliver water in a manner that is fully consistent with and subject to the Colorado River Compact, the Upper Colorado River Basin Compact, the Water Treaty of 1944 with Mexico, the decree of the Supreme Court in *Arizona v. California*, and the provisions of CRSPA and the Colorado River Basin Project Act of 1968 that govern allocation, appropriation, development, and exportation of the waters of the Colorado River Basin, and consistent with applicable determinations of annual water release volumes from Glen Canyon Dam made pursuant to the LROC for Colorado River Basin Reservoirs, which are currently implemented through the 2007 Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead. As such, water delivery is an overarching consideration for dam operations that will necessarily inform the actions that can be taken to achieve the resource goals set forth above.

ATTACHMENT B:

DESCRIPTION OF THE SELECTED ALTERNATIVE (ALTERNATIVE D)

The objective of Alternative D (the preferred alternative in the LTEMP FEIS and the selected alternative in the LTEMP ROD) is to adaptively operate Glen Canyon Dam to best meet the resource goals of the LTEMP. Like Alternative C, Alternative D features condition-dependent flow and non-flow actions that will be triggered by resource conditions.

Alternative D was developed by the DOI after a full analysis of the other six LTEMP alternatives had been completed. This alternative was identified as the preferred alternative by the DOI, and its identification as the preferred alternative was supported by WAPA and the Basin States. Alternative D was also considered the environmentally preferred alternative, based on its relative impacts (compared to other alternatives) on the full range of environmental resources. Alternative D adopts operational and experimental characteristics from Alternative C and Alternative E. The effects of operations under Alternatives C and E were modeled, and the results of that modeling suggested ways in which characteristics of each could be combined and modified to improve performance and reduce impacts, while meeting the purpose, need, and objectives of the LTEMP EIS. Alternative D is expected to result in an improvement in conditions for humpback chub, trout, and the aquatic food base; have the least impact on vegetation, wetlands, and terrestrial wildlife; improve sandbar building potential and conserve sediment; sustain or improve conditions for reservoir and river recreation; improve preservation of cultural resources; respect and enhance Tribal resources and values; and have limited impacts on hydropower resources.

On the basis of modeling results for Alternative C and E, discussions with subject matter experts and Cooperating Agencies, and specific impact analyses of various potential Alternative D characteristics conducted using the screening tool (see Section 2.1 of the FEIS for a discussion of the models integrated in the screening tool), the DOI developed the operational and experimental characteristics of Alternative D. This formulation of the alternative then was modeled with the same models used for the analysis of the original six alternatives.

Adjustments were made to Alternative D after the integrated multiple-resource modeling, illustrated in Figure 4-1 of the FEIS, was completed in March 2015, prior to the release of the DEIS in January 2016. This modeling considered a full-range of hydrology and sediment conditions, as described in Section 4.1 of the FEIS. Adjustments to Alternative D included (1) an increase in release volume in August with corresponding decreases in May and June (in an 8.23-maf year, the increase was 50 kaf in August, i.e., from 750 to 800 kaf; and a reduction of 25 kaf each in May and June; these changes were applied proportionally to monthly volumes in drier and wetter years); (2) elimination of load-following curtailment prior to sediment-triggered HFEs; (3) an adjustment of the duration of load-following curtailment after a fall HFE; and (4) a prohibition on sediment-triggered spring HFEs in the same water year as an extended-duration (>96 hr) fall HFE. Adjustments made to Alternative D after the DEIS was published, and based on comments received from Cooperating Agencies and stakeholders on the DEIS, included (1) elimination of load-following curtailment after a fall HFE and (2) a prohibition on proactive spring HFEs in the same water year as an extended-duration fall HFE.

The description of Alternative D provided in this attachment to the ROD represents the final version of the alternative that resulted from these changes.

Once the adjustments to Alternative D were made, analyzing them using multiple-resource modeling would have taken many months and incurred significant additional cost. Therefore, instead of performing multiple-resource modeling on the effects of these adjustments, the joint-leads chose to perform streamlined modeling using the screening tool (see Section 2.1 of the FEIS for a description of this modeling tool) and analysis to assess the magnitude and direction of these effects of the adjustments. As described in Section 4.1 of the FEIS, for most resources, these adjustments to Alternative D are expected to result in little if any change in impacts relative to those predicted for the earlier modeled version of Alternative D. However, the streamlined analysis did show that the adjustments would result in some changes to the expected impacts on sediment and hydropower resources, but that for all resources other than hydropower these changes would not affect the relative performance of Alternative D compared to other alternatives (see discussion in Section 4.1 of the FEIS). Because the adjustments to Alternative D would not change Alternative D's relative performance for most resources, and the changes to hydropower impacts would be reductions—not increases—in impact, the agencies chose not to perform additional multiple-resource modeling. In addition to presenting the original multiple-resource modeling results, the results of the streamlined modeling evaluating the effects of these adjustments on sediment and hydropower are presented in Sections 4.3.3.4 and 4.13.3.4 of the FEIS, respectively. Because, for most resources, these adjustments are expected to result in little if any change in impact relative to those predicted for the earlier modeled version of Alternative D, the only quantitative analysis results presented in those sections of the FEIS are those from the original multiple-resource modeling.

1 OPERATIONAL CHARACTERISTICS OF ALTERNATIVE D

Operational characteristics and condition-dependent experimental elements under Alternative D are described in this section. The alternative uses decision trees to identify when a change in the implementation of experimental actions may be considered; however, DOI will retain sufficient flexibility in the implementation of experiments to ensure the protection of resources (Section 1.3). Experimental flows and non-flow actions could be triggered by changes in sediment input, humpback chub numbers and population structure, trout numbers, and water temperature after consideration of effects on all resources. Alternative D differs from Alternatives C and E in the specific trigger conditions and actions that will be taken.

1.1 BASE OPERATIONS UNDER ALTERNATIVE D

Table 1 presents operational characteristics of Alternative D. Table 2 and Figure 1 present the monthly release volumes, monthly proportion of total annual volume, mean daily flow, and daily fluctuation range in an 8.23-maf year. Within a year, monthly operations may be increased or decreased based on factors referenced in Section 1.2 and 1.3. Table 3 presents the monthly volumes under different hydrological conditions for annual volumes ranging from 7.0 to 14.0 maf. Monthly volumes would be increased or decreased proportionally according to

TABLE 1 Operational Characteristics of Alternative D

Elements of Base Operations[a]	Values under Preferred Alternative
Monthly pattern in release volume	Monthly volumes are described in Tables 2 and Table 3; volume released in Oct.–Dec. = 2.0 maf in ≥ 8.23-maf years and 1.5 maf in years ≤ 7.48 maf
Minimum flows	8,000 cfs between 7 a.m. and 7 p.m. 5,000 cfs between 7 p.m. and 7 a.m.
Maximum non-experimental flows[b]	25,000 cfs
Daily range[c]	Equal to 10 × monthly volume (in kaf) in Jun.–Aug., and 9 × monthly volume (in kaf) in other months; daily range not to exceed 8,000 cfs
Ramp rates	4,000 cfs/hr up 2,500 cfs/hr down

[a] Base operations are defined as operations in those years when no condition-dependent or experimental actions are triggered. Examples of experimental actions include HFEs, LSF, and TMFs (see Table 2).

[b] Maximum flows presented are for normal operations and may be exceeded as necessary for HFEs, emergency operations, and equalization purposes.

[c] Values presented are the normal daily range in mean hourly flow. Some variation in instantaneous flows within hours is allowed to accommodate emergency conditions, regulation requirements, and reserve requirements.

TABLE 2 Flow Parameters under Alternative D in an 8.23-maf Year[a]

Month	Monthly Release Volume (kaf)[b]	Proportion of Total Annual Volume	Mean Daily Flow (cfs)	Daily Fluctuation Range (cfs)
October	643	0.0781	10,451	5,783
November	642	0.0780	10,781	5,774
December	716	0.0870	11,643	6,443
January	763	0.0927	12,409	6,867
February	675	0.0820	12,154	6,075
March	713	0.0866	11,596	6,417
April	635	0.0772	10,672	5,715
May	632	0.0768	10,278	5,688
June	663	0.0806	11,142	6,630
July	749	0.0910	12,181	7,490
August	800	0.0972	13,011	8,000
September	600	0.0729	10,083	5,400

[a] Within a year, monthly operations may be increased or decreased based on factors referenced in Section 1.2 and 1.3.

[b] Values have been rounded.

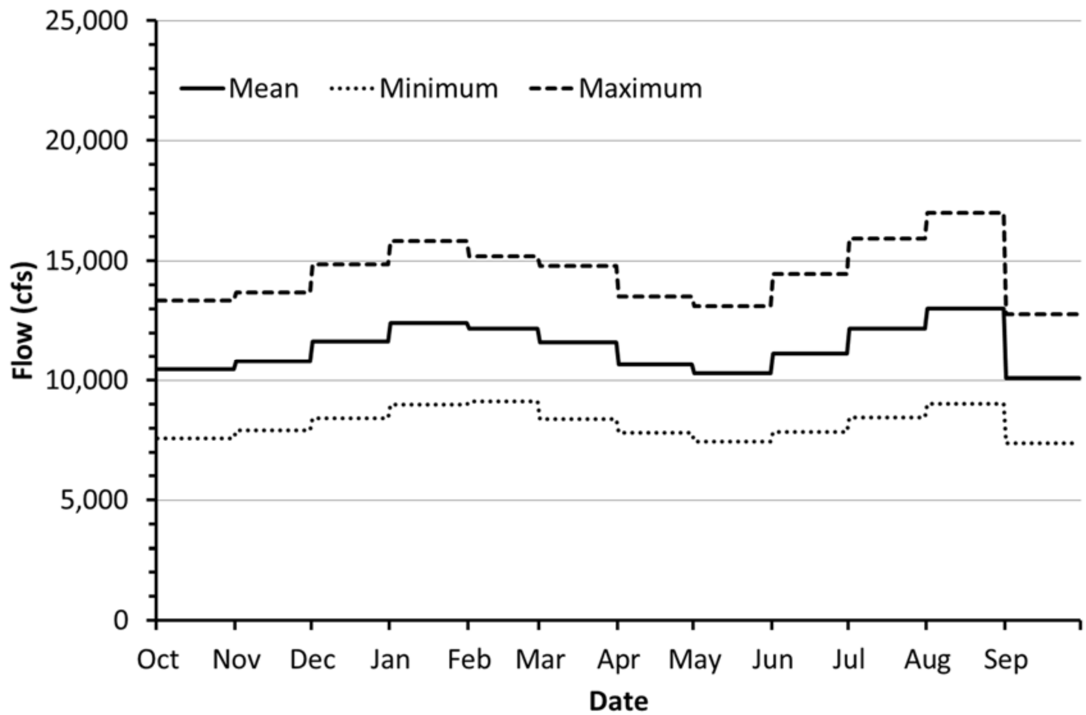


FIGURE 1 Mean, Minimum, and Maximum Daily Flows under Alternative D in an 8.23-maf Year Based on Values Presented in Table 2

TABLE 3 Monthly Release Volumes under Alternative D

	Monthly Release Volume (thousand ac-ft)[a]									
Total Annual	7,000	7,480	8,230	9,000	9,500	10,500	11,000	12,000	13,000	13,000
October	480	480	643	643	643	643	643	643	643	643
November	500	500	642	642	642	642	642	642	642	642
December	600	600	716	716	716	716	716	716	716	716
January	664	723	763	857	919	1,041	1,102	1,225	1,347	1,470
February	587	639	675	758	813	921	975	1,083	1,192	1,300
March	620	675	713	801	858	973	1,030	1,144	1,259	1,373
April	552	601	635	713	764	866	917	1,019	1,121	1,223
May	550	599	632	710	761	862	913	1,014	1,116	1,217
June	577	628	663	745	798	905	958	1,064	1,171	1,277
July	652	709	749	842	902	1,022	1,082	1,202	1,322	1,443
August	696	758	800	899	963	1,091	1,156	1,284	1,413	1,537
September	522	568	600	674	722	819	867	963	1,059	1,160

[a] Release volumes in October, November, and December typically do not vary in years with annual volumes $\geq$ 8.23 maf because the forecasted annual release volume is not known in the beginning of the water year. In other months, release volumes generally follow the proportions shown in the third column of Table 2, up to the maximum and minimum flow constraints presented in Table 1. Within a year, monthly operations may be increased or decreased based on factors referenced in Section 1.2 and 1.3.

forecasted hydrology using the values in Table 3. Under Alternative D, the pattern of monthly releases will be relatively even compared to under Alternative A (Table 2). The total monthly release volume of October, November, and December will be equal to that under Alternative A (i.e., 2 maf in years with ≥ 8.23 maf annual release volume) to avoid the possibility of the operational tier differing from that of Alternative A, as established in the Interim Guidelines (Reclamation 2007). The August volume was set to a moderate volume level (800 kaf in an 8.23-maf release year) to consider both sediment conservation prior to a potential HFE and power-production and capacity concerns. January through July monthly volumes were set at levels that roughly track WAPA's contract rate of delivery (CROD). This produced a redistribution of monthly release volumes under Alternative D that will result in the most even distribution of flows of any alternative except for Alternative G.

Under base operations of Alternative D, the allowable within-day fluctuation range from Glen Canyon Dam will be proportional to the volume of water scheduled to be released during the month (10 × monthly volume in kaf in the high-demand months of June, July, and August and 9 × monthly volume in kaf in other months; Table 2; Figure 1). For example, if the scheduled release volume in July was 800 kaf, the daily fluctuation range would be 8,000 cfs. If the scheduled release volume was 800 kaf in December, the daily range would be 7,200 cfs. The maximum allowable daily fluctuation range in flows in any month will be 8,000 cfs, which is also the maximum daily fluctuation range under Alternative A (No-Action Alternative).

An 8,000-cfs maximum daily fluctuation limit was established in the 1996 ROD (Reclamation 2006) to address safety, recreation, and sediment concerns (Reclamation 1995). The analysis conducted for the LTEMP EIS has not identified new evidence to suggest that these concerns are no longer relevant or that this fluctuation limit is no longer appropriate. The determination of 8,000 cfs as a maximum daily fluctuation level that is suitable for recreation was based on Bishop et al. (1987). Bishop et al. (1987) surveyed both the river guides and the general public regarding preferences, and the river guides reported a preference for a maximum of 8,000 cfs daily change for a "tolerable recreation experience" under relatively high average daily flows. The current river guide community has continued to state the preference for retaining the 8,000-cfs maximum daily fluctuation that is currently in place.

The down-ramp rate under Alternative D will be limited to no greater than 2,500 cfs/hr, which is 1,000 cfs/hr greater than what is allowed under Alternative A. The up-ramp rate will be 4,000 cfs/hr, and this is the same as what is allowed under Alternative A.

Figure 1 shows minimum, mean, and maximum daily flows in an 8.23-maf year, assuming all days in a month adhere to the same mean daily flow within a month. Figure 2 shows the hourly flows in a simulated 8.23-maf year within the constraints of Alternative D. Figure 3 shows details of hourly flows during a week in July.

Annually, Reclamation will develop a hydrograph based on the characteristics above. Reclamation will seek consensus on the annual hydrograph through monthly operational coordination calls with governmental entities, and regular meetings of the GCDAMP Technical Working Group (TWG) and AMWG. Reclamation will conduct monthly Glen Canyon Dam operational coordination meetings or calls with the DOI bureaus (USGS, NPS, FWS, and BIA),

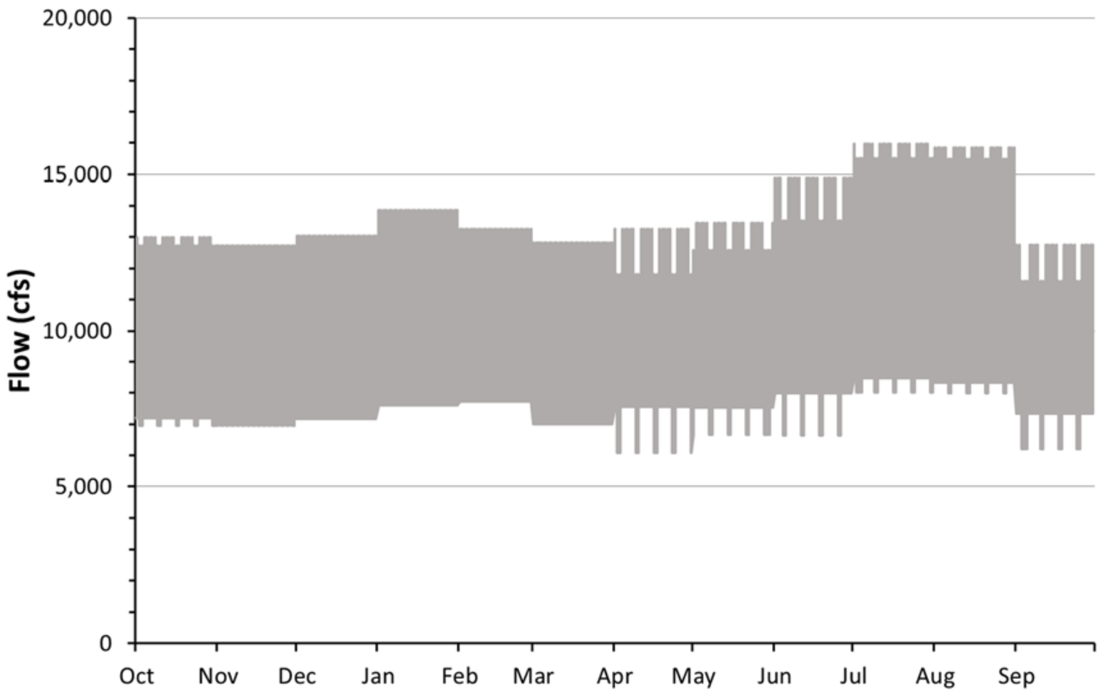


FIGURE 2 Simulated Hourly Flows under Alternative D in an 8.23-maf Year (Note that there are differences in the mean, maximum, and minimum flows shown here and in Figure 1. These differences reflect flexibility in operational patterns allowed within the constraints of the alternative.)

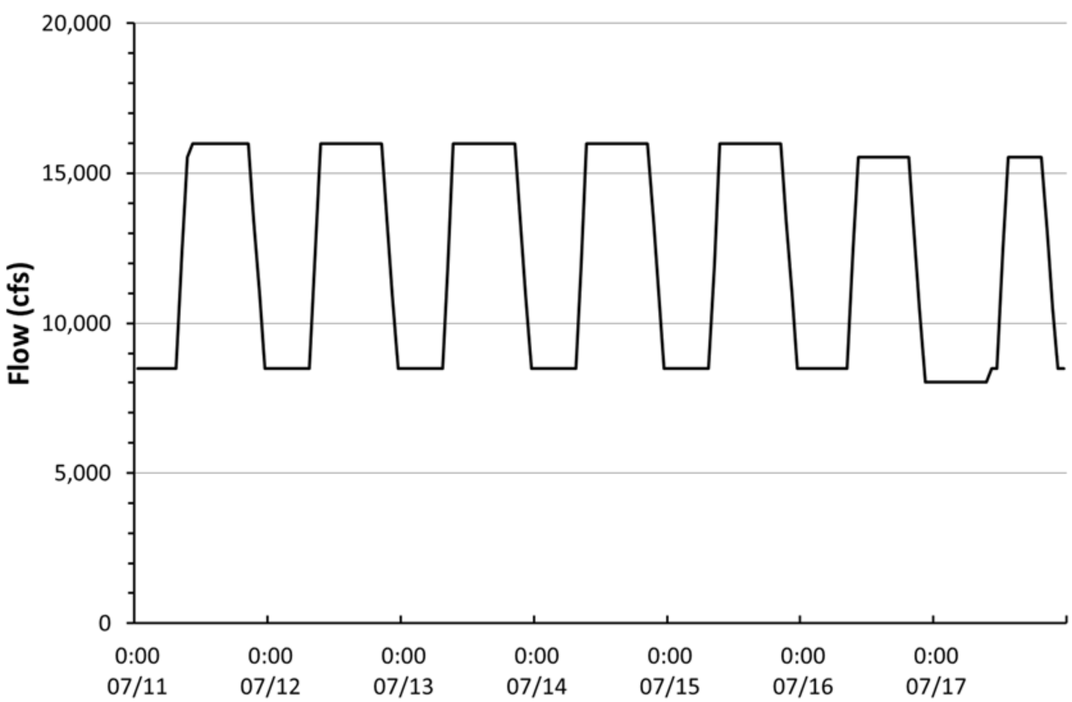


FIGURE 3 Simulated Hourly Flows under Alternative D for a Week in July in an 8.23-maf Year Showing Typically Lower Weekend Flows (The week starts on Monday and ends on Sunday.)

WAPA, and representatives from the Basin States and UCRC. The purpose of these meetings or calls is for the participants to share and seek information on Glen Canyon Dam operations. One liaison from each Basin State and from the UCRC may participate in the monthly operational coordination meetings or calls.

1.2 OPERATIONAL FLEXIBILITY UNDER ALTERNATIVE D

Reclamation retains the authority to utilize operational flexibility at Glen Canyon Dam because hydrologic conditions of the Colorado River Basin (or the operational conditions of Colorado River reservoirs) cannot be completely known in advance. Consistent with current operations, Reclamation, in consultation with WAPA, will make specific adjustments to daily and monthly release volumes during the water year. Monthly release volumes may be rounded for practical implementation or for maintenance needs. In addition, when releases are actually implemented, minor variations may occur regularly for a number of operational reasons that cannot be projected in advance.

Reclamation also will make specific adjustments to daily and monthly release volumes, in consultation with other entities as appropriate, for a number of reasons, including operational, resource-related, and hydropower-related issues. Examples of these adjustments may include, but are not limited to, the following:

- For water distribution purposes, volumes may be adjusted to allocate water between the Upper and Lower Basins consistent with the Law of the River as a result of changing hydrology;

- For resource-related issues that may occur uniquely in a given year, release adjustments may be made to accommodate nonnative species removal, to assist with aerial photography, or to accommodate other resource considerations separate from experimental treatments under the LTEMP;

- For hydropower-related issues, adjustments may occur to address issues such as electrical grid reliability, actual or forecasted prices for purchased power, transmission outages, and experimental releases from other Colorado River Storage Project dams.

In addition, Reclamation may make modifications under circumstances that may include operations that are prudent or necessary for the safety of dams, public health and safety, other emergency situations, or other unanticipated or unforeseen activities arising from actual operating experience (including, in coordination with the Basin States, actions to respond to low reservoir conditions as a result of drought in the Colorado River Basin). In addition, the Emergency Exception Criteria established for Glen Canyon Dam will continue under this alternative. (See, e.g., Section 3 of the Glen Canyon Operating Criteria at 62 FR 9448, March 3, 1997.)

Section 1.3 addresses adjustments to base operations for adaptive management-based experimental operations with flow components.

1.3 IMPLEMENTATION PROCESS FOR EXPERIMENTS UNDER ALTERNATIVE D

Alternative D identifies condition-dependent flow and non-flow treatments intended to safeguard against unforeseen adverse changes in resource impacts, and to prevent irreversible changes to those resources. These condition-dependent treatments will be implemented experimentally during the LTEMP period unless they prove ineffective or result in unacceptable adverse impacts on other resources.

Prior to implementation of any experiment, the relative effects of the experiment on the following resource areas will be evaluated and considered: (1) water quality and water delivery, (2) humpback chub, (3) sediment, (4) riparian ecosystems, (5) historic properties and traditional cultural properties, (6) Tribal concerns, (7) hydropower production and WAPA's assessment of the status of the Basin Fund, (8) the rainbow trout fishery, (9) recreation, and (10) other resources. Although these key resources are listed for consideration on a regular basis, DOI intends to retain sufficient flexibility in implementation of experiments to allow for response to unforeseen circumstances or events that involve any other resources not listed here. The recent discovery of nonnative green sunfish in the Glen Canyon reach illustrates the need to be responsive to unforeseen conditions. DOI will engage in the communication and consultation process described in Section 1.4, when making decisions regarding implementation of experiments.

The proposed approach differs fundamentally from a more formal experimental design (e.g., before-after control-impact design, factorial design) that attempts to resolve uncertainties by controlling for or treating potentially influential or confounding factors. There are several reasons to avoid such a formal design and instead focus on the condition-dependent approach described here. Among these are (1) the difficulties in controlling for specific conditions in a system as complex as the Colorado River; (2) wide variability in temperature and flow conditions that are important drivers in ecological processes; (3) inherent risk of some experimentation to protected sensitive resources, in particular, endangered humpback chub; (4) conflicting multiple-use values and objectives; and (5) low expected value-of-information for the uncertainties that could be articulated, and around which a formal experimental design would be established. For these reasons, a condition-dependent adaptive approach is proposed.

The alternative utilizes the principle that a condition-dependent adaptive design is preferable to a formal experimental design because of the need for a flexible and adaptive program that is responsive to learning. A more formal experimental design, while potentially beneficial in resolving specific uncertainties, would involve multiple-year tests under different conditions, and with sufficient replicates of experimental conditions to statistically test the significance of treatment effects. Such an experimental design would necessarily span a period of years, during which environmental conditions would undoubtedly vary, and thus confound interpretation of results. The duration of the experiment could be lengthened and the potential for confounding effects increased if there was a desire to test system response under specific conditions that cannot be controlled (e.g., annual volume, water temperature, sediment load, and species population levels). These factors make a formal experimental design impractical in the Grand Canyon. Like Alternatives C and E, Alternative D will use condition-dependent triggers to inform operations and experimental flow and non-flow treatments in a given year.

Implementation criteria for condition-dependent experimental treatments of Alternative D are provided in Table 4, and decision trees for implementation of experimental treatments are presented in Figures 4 and 5. (Note: In both of these figures, triggering would also be conditional on annual implementation considerations and long-term off-ramps presented in Table 4. The nodes shown in rectangles are condition-dependent action nodes; the nodes shown in circles are information-dependent nodes that require the evaluation of accumulated evidence.) Included in Table 4 are the triggers for experimental changes in operations, implementation considerations for determining if an experimental treatment should proceed, conditions that would cause the treatment to be terminated prior to completion (i.e., off-ramps), and the number of replicates that are initially considered needed. In many cases, two to three replicates of an experimental treatment are considered necessary. The results of these tests will be used to determine if these condition-dependent treatments should be retained as part of the suite of long-term actions implemented under LTEMP. In other cases, following the process described elsewhere in this section, implementation of experimental treatments will continue throughout the LTEMP period if triggered (e.g., spring and fall HFEs), except in years when it was determined that the proposed experiment could result in unacceptable adverse impacts on resource conditions. For these experiments, effectiveness will be monitored and the experiments will be terminated or modified, only if sufficient evidence suggested the treatment was ineffective or had unacceptable adverse impacts on other resources. All experimental treatments will be closely monitored for adverse side effects on important resources. At a minimum, an unacceptable adverse impact will include significant negative impacts on resources as a result of experimental treatments that have not been analyzed for Alternative D in the LTEMP EIS.

Sections 2.1 and 2.2 describe specific processes for the development and implementation of experiments related to sediment, aquatic resources, and riparian vegetation. The overall approach attempts to strike a balance between identifying specific experiments and providing flexibility to implement those experiments when resource conditions are appropriate. As discussed above, rather than proposing a prescriptive approach to experimentation, an adaptive management-based approach that is responsive and flexible will be used to adapt to changing environmental and resource conditions and new information. The potential for confounding interactions among individual experimental treatments is discussed when relevant for each of the proposed treatments. Given the size of the project area and the variability inherent in the system, this pragmatic approach to experimentation is warranted. Although confounding treatments are possible given the complexity of the experimental plan, they are not expected to limit learning over the life of the LTEMP.

TABLE 4 Implementation Criteria for Experimental Treatments of Alternative D

Experimental Treatment	Trigger[a] and Primary Objective	Replicates	Duration	Annual Implementation Considerations[b]	Long-Term Off-Ramp Conditions[c]	Action if Successful
Sediment-Related Experiments[d]						
Spring HFE up to 45,000 cfs in Mar. or Apr.	Trigger: Sufficient Paria River sediment input in spring accounting period (Dec.–Jun.) to achieve a positive sand mass balance in Marble Canyon with implementation of an HFE Objective: Rebuild sandbars	Not conducted during first 2 years of LTEMP, otherwise implement in each year triggered, dependent on resource condition and response	≤96 hr	Potential short-term unacceptable impacts on resources listed in Section 1.3; unacceptable cumulative effects of sequential HFEs; sediment-triggered spring HFEs will not occur in the same water year as an extended-duration (>96 hr) fall HFE	Sediment-triggered spring HFEs are not effective in building sandbars; or long-term unacceptable adverse impacts on the resources listed in Section 1.3 are observed	Implement as adaptive treatment when triggered and existing resource conditions allow
Proactive spring HFE up to 45,000 cfs (Apr., May, or Jun.)	Trigger: High-volume year with planned equalization releases (≥10 maf) Objective: Protect sand supply from equalization releases	Not conducted during first 2 years of LTEMP, otherwise implement in each year triggered, dependent on resource condition and response	First test 24 hr; subsequent tests could be shorter, but not longer, depending on results of first tests	Potential short-term unacceptable impacts on resources listed in Section 1.3; unacceptable cumulative effects of sequential HFEs; will not be implemented in the same water year as a sediment-triggered spring HFE or extended-duration fall HFE	Proactive spring HFEs are not effective in building sandbars; or long-term unacceptable adverse impacts on the resources listed in Section 1.3 are observed	Implement as adaptive treatment when triggered and existing resource conditions allow

TABLE 4 (Cont.)

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

TABLE 4 (Cont.)

Experimental Treatment	Trigger[a] and Primary Objective	Replicates	Duration	Annual Implementation Considerations[b]	Long-Term Off-Ramp Conditions[c]	Action if Successful
Aquatic Resource-Related Experiments[e]						
Trout management flows	Trigger: Predicted high trout recruitment in the Glen Canyon reach Objective: Test efficacy of flow regime on trout numbers and survival of humpback chub	Implement as needed when triggered after consultation with Tribes; test may be conducted early in the 20-year period even if not triggered by high trout recruitment[f]	Implemented in as many as 4 months (May–Aug.)	Potential short-term unacceptable impacts on resources listed in Section 1.3	TMFs have little or no effect on trout recruitment after at least three tests; or long-term unacceptable adverse impacts on the resources listed in Section 1.3 are observed	Implement as adaptive treatment triggered by predicted high trout recruitment in Glen Canyon, taking into consideration Tribal concerns
Tier 1: Expanded translocation of humpback chub in the Little Colorado River	Trigger: Number of adult or subadult humpback chub in the Little Colorado River reach below Tier 1 triggers Objective: Increase number of adult and subadult humpback chub	Implement in each year triggered unless determined ineffective	As needed	Potential short-term unacceptable impacts on resources listed in Section 1.3	Expanded translocation has little or no effect on increasing the number of adult or subadult humpback chub; or long-term unacceptable adverse impacts on the resources listed in Section 1.3 are observed	Implement as adaptive treatment when triggered and existing resource conditions allow
Tier 1: Implement head-start program for larval humpback chub	Trigger: Number of adult or subadult humpback chub in the Little Colorado River reach below Tier 1 triggers Objective: Increase number of adult and subadult humpback chub	Implement in each year triggered unless determined ineffective	As needed	Potential short-term unacceptable impacts on resources listed in Section 1.3	Head-start program has little or no effect on increasing the number of adult or subadult humpback chub; or long-term unacceptable adverse impacts on the resources listed in Section 1.3 are observed	Implement as adaptive treatment when triggered and existing resource conditions allow

TABLE 4 (Cont.)

Experimental Treatment	Trigger[a] and Primary Objective	Replicates	Duration	Annual Implementation Considerations[b]	Long-Term Off-Ramp Conditions[c]	Action if Successful
Aquatic Resource-Related Experiments (Cont.)						
Tier 2: Mechanical removal of nonnative fish in Little Colorado River reach	Trigger: Tier 1 actions ineffective; humpback chub numbers in Little Colorado River below Tier 2 triggers Objective: Increase number of adult and subadult humpback chub	Implement in each year triggered unless determined ineffective after consultation with Tribes	Monthly removal trips (Feb.–Jul.) until "predator index" or adult humpback chub reach acceptable levels (see Appendix O)	Potential short-term unacceptable impacts on resources listed in Section 1.3	Mechanical removal has little or no effect on reducing predator index in the Little Colorado River reach; no population-level benefit on humpback chub; or long-term unacceptable adverse impacts on the resources listed in Section 1.3 are observed	Implement as adaptive treatment when triggered, taking into consideration Tribal concerns
Low summer flows (minimum daily mean 5,000 to 8,000 cfs) to target ≥ 14°C at Little Colorado River confluence	Trigger: Initial experiment: in the second 10 years of the LTEMP period, when target temperature of ≥14°C can be achieved only with low summer flow Objective: Increase humpback chub growth	Subsequent experimental use if: (1) initial test was successful, (2) humpback chub population concerns warrant their use, (3) water temperature appears to be limiting recruitment, and (4) target temperature of ≥14°C could be achieved only with low summer flow	3 months (Jul.–Sep.)	Potential short-term unacceptable impacts on resources listed in Section 1.3	Low summer flows do not increase growth and recruitment of humpback chub; increase in warmwater nonnative species or trout at the Little Colorado River; long-term unacceptable adverse impacts on the resources listed in Section 1.3 are observed; or sufficient warming does not occur as predicted	Implement as adaptive treatment when conditions allow

TABLE 4 (Cont.)

Experimental Treatment	Trigger[a] and Primary Objective	Replicates	Duration	Annual Implementation Considerations[b]	Long-Term Off-Ramp Conditions[c]	Action if Successful
Aquatic Resource-Related Experiments (Cont.)						
Macroinvertebrate production flows	Trigger: None Objective: Improve food base productivity and abundance or diversity of mayflies, stoneflies, and caddisflies	Target two to three replicates	Up to 4 months (May–Aug.)[g]	Potential short-term unacceptable impacts on resources listed in Section 1.3; coordinate planning with other experiments to avoid confounding conditions or results	Steady weekend flows have little or no benefit on food base, trout fishery, or native fish; increase in warmwater nonnative species or trout at the Little Colorado River; or long-term unacceptable adverse impacts on the resources listed in Section 1.3 are observed	Implement as adaptive treatment in target months when conditions allow
Riparian Vegetation Experiments						
Non-flow vegetation treatments	Trigger: None Objective: Improve vegetation conditions at key sites	Not applicable	20 years if successful pilot phase	Potential short-term unacceptable impacts on resources listed in Section 1.3	Control and replanting techniques are not effective or practical; or long-term unacceptable adverse impacts on the resources listed in Section 1.3 are observed	Implement as adaptive treatment if invasive species can be reduced and native species increased

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

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

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

[d] Details of implementation of sediment experiments are presented in Section 2.1.

[e] Details of implementation of aquatic resource experiments are presented in Section 2.2.

[f] The decision to conduct TMFs in a given year will consider the resource conditions, as specified in Section 1.3, and will also involve considerations regarding the efficacy of the test based on those resource conditions.

[g] The duration and other characteristics of experimental macroinvertebrate production flows could be adjusted based on the results of initial experiments.

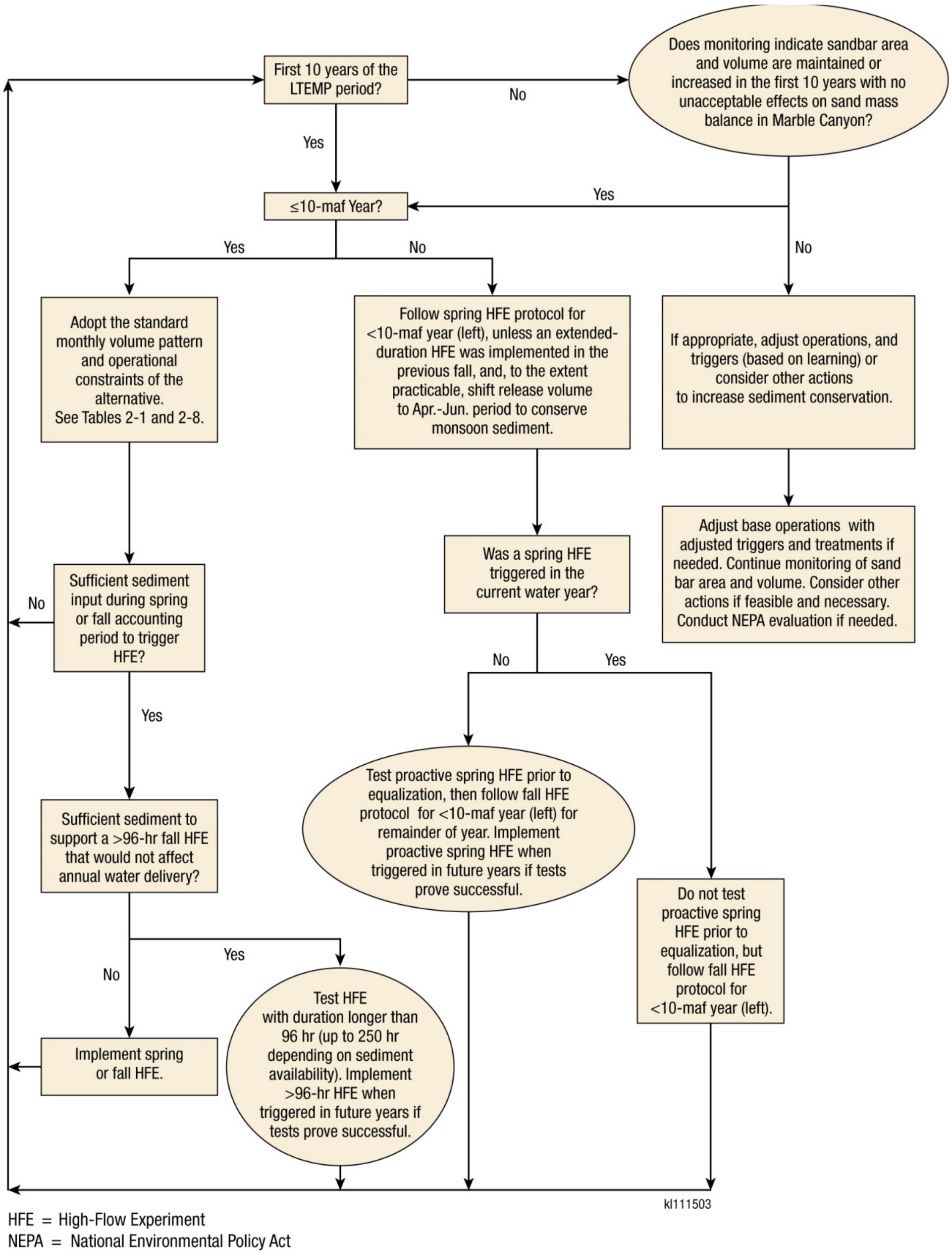
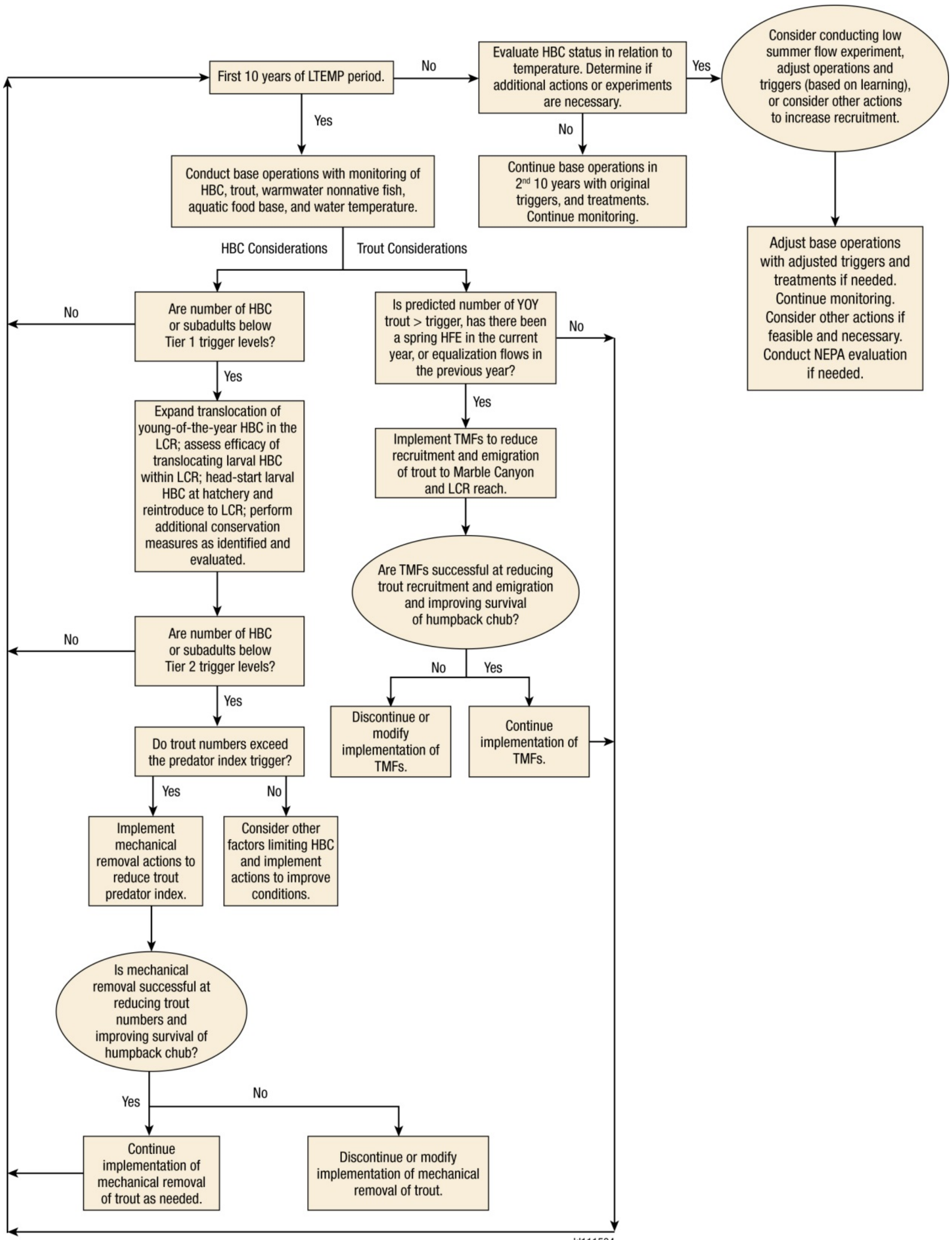


FIGURE 4 Decision Tree for Implementation of Sediment-Related Experimental Treatments under Alternative D (Implementation will be conditional on annual considerations presented in Section 1.3. If off-ramp conditions listed in Table 4 exist, related experimental treatments will be suspended.)



HBC = Humpback Chub
HFE = High-Flow Experiment
LCR = Little Colorado River
NEPA = National Environmental Policy Act
TMF = Trout Management Flow

FIGURE 5 Decision Tree for Implementation of Aquatic Resource-Related Experimental Treatments under Alternative D (Implementation will be conditional on annual considerations presented in Section 1.3. If off-ramp conditions listed in Table 4 exist, related experimental treatments will be suspended.)

1.4 COMMUNICATION AND CONSULTATION PROCESS FOR ALTERNATIVE D

In implementing the processes described in Section 1.3 and the associated decision process shown in Figures 4 and 5, the DOI will exercise a formal process of stakeholder engagement to ensure decisions are made with sufficient information regarding the condition and potential effects on important resources. As an initial platform to discuss potential future experimental actions, the DOI will hold GCDAMP annual reporting meetings for all interested stakeholders; these meetings will present the best available scientific information and learning from previously implemented experiments and ongoing monitoring of resources. As a follow-up to this process, the DOI will meet with the TWG to discuss the experimental actions being contemplated for the year.

The DOI also will conduct monthly Glen Canyon Dam operational coordination meetings or calls with the DOI bureaus (USGS, NPS, FWS, BIA, and Reclamation), WAPA, AZGFD, and representatives from the Basin States and the UCRC. Each DOI bureau will provide updates on the status of resources and dam operations. In addition, WAPA will provide updates on the status of the Basin Fund, projected purchase power prices, and its financial and operational considerations. These meetings or calls are intended to provide an opportunity for participants to share and obtain the most up-to-date information on dam operational considerations and the status of resources (including ecological, cultural, Tribal, recreation, and the Basin Fund). One liaison from each Basin State and from the UCRC will be allowed to participate in the monthly operational coordination meetings or calls.

To determine whether conditions are suitable for implementing or discontinuing experimental treatments or management actions, the DOI will schedule implementation/planning meetings or calls with the DOI bureaus (USGS, NPS, FWS, BIA, and Reclamation), WAPA, AZGFD, and one liaison from each Basin State and from the UCRC, as needed or requested by the participants. The implementation/planning group will strive to develop a consensus recommendation to bring forth to the DOI regarding resource issues as detailed at the beginning of this section, as well as including WAPA’s assessment of the status of the Basin Fund. The Secretary of the Interior will consider the consensus recommendations of the implementation/planning group, but retains sole discretion to decide how best to accomplish operations and experiments in any given year pursuant to the ROD and other binding obligations.

DOI will also continue separate consultation meetings with the Tribes, AZGFD, the Basin States, and UCRC upon request, or as required under existing RODs.

2 EXPERIMENTS TO BE EVALUATED UNDER ALTERNATIVE D

2.1 SEDIMENT-RELATED EXPERIMENTS

Under Alternative D, the existing HFE protocol was updated and incorporated into the LTEMP process as specified in Appendix P of the FEIS. Changes to the existing protocol were related to implementation of the new HFEs that are included under Alternative D and an extension of the protocol to the end of the LTEMP period. This new protocol will replace the existing protocol when the LTEMP ROD is issued. Spring and fall HFEs will be implemented when triggered during the 20-year LTEMP period based on the estimated sand mass balance resulting from Paria River sediment inputs during the spring and fall accounting periods, and the dam release pattern during the accounting period. HFE releases will be 1 to 250 hr long and between 31,500 cfs and 45,000 cfs. Depending on the cumulative amount of sediment input from the Paria River during the spring (December 1 through June 30) or fall (July 1 through November 30) accounting periods and the expected accumulation of sand, the maximum possible magnitude and duration of HFE that would achieve a positive sand mass balance in Marble Canyon, as determined by modeling, will be implemented.

Sand mass balance modeling will be used to ensure that the duration and magnitude of an HFE are best matched with the mass of sand present in the system during a particular release window. The magnitude and duration of HFEs will not affect the total annual release from Glen Canyon Dam. Reclamation will consider the total water to be released in the water year when determining the magnitude and duration of an HFE.

Sediment-related experiments under Alternative D include (1) sediment-triggered spring and fall HFEs up to 96-hr duration; (2) short-duration (24-hr) proactive spring HFEs in high-volume equalization years prior to equalization releases; and (3) implementation of up to four extended-duration (>96-hr) HFEs, up to 250 hr long, depending on sediment conditions. The pattern of transferring water volumes from other months to make up the HFE volume will be discussed in the monthly Glen Canyon Dam operational coordination meetings described in Section 1.4.

If sediment resources are stable or improving, the combination of base operations, HFEs, and other treatments will continue as prescribed for Alternative D. If sediment resource conditions decrease to unacceptable levels during the LTEMP period, operations may be modified to the extent allowable under the LTEMP ROD or will be evaluated and considered under a separate NEPA process, potentially including additional studies of sediment augmentation or other actions.

For all sediment experiments, testing will be modified or temporarily or permanently suspended if (1) experimental treatments were ineffective at accomplishing their objectives, or (2) there were unacceptable adverse impacts on resources (Table 4). Monitoring results will be evaluated to determine whether additional tests, modification of experimental treatments, or discontinuation of experimental treatments were warranted.

Implementation of HFEs will consider resource condition assessments and resource concerns using the annual processes described in Sections 1.3 and 1.4. HFEs may not be tested when there appears to be the potential for unacceptable impacts on the resources listed in Section 1.3. In addition, there is uncertainty associated with cumulative impacts from sequential HFEs. These cumulative impacts will be considered before implementing an HFE.

2.1.1 Sediment-Triggered Spring HFEs under Alternative D

Under Alternative D, sediment-triggered spring HFEs will be implemented after an initial 2-year delay in order to enable testing of the effectiveness of TMFs, if warranted, and address concerns raised by the apparent positive response of trout to the 2008 spring HFE (Korman, Kaplinski et al. 2011; Melis et al. 2011). Modeling trout response to spring HFEs for the EIS was based on relationships developed from the observed response to the 2008 spring HFE. That modeling also evaluated uncertainty related to the effectiveness of TMFs to control excess trout produced by HFEs. Modeling indicated that even at a relatively low level of effectiveness (10% reduction in trout recruitment), TMFs could effectively reduce the number of trout out-migrants from Glen Canyon to the Little Colorado River reach (RM 61) where humpback chub occur.

After the first 2 years of the LTEMP period, spring HFEs will be implemented when triggered by sediment conditions, except in water years when an extended-duration fall HFE was conducted. Modeling indicates that there may be sufficient sediment input for spring HFEs in about 26% of the years in the LTEMP period. Sediment-triggered spring HFEs will be implemented when triggered during the entire LTEMP period unless new information indicated they were not effective in building sandbars, or there were unacceptable adverse effects on resources (Section 1.3).

Implementation of a spring HFE will provide important replication of the 2008 spring HFE and aid in understanding the effect of spring HFEs on the trout population. It is possible that the strong 2008 response was a result of the specific conditions present in 2008 (e.g., condition of the food base, trout population size). It is unclear whether implementation under current conditions will produce the same result, and there is a good deal of learning that could result from early implementation. Implementing a spring HFE early in the LTEMP period when chub numbers are relatively high may also be a relatively low-risk option. To provide a means of controlling trout recruitment following tests of spring HFEs, TMFs will be experimentally implemented and tested for efficacy as early in the LTEMP period as possible (see discussion of TMFs below).

Implementation of sediment-triggered spring HFEs will consider resource condition assessments and resource concerns using the processes described in Sections 1.3 and 1.4. Spring HFEs may not be tested when there appears to be the potential for unacceptable adverse impacts on the resources listed in Section 1.3. In addition, there is uncertainty associated with the cumulative impacts of sequential HFEs on sediment, aquatic, and potentially other resources. These cumulative impacts will be considered before implementing a spring HFE, particularly if a fall HFE had been implemented in the same water year.

2.1.2 Proactive Spring HFEs under Alternative D

GCMRC scientists identified proactive spring HFEs as a potential experimental treatment to transport and deposit in-channel sand at elevations above those of equalization flows. These HFEs will be tested only in years with high annual water volume (i.e., ≥10 maf), and modeling suggests this would be a relatively rare treatment. A first test will be a 24-hr 45,000-cfs release conducted in April, May, or June. Duration in subsequent tests could be shortened depending on the observed response during the first tests. It would be preferable to test proactive spring HFEs at least two to three times in the 20-year LTEMP period, but being able to do so will be dependent upon annual hydrology. Modeling indicates that proactive spring HFEs will be triggered in about 10% of the years in the LTEMP period.

Proactive spring HFEs will not be tested in the first 2 years of the LTEMP. In addition, proactive spring HFEs will not be tested in years when there had been a sediment-triggered spring HFE or an extended-duration fall HFE earlier in the same water year. Proactive spring HFEs could be performed in the same water year as a 96-hr or shorter sediment-triggered fall HFE, although prior to implementation, the potential effects of these HFEs will be carefully evaluated using the processes described in Sections 1.3 and 1.4. The first test will be carefully evaluated to determine whether additional tests were warranted based on the efficacy of building and maintaining sandbars. If initial tests show positive results without unacceptable adverse effects on the resources listed in Section 1.3, proactive spring HFEs will be implemented when triggered during the entire LTEMP period.

Implementation of proactive spring HFEs will consider resource condition assessments and resource concerns using the processes described in Sections 1.3 and 1.4. Proactive spring HFEs may not be tested when there appears to be the potential for unacceptable impacts on the resources identified in Section 1.3. The cumulative impacts of sequential HFEs will be considered before implementing a proactive spring HFE.

2.1.3 Sediment-Triggered Fall HFEs under Alternative D

The effects of sediment-triggered fall HFEs on trout recruitment are uncertain, but fall HFEs are expected to have less effect on trout production than spring HFEs. HFEs in November 2012, 2013, and 2014 resulted in little or no increase in the number of YOY trout (VanderKooi 2015; Winters et al. 2016), and this observation may be based on the observed resilience of the food base to disturbance in the fall (Kennedy et al. 2015). However, factors affecting trout response to fall HFEs are not well understood. Modeling for the EIS considered the effect of fall HFEs on trout and modeled fall HFEs in two ways: in one, the effect of fall HFEs was half as long as that of a spring HFE (i.e., it affected trout production only in the water year in which it occurred); in the other, fall HFEs had no effect on trout production. Modeling the effect of fall HFEs in these two ways had an effect on the overall predicted number of trout produced, the number of out-migrants, and ultimately their effect on humpback chub, but the relative performance among alternatives was unchanged.

Modeling indicates fall HFEs would be triggered in about 77% of the years in the LTEMP period. Testing fall HFEs is considered to be a relatively low-risk treatment due to the lack of observed or documented trout response from previous fall HFEs, and will be implemented when triggered during the entire LTEMP period unless new information indicated fall HFEs were not effective in building sandbars, or there were unacceptable adverse effects.

Implementation of sediment-triggered fall HFEs will consider resource condition assessments and resource concerns using the processes described in Sections 1.3 and 1.4. Fall HFEs may not be tested when there appears to be the potential for unacceptable impacts on the resources listed in Section 1.3. The cumulative impacts of sequential HFEs will be considered before implementing a sediment-triggered fall HFE.

2.1.4 Extended-Duration Fall HFEs under Alternative D

Under Alternative D, sediment-triggered fall HFEs with durations longer than 96 hr (up to 250 hr) will be tested. The duration of these extended-duration fall HFEs will be based on the amount of sediment delivered from the Paria River during the fall accounting period and will be no more than the maximum magnitude and duration of HFE that will achieve a positive sand mass balance in Marble Canyon, as determined by modeling. Based on examination of the observed historical sediment input from the Paria River, it was determined that HFEs up to 10.4 days in length (250 hr) could be supported before exhausting seasonal sediment inputs and affecting water delivery requirements. GCMRC scientists have suggested that increasing the duration of HFEs when sediment supply can support a longer duration may lead to more sand being deposited at higher elevations, resulting in bigger sandbars. Modeling indicates the sediment trigger for this treatment may be reached in 25% of the years in the LTEMP period. There will be no more than four extended-duration fall HFEs over the 20-year LTEMP period.

The duration of the first implementation of an extended-duration HFE will be limited to no more than 192 hr (twice as long as the current limit of 96 hr). This duration is considered long enough to produce a measurable result if the treatment represents an effective approach to building sandbars under enriched sediment conditions. The duration of all tests will be based on available sediment, current hydrology, reviews of available information, the expert opinion of GCMRC and other Grand Canyon scientists, and consideration of potential effects on the resources listed in Section 1.3. If feasible, monitoring will include real-time observations of sediment concentrations to determine if sediment deposition continues throughout the duration of the extended HFEs.

Implementation of extended-duration fall HFEs will consider resource condition assessments and resource concerns using the processes described in Sections 1.3 and 1.4. Extended-duration fall HFEs may not be tested when there appears to be potential unacceptable impacts on the resources listed in Section 1.3. Because the effects of extended-duration HFEs on Lake Mead water quality are a concern, DOI will coordinate with relevant water quality monitoring programs or affected agencies prior to implementing any test of extended-duration HFEs. The cumulative impacts of sequential HFEs will be considered before implementing an extended-duration fall HFE.

Another important concern that results from the large volume of water bypassed is water delivery. Water delivery issues will be considered before deciding to implement an extended-duration fall HFE. An extended-duration HFE will not be implemented if annual release volume would be affected. It is possible that in lower volume years, there would not be sufficient water available to support an extended-duration HFE. A 250-hr extended-duration HFE would result in a monthly total release of approximately 1.2 maf. In lower volume release years (e.g., 7.0 maf or 7.48 maf), the maximum duration may be less than 250 hr. In addition, a sediment-triggered spring HFE or proactive spring HFE will not be conducted in the same water year as an extended-duration fall HFE. If an extended-duration fall HFE was triggered but not implemented for any of the reasons described above, a fall HFE 96 hr or less in duration could be implemented instead. Implementation will necessitate reducing water volume in other months of the same water year.

In order to fully test the efficacy of these longer HFEs, several replicates would be desirable in the 20-year LTEMP period. Extended-duration HFEs will be considered successful and will be continued up to a total of four times in the 20-year LTEMP period as part of an adaptive experimental treatment if there was a widespread increase in bar size relative to ≤96-hr HFEs, and if sand mass balance was not significantly compromised relative to the ability to maintain a long-term equilibrium. Extended-duration HFEs will not continue to be tested if they were not effective in building sandbars, if resulting total sandbar volumes were no bigger than those created by shorter-duration HFEs, or if unacceptable adverse impacts on the resources listed in Section 1.3 were observed.

2.2 AQUATIC RESOURCE-RELATED EXPERIMENTS

Under Alternative D, most experimental flow and non-flow actions will be triggered by either estimated numbers of nonnative fish, a combination of estimated numbers of nonnative fish and humpback chub, or measured water release temperature at Glen Canyon Dam, depending on the action under consideration. Humpback chub triggers and nonnative fish triggers were developed during formal Section 7 ESA consultation with the FWS. These triggers may be modified based on experimentation conducted during the LTEMP period.

Aquatic resource experiments that may be tested under Alternative D include (1) TMFs, (2) Tier 1 conservation actions for humpback chub, (3) Tier 2 mechanical removal of nonnative fish, (4) low summer flows in the second 10 years of the LTEMP, and (5) macroinvertebrate production flows. Aquatic resource experiments will seek to refine our understanding of the impacts of water releases, HFEs, and TMFs on these resources. The primary uncertainty surrounding HFEs revolves around the extent to which the seasonality of HFEs or the number of adult rainbow trout determines the strength of rainbow trout recruitment.

Experimental nonnative fish control actions will be implemented if the humpback chub population declined, and proactive conservation actions had failed to reverse declining populations. Two different tiers of population metrics will be used to trigger responses, including actions to increase growth and survival of humpback chub (Tier 1) and mechanical removal of nonnative fish (Tier 2), which will only be implemented when Tier 1 actions fail to slow or reverse the decline in the humpback chub population. This tiered approach and the triggers that will be used to implement it are described below and in the LTEMP Biological Assessment and BO presented in Appendix O of the FEIS.

For all aquatic resource experiments, testing will be modified or temporarily or permanently suspended if (1) experimental treatments were ineffective at accomplishing their objectives, or (2) there were potential unacceptable adverse impacts on the resources listed in Section 1.3. Monitoring results will be evaluated to determine whether additional tests, modification of experimental treatments, or discontinuation of experimental treatments were warranted.

Implementation of aquatic resource experiments will consider resource condition assessments and resource concerns using the processes described in Sections 1.3 and 1.4. Aquatic resource experiments may not be tested when there appears to be the potential for unacceptable impacts on the resources listed in Section 1.3.

2.2.1 Trout Management Flows under Alternative D

TMFs are a special type of fluctuating flow designed to reduce the recruitment of trout by disadvantaging YOY trout (Figure 6). TMFs have been proposed and developed on the basis of research described in Korman et al. (2005). The underlying premise of TMFs is based on observations that YOY trout tend to occupy near-shore shallow-water habitats to avoid predation by larger fish. TMFs feature repeated fluctuation cycles that consist of relatively high flows (e.g., 20,000 cfs) sustained for a period of time (potentially ranging from 2 days to 1 week) followed by a rapid drop to a very low flow (e.g., 5,000 cfs to 8,000 cfs).[4] This low flow would be maintained for a period of less than a day (e.g., 12 hr) to prevent adverse effects on the food base. Low flows would be timed to start in the morning, after sunrise, to expose stranded fish to direct sunlight and heat. Up-ramp rates to the TMF would be the same as the limit for this alternative overall (i.e., 4,000 cfs/hr). The down-ramp from peak to base would be over a single hour (e.g., 15,000 cfs/hr for a drop from 20,000 cfs to 5,000 cfs). In a TMF flow cycle, YOY trout are expected to occupy near-shore habitat when flows are highest, and would be stranded by the sudden drop to low flow. Because older age classes of trout tend to occupy deeper habitats toward the middle of the river channel, they are less susceptible to stranding and are less likely to be directly affected by TMFs.

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4 TMFs have the potential to result in stranding of boats in the Glen Canyon reach, as well as a potential risk to public safety. Public notification and outreach in advance of implementing TMFs, as is currently done for planned HFEs, would be necessary to avoid safety concerns.

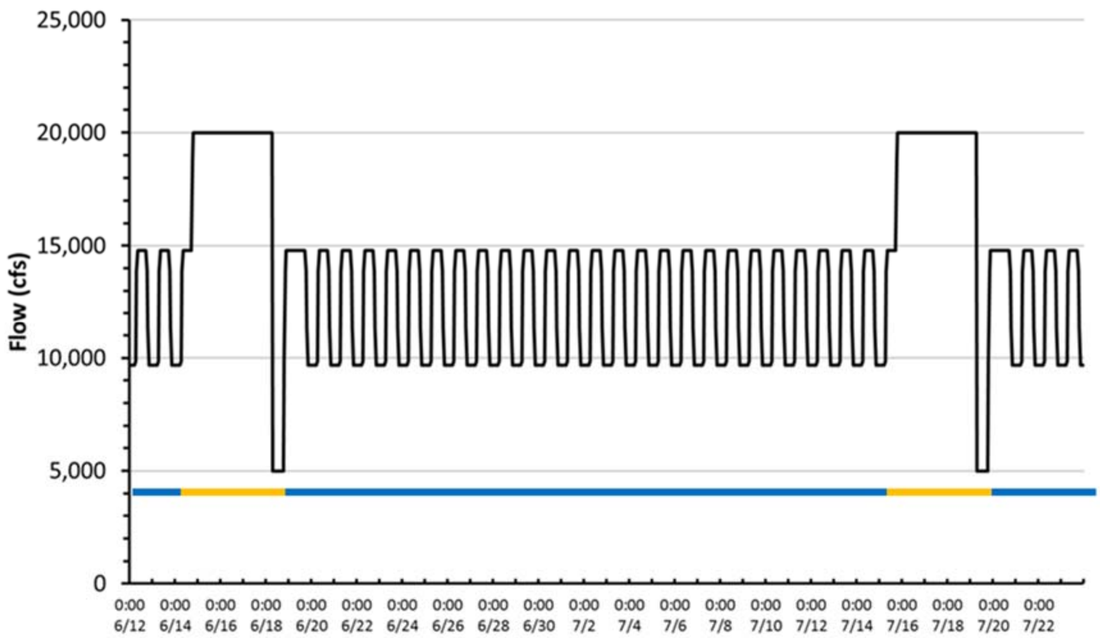

FIGURE 6 Example Implementation of a Two-Cycle TMF in June and July with Resumption of Normal Fluctuations between Cycles and Afterward (Monitoring for effectiveness would occur before and after each cycle. The horizontal line below the graph shows periods of normal fluctuation [blue] and TMFs [orange].)

TMFs are a potential tool that could be used to control annual trout production in the Glen Canyon reach for purposes of managing the trout fishery and for limiting emigration from the Glen Canyon reach to Marble Canyon and the Little Colorado River reach. If resource conditions are appropriate, TMFs may be tested under Alternative D early in the experimental period, preferably in the first 5 years. These first tests could be triggered by modeled trout recruitment levels or otherwise implemented to test the effectiveness of TMFs.[5] The intent of these early tests will be to determine the effectiveness of TMFs and a best approach to trout management. If TMFs are determined to be effective for controlling trout numbers while minimizing impacts on other resources, they may be deployed as an adaptive experimental treatment triggered by estimated trout recruitment.

It should be noted that several Tribes have expressed concerns about TMFs as a taking of life within the canyon without a beneficial use. The Pueblo of Zuni has expressed concern that the taking of life by trout stranding has an adverse effect on the Zuni value system. The joint-lead agencies will continue to work with the Tribes regarding options for trout management, and to determine the most appropriate means of mitigating impacts on Tribal values if TMFs are implemented.

5 The decision to conduct TMFs in a given year would consider the resource conditions, as specified in Section 1.3, and would also involve considerations regarding the efficacy of the test based on those resource conditions.

As many as three TMF cycles/month in a period of up to 4 months during May through August could be tested, depending on the results of early tests. Aspects of TMF design that will be investigated include:

- Duration of high flows needed to lure YOY rainbow trout into near-shore habitats,
- Magnitude of the high flow that will be more effective in luring YOY trout to near-shore habitats,
- Whether or not moving to high flows first is needed to reduce YOY trout numbers (as opposed to simply dropping rapidly from normal flows to minimum flows),
- Timing of TMF cycles during the May–August period of trout emergence, and
- Number of cycles necessary to effectively limit trout recruitment.

If TMFs prove to be effective in controlling trout production and emigration to the Little Colorado River reach, and they become an integral part of the LTEMP, regular implementation of TMFs may need to include variable timing to prevent adaptation of the population to specific timing (e.g., increase in recruitment by fall-spawning rainbow trout).

Certain aspects of TMF effectiveness can be addressed through observational studies (e.g., the number of YOY rainbow trout observed in the near-shore environment in daily increments after the high flow is initiated);[6] others may be addressed through consideration of the physical environment in Glen Canyon (i.e., what areas are inundated or exposed at different flows). Ultimately, however, effectiveness will be judged based on comparison of fall trout recruitment estimates to expectations based on prior years. It may take several years to make this determination, depending on the strength of the response and the type of TMFs tested. Ultimately, however, effectiveness would be based on the ability of TMFs to reduce recruitment in and emigration from the Glen Canyon reach. The driving forces behind emigration are not fully understood, but are expected to be related to population size and food base in the Glen Canyon reach.

For the EIS modeling, a trigger of 200,000 YOY trout was used to determine when TMFs would be implemented. A regression equation based on annual volume, the variability in flows from May through August, and the occurrence of a spring HFE was used to predict the number of YOY. The actual trigger used could be higher or lower depending on the results of experiments that will be conducted on the effectiveness of TMFs. In addition, the predictive regression equation could be modified based on new information. The trigger and predictive equation used will be modified as needed in an adaptive management context utilizing the

6 Because older age classes of trout tend to occupy deeper habitats toward the middle of the river channel, they are less susceptible to stranding and are less likely to be directly affected by TMFs.

process described in Section 1.3. Triggers for implementation of TMFs will also be developed in consultation with the AZGFD and other entities as appropriate.

Monitoring of other resources, particularly food base and the physiologic condition of adult rainbow trout, will also be considered. In addition, the number of YOY trout at the end of the summer will be estimated to determine if it equals or exceeds the estimated number of recruits needed to sustain the desired number of adult trout. If the estimated number of recruits is less than the recruitment target, TMFs will be re-evaluated for modification before implementation in subsequent years. It is anticipated that the trout population could rebound from a 1-year drop below this target level.

As discussed in relation to sediment experiments above, there is concern among scientists and stakeholders with regard to the risk associated with implementation of spring HFEs as related to trout response and subsequent effects on the humpback chub population. For this reason, TMFs will be implemented and tested for effectiveness as early in the LTEMP period as possible, preferably before the first spring HFEs are triggered, even if not triggered by high trout recruitment. TMFs could be implemented in years that feature a spring HFE and in the water year that follows an equalization flow because of the expected positive effects of equalization on rainbow trout recruitment. Any implementation of TMFs will consider the status of the trout fishery prior to implementation. Modeling indicates TMFs will be triggered by trout recruitment numbers in 32% of the years in the LTEMP period.

There is potential for confounding effects when coupling TMFs with HFEs. If trout recruitment is still high after implementation of TMFs that follow HFEs, this would suggest TMFs were not effective as designed for that trial. If recruitment is lower than expected after TMF implementation, however, uncertainty will remain about whether an HFE failed to stimulate trout recruitment or whether TMFs were effective in suppressing otherwise strong recruitment. It may not be necessary to determine the underlying effect on trout numbers unless TMFs have undesirable side effects on other resources or the trout population.

If TMFs are found to be highly effective in controlling trout recruitment and emigration of trout, and emigration only occurs or primarily occurs immediately following high recruitment years, it may be possible to limit TMF implementation and achieve multiple resource goals, particularly if unintended impacts of TMFs on other resources such as native fish become evident. Timing of TMFs may also be adjusted based on the best scientific information available related to trout emigration behavior. If adverse impacts of TMFs become evident, this may also suggest revisiting whether or not TMFs are necessary in response to spring HFEs. Lastly, if, there is an observed increase in trout recruitment due to fall HFEs, then application of TMFs in the spring following a fall HFE will be considered.

Implementation of TMFs will consider resource condition assessments and resource concerns using the processes described in Sections 1.3 and 1.4. TMFs may not be tested when there appears to be the potential for unacceptable impacts on the resources listed in Section 1.3.

2.2.2 Tier 1 Conservation Actions for Humpback Chub under Alternative D

Tier 1 conservation actions designed to improve rearing and recruitment of juvenile humpback chub will be implemented if the combined point estimate for adult (≥200 mm) humpback chub in the Colorado River mainstem Little Colorado River aggregation (RM 57–RM 65.9) and in the Little Colorado River falls below 9,000 (2,000 in the mainstem and 7,000 in the Little Colorado River), as estimated by the currently accepted humpback chub population model, or if recruitment of subadult (150 mm–199 mm) humpback chub does not meet or exceed estimated adult mortality (Appendix O of the FEIS). Tier 1 actions will include expanded translocations of YOY humpback chub within the Little Colorado River to areas within the river that have relatively few predators (i.e., above Chute Falls, Big Canyon), or larval fish will be taken to a rearing facility and released in the Little Colorado River inflow area once they reach 150 mm to 200 mm. In addition to these translocation activities, 300 to 750 larval or YOY humpback chub will be collected from the Little Colorado River and reared in a fish hatchery to less vulnerable sizes before releasing them. Once these fish reach 150 mm to 200 mm, they will be translocated to the Little Colorado River in the following year.

2.2.3 Tier 2 Mechanical Removal of Nonnative Fish under Alternative D

Mechanical removal of nonnative fish in the Little Colorado River reach (potentially from RM 50–RM 66) will be conducted if the Tier 1 conservation actions described in the previous section were not successful in halting a decline in the number of adult humpback chub. Mechanical removal, using the methods described in Section 2.2.1 and Appendix O of the FEIS, will be conducted if the point estimate of adult humpback chub falls below 7,000 (the trigger level used in Reclamation 2011), as estimated by the currently accepted humpback chub population model. Up to six monthly removal trips (February through July) will be implemented in each year triggered.

Mechanical removal will stop if the “predator index” is depleted to less than 60 rainbow trout/km (see Appendix O of the FEIS) for at least 2 years in the reach between RM 63 and RM 64.5, and immigration rate is low, or the adult humpback chub population estimates exceed 7,500, and recruitment of subadult chub exceeds adult mortality for at least 2 years. The predator index calculates predator densities by incorporating additional species, in addition to rainbow trout, and makes assumptions about their relative predation rates compared to rainbow trout. For example, brown trout are estimated to be about 17 times more predacious on humpback chub than are rainbow trout (Ward and Morton-Starner 2015). Additional predators (e.g., smallmouth bass) could be included based on their piscivory level relative to that of rainbow trout.

If humpback chub adult numbers continue to decline and Tier 1 and Tier 2 actions are not working, FWS, in coordination with Reclamation, NPS, and the Tribes, will consider other actions to stop the decline. Triggers will be reviewed and modified as necessary, and actions and triggers will be modified if humpback chub are found to be affected by other factors.

Implementation of mechanical removal will consider resource condition assessments and resource concerns using the processes described in Sections 1.3 and 1.4.

The DOI recognizes that lethal mechanical removal is a concern for Tribes, particularly the Hopi Tribe and Pueblo of Zuni, because it is a taking of life in the canyon without a beneficial use. (See Sections 3.5.3.4 and 4.9.1.3 of the FEIS for more information regarding concerns of the Tribes.) Reclamation had committed in agreements with the Tribes in 2012 to consider live removal when feasible (Reclamation 2012); however, the presence of whirling disease prohibits live removal of trout due to the risk of spreading the disease to other waters. Reclamation and NPS have worked with the Tribes to determine a beneficial use of the removed fish on other projects and understand that what is considered beneficial use may not be the same for all Tribes. Reclamation and NPS are committed to consult further with the Tribes to determine acceptable mitigation for nonnative fish control.

2.2.4 Low Summer Flows under Alternative D

Low summer flows could be considered a potential tool for improving the growth and recruitment of young humpback chub if temperature had been limiting these processes for a period of years. Low summer flows may lead to warmer water temperatures in the Little Colorado River reach and farther downstream, as well as contribute to enhanced growth rates of young humpback chub. There are also potential negative effects from low summer flows on several resources such as hydropower, sediment, water quality, vegetation, and recreation. Low summer flows may also negatively affect humpback chub due to an increase in warmwater nonnative fish or a decrease in the aquatic food base. There was one test of low steady summer flows below Glen Canyon Dam in 2000; however, the results relative to humpback chub were not conclusive (Ralston 2011).

Because of the uncertainty related to the effects of low summer flows on humpback chub, other native fish, warmwater nonnative fish, water quality, and potentially other resources, DOI will ensure that the appropriate baseline data are collected throughout the implementation of the LTEMP. In addition, DOI will convene a scientific panel that includes independent experts prior to the first potential use of low summer flows to synthesize the best available scientific information related to low summer flows. The panel may meet periodically to update the information, as needed. This information will be shared as part of the AMWG annual reporting process.

It is thought that the potential benefit of an increase in temperature could be greatest if a water temperature of at least 14°C could be achieved, because these warmer temperatures could favor higher humpback chub growth rates (nearly 60% higher). For comparison, the July through September growth increments of YOY humpback chub are estimated to be 4, 7, 11, 14, and 17 mm at temperatures of 12, 13, 14, 15, and 16°C, respectively, based on a growth-temperature regression in Robinson and Childs (2001). Note that reduction in summer flows would necessitate increasing flows in other months relative to base operations (Table 6; Figure 7).

If tested, low summer flows would occur for 3 months (July, August, and September), and only in the second 10 years of the LTEMP period. The duration of low summer flows could be shortened to less than 3 months in successive experiments if supported by the scientific panel described above or based on the scientific data and observed effects. The probability of

TABLE 6 Flow Parameters for a Year with Low Summer Flows under Alternative D in an 8.23-maf Year[a]

Month	Monthly Release Volume (kaf)[b]	Proportion of Total Annual Volume	Mean Daily Flow (cfs)	Daily Fluctuation Range (cfs)
October	643	0.0781	10,451	5,783
November	642	0.0780	10,781	5,774
December	716	0.0870	11,643	6,443
January	764	0.0928	12,423	6,874
February	675	0.0820	12,153	6,074
March	691	0.0840	11,245	6,223
April	859	0.1044	14,433	7,730
May	851	0.1034	13,841	7,659
June	930	0.1130	15,631	8,000
July	492	0.0598	8,000	2,000
August	492	0.0598	8,000	2,000
September	476	0.0578	8,000	2,000

[a] Within a year, monthly operations may be increased or decreased based on factors referenced in Section 1.2.

[b] Values have been rounded.

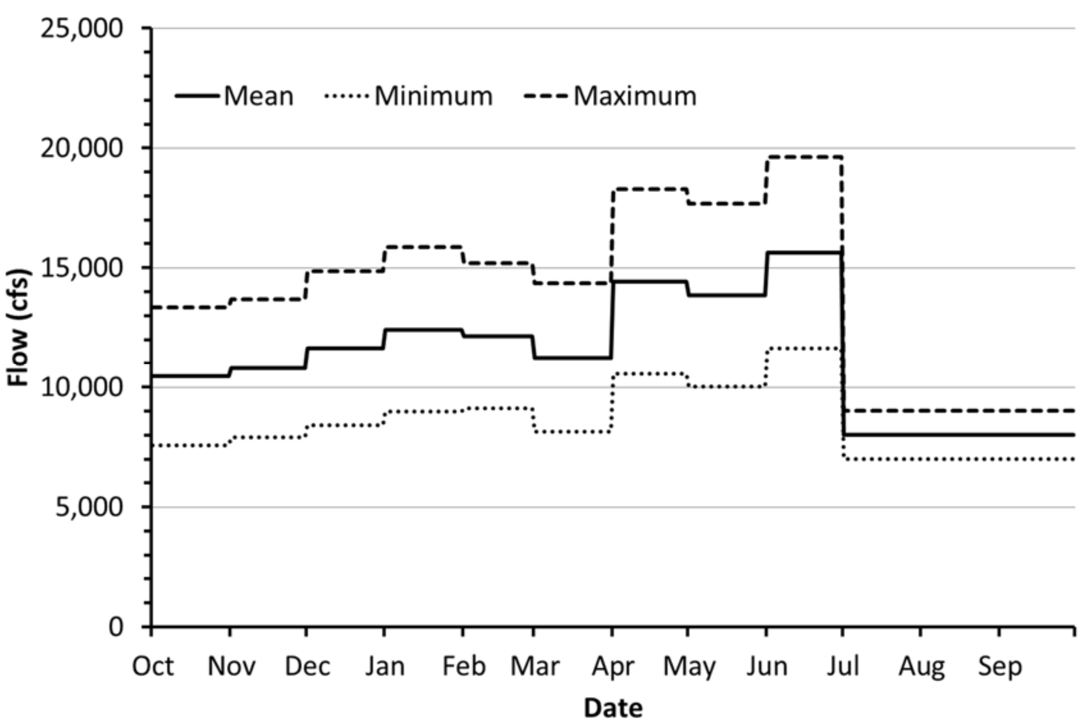

FIGURE 7 Mean, Minimum, and Maximum Daily Flows under Triggered Low Summer Flows of Alternative D in an 8.23-maf Year Based on the Values Presented in Table 6

triggering a low summer flow experiment is considered low (about 7% of years), because the water temperature conditions that would allow such a test occur infrequently (see Appendix D of the FEIS).

Low summer flows will only be implemented in years when the projected annual release was less than 10 maf, and if the temperature at the Little Colorado River confluence was below 14°C without low summer flows, and the release temperature was sufficiently high that 14°C could be achieved at the Little Colorado River with the use of low summer flows.

The ability to achieve target temperatures at the Little Colorado River confluence by providing lower flows is dependent on release temperatures, which are in turn dependent on reservoir elevation. For example, using the temperature model of Wright, Anderson et al. (2008) in an 8.23-maf year, release temperatures of 10.8°C, 11.0°C, and 11.7°C would be needed in July, August, and September, respectively, to achieve a target temperature of 14°C at the Little Colorado River confluence at flows of 8,000 cfs.

Release temperatures fall into three categories for any temperature target: (1) too low to achieve the target temperature at the Little Colorado River even at low flow; (2) high enough to achieve the target temperature at the Little Colorado River only if low flows (5,000 cfs to 8,000 cfs) are provided; and (3) high enough to achieve target temperature at the Little Colorado River regardless of the flow level. Low summer flows will only be triggered in years that fell into the second category.

Implementation of a low summer flow experiment is complicated by two factors: the earliest date at which it could be determined that a target temperature of at least 14°C could be achieved in all 3 months, and the ability to release the remaining annual volume once that determination is made. The earliest time a determination could be made would be in early April of each year, and it would be based on the April 1 forecast of reservoir elevation. Because low summer flows could be implemented in the 3 months at the end of the water year, it is possible that by the time a determination was made to conduct a low summer flow experiment, it may not be possible to release enough water in the remainder of the spring to compensate for the low flow period. A low summer flow experiment will only be tested in years when performing the experiment will not result in a deviation from the annual Glen Canyon Dam release volumes made pursuant to the Long-Range Operating Criteria for Colorado River Basin Reservoirs, which are currently implemented through the 2007 Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead.

A first test of low summer flows would feature low flows of 8,000 cfs and relatively little fluctuation (±1,000 cfs per day). Depending on the results of the first test with regard to warming and humpback chub response, the magnitude of the low flow could be adjusted up or down (as low as 5,000 cfs), and the level of fluctuation also modified up to the range allowed under Alternative D (i.e., 10× monthly volume [in kaf] in July and August, and 9 × monthly volume [in kaf] in September).

The first test of low summer flows will be determined to be successful or unsuccessful for humpback chub based on input from an independent scientific panel review. If the first test was determined to be unsuccessful (and it was determined to have been implemented without major confounding factors), then additional tests will not be performed. Low summer flows will be considered successful if it can be determined that they produced sufficient growth of YOY humpback chub and that growth resulted in an increase in recruitment, but avoided unacceptable increases in warmwater nonnative fishes, trout, or aquatic parasites, or resulted in unacceptable adverse impacts on other aquatic resources. If it was determined to be successful, then additional low summer flows would occur only when humpback chub population concerns warranted them and water temperature has been colder for a period of years, and the desired warming could be achieved only with low summer flows. The temperature target could be adjusted 1°C higher based on the results of the first test or the limitations between predicted and measured temperatures.

Implementation of low summer flows will consider resource condition assessments and resource concerns using the processes described in Sections 1.3 and 1.4. Low summer flows may not be conducted in years when there appears to be the potential for unacceptable impacts on the resources listed in Section 1.3.

The effects of low summer flows on Lake Mead water quality are an identified concern. DOI will coordinate with relevant water quality monitoring programs or affected agencies prior to implementing any test of low summer flows. There are additional concerns related to the risk of warmwater nonnative fish expansion or invasion (e.g., the elevation of Lake Mead was high or the number of warmwater nonnative fish was high). These issues are potential off-ramps as described in Section 1.3 using the process described in Section 1.4.

2.2.5 Macroinvertebrate Production Flows under Alternative D

A more diverse and productive aquatic food base could benefit a variety of priority resources, including native fish (including the endangered humpback chub), the rainbow trout fishery, and other riparian species that occur in Glen, Marble, and Grand Canyons. Mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera), collectively referred to as EPT, are important components of a healthy aquatic food base, but they are notably absent from the Glen and Marble Canyon reaches and very low in abundance and diversity in the Grand Canyon. GCMRC has hypothesized that EPT taxa are recruitment limited, because daily flow fluctuations to meet hydropower demand cause high egg mortality, and the absence of EPT has an adverse effect on the carrying capacity and condition of the trout fishery and native fish communities. EPT are thought to be recruitment limited because Glen Canyon Dam fluctuations create a large varial (intermittently wetted) zone along shorelines. Because the Colorado River in Glen, Marble, and Grand Canyons is canyon-bound and the tributaries that join the river all have comparatively low flow, the size of the varial zone does not appreciably decrease with distance downstream. Thus, although water temperature regimes become more naturalized with distance downstream, the effect that daily flow fluctuations to meet hydropower demand have on the stability of shoreline habitat does not attenuate much with distance from the dam.

This hypothesis attributes the absence of EPT and the poor health of the invertebrate assemblage to the width of the varial zone, similar to earlier investigations (Blinn et al. 1995), but focuses on the effects unstable shorelines have on the eggs of these species. This hypothesis assumes that egg-laying by EPT occurs principally along shorelines. According to the hypothesis, EPT taxa downstream of Glen Canyon Dam are recruitment limited, because daily flow fluctuations to meet hydropower demand negatively affect habitat quality along the shorelines where egg laying is assumed to occur.

To test this hypothesis, macroinvertebrate production flows will be provided every weekend from May through August (34 days total).[7] The flow on weekends will be held steady at the minimum flow for that month, which would ensure that the insect eggs laid during weekends will remain submerged throughout larval development. If the hypothesis is true, there would be an increase in insect production due to the reproductive success of insects that laid eggs during weekends. No change in monthly volumes, ramping rates, or the maximum daily range in flow during weekdays would be required for this experiment. To offset the smaller water releases that would occur during weekends within a given month, larger releases would need to occur during the weekdays within a given month.

Implementation of macroinvertebrate production flows will consider resource condition assessments and resource concerns using the processes described in Sections 1.3 and 1.4. These flows may not be tested when there appears to be the potential for unacceptable impacts on the resources listed in Section 1.3.

Effects of the tests will be evaluated using observation to determine the location where insect eggs are deposited and the emergence rates of species. Depending on the outcome of the tests, the experiment could be discontinued if there were unacceptable effects on other resources. There is also the possibility that implementation would result in confounding interactions with TMF experiments, and this will be discussed during the communication and consultation process as described in Section 1.4.

2.2.6 Conservation Measures under Alternative D

Applicable conservation measures identified in previous BOs related to Glen Canyon Dam operations will be carried forward in Alternative D and are described fully in Appendix O of the FEIS. Additional conservation measures to minimize or reduce the effects of actions under Alternative D, or that benefit or improve the status of listed species as part of the LTEMP, also are described in Appendix O of the FEIS.

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ATTACHMENT C:

HIGH-FLOW EXPERIMENT PROTOCOL FOR THE SELECTED ALTERNATIVE (ALTERNATIVE D)

High-volume dam releases for sediment conservation are an experimental action that will be implemented under the selected alternative (Alternative D) of the Glen Canyon Dam Long-Term Experimental and Management Plan (LTEMP). Implementation of high-flow experiments (HFEs) under the selected alternative will follow the HFE protocol described below for the overall process of implementation of HFEs, including implementation considerations and conditions that will result in discontinuing specific experiments.

HFE releases are restricted to limited periods of the year when the highest volumes of sediment are most likely available for building sandbars. Water year releases will follow the pattern identified for the selected alternative as adopted by the Secretary of the Interior in the LTEMP Record of Decision (ROD) and the Long Range Operating Criteria (LROC) as currently implemented through the 2007 Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (Reclamation 2007a). Sediment-triggered HFEs may be made in spring (March or April) or fall (October or November) (Figure 1). Fall Extended HFEs duration will range from less than 1 hr to 250 hr. Spring and fall HFEs which are not Extended HFEs, will have a duration range from less than 1 hr to 96 hr. Proactive HFEs may be made in spring or early summer (April, May or June), and will have a duration range up to 24 hr. HFE magnitude will range from 31,500 cfs to 45,000 cfs. Frequency of HFEs will be determined by tributary sediment inputs, annual release volumes, resource conditions, and the decision process carried out by the Department of the Interior (DOI) (Sections 1.3 and 1.4 of Attachment B). Extended-duration fall HFEs are limited to a frequency of 4 times total in a 20-year period.

The HFE protocol uses a “store and release” approach for sediment-triggered HFEs, in which sediment inputs are tracked over two accounting periods, one for each seasonal HFE: spring (December through June) and fall (July through November) (Figure 1). In addition, the HFE protocol can trigger proactive spring HFEs that will be tested only in years with high annual water volume (i.e., $\geq$10 maf) when no sediment-triggered HFE occurs. Implementation of an HFE may require reallocating water from other months in order to maintain flows above the required minimum (i.e., 5,000 to 8,000 cfs). The protocol will implement the maximum possible magnitude and duration of HFE that will achieve a positive sand mass balance in Marble Canyon, as determined by modeling.

1 DECISION-MAKING PROCESS

The HFE protocol is a decision-making process that consists of three components: (1) planning, (2) modeling, and (3) decision and implementation. The following three subsections describe each of these components.

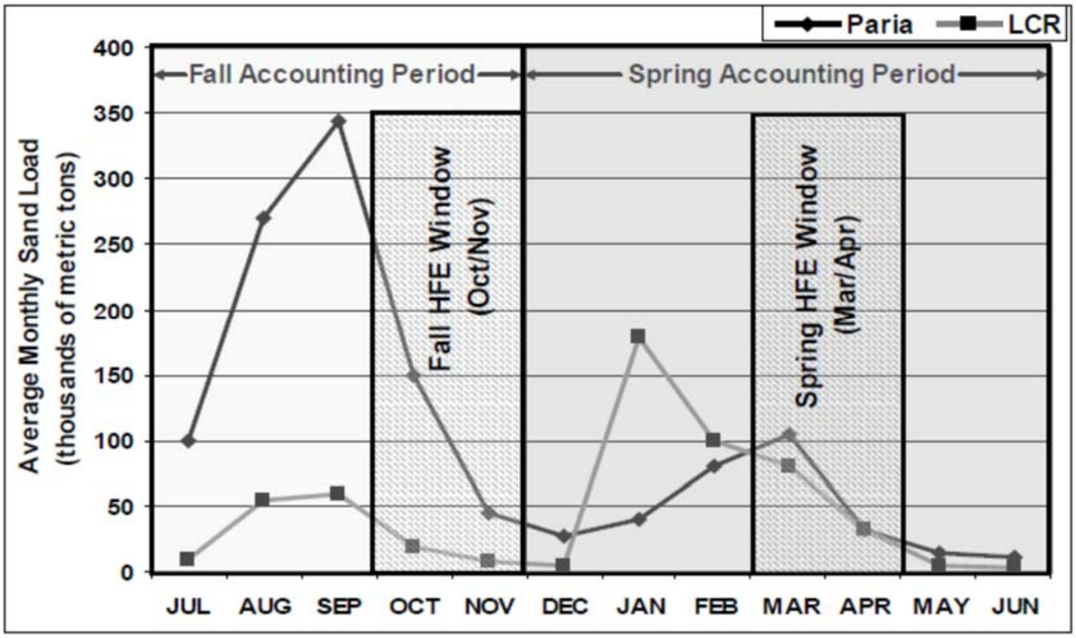

FIGURE 1 Average Monthly Sand Load from the Paria River and Little Colorado River Showing the Fall and Spring HFE Accounting Periods and Implementation Windows

1.1 PLANNING

The first component of the HFE protocol is planning. An important aspect of planning is the development and implementation of research and monitoring activities appropriate to monitor the effects of the HFEs. The Bureau of Reclamation (Reclamation) will be prepared to conduct an HFE if resource conditions are suitable, there is sufficient sediment input or projected annual release to trigger an HFE, and DOI determines conditions are suitable for proceeding. An annual process prior to a decision on conducting experiments, including an HFE, will evaluate the information on the status and trends of the following resources: (1) water quality and water delivery, (2) humpback chub, (3) sediment, (4) riparian ecosystems, (5) historic properties and traditional cultural properties, (6) Tribal concerns, (7) hydropower production and Western Area Power Administration's (WAPA's) assessment of the status of the Basin Fund, (8) the rainbow trout fishery, (9) recreation, and (10) other resources. Although these resources are listed for consideration on a regular basis, DOI intends to retain sufficient flexibility in implementation of HFEs to allow for response to unforeseen circumstances or events that involve any other resources not listed here. The recent discovery of nonnative green sunfish in the Glen Canyon reach illustrates the need to be responsive to unforeseen conditions.

In implementing HFEs and other experiments, the DOI will exercise a formal process of stakeholder engagement to ensure decisions are made with sufficient information regarding the condition and potential effects on important resources. As an initial platform to discuss potential future experimental actions, the DOI will hold Glen Canyon Dam Adaptive Management Program (GCDAMP) annual reporting meetings for all interested stakeholders; these meetings will present the best available scientific information and learning from previously implemented experiments and ongoing monitoring of resources. As a follow up to this process, the DOI will meet with the GCDAMP Technical Work Group (TWG) to discuss the experimental actions being contemplated for the year.

The DOI also will conduct monthly Glen Canyon Dam operational coordination meetings or calls with the DOI bureaus (U.S. Geological Survey [USGS], National Park Service [NPS], Fish and Wildlife Service [FWS], Bureau of Indian Affairs [BIA], and Reclamation), Western Area Power Administration (WAPA), Arizona Game and Fish Department (AZGFD), and representatives from the Basin States and the Upper Colorado River Commission (UCRC). Each DOI bureau will provide updates on the status of resources and dam operations. In addition, WAPA will provide updates on the status of the Basin Fund, projected purchase power prices, and its financial and operational considerations. These meetings or calls are intended to provide an opportunity for participants to share and obtain the most up-to-date information on dam operational considerations and the status of resources (including ecological, cultural, Tribal, recreation, and the Basin Fund). One liaison from each Basin State and from the UCRC will be allowed to participate in the monthly operational coordination meetings or calls.

1.2 MODELING

Mathematical models are used to make recommendations for future sediment-triggered HFEs using contemporary sediment data and forecasted hydrologic data to determine whether suitable sediment and hydrology conditions exist for a sediment-triggered HFE.

The two basic inputs for the modeling are the water input or hydrology, which is taken from the Colorado River Simulation System (CRSS) (Reclamation 1988, 2007b) and the sediment input, which in this case is restricted to inputs from the Paria River. A flow routing model (Wiele and Smith 1996) is used to simulate water passing downstream. A sediment budget model (Wright et al. 2010) is used to integrate the flow routing with the sediment inputs and outputs to determine whether or not a sediment mass balance is achieved for sediment-triggered HFEs (Russell and Huang 2010).

The sand budget is the net amount of sand in metric tons that has accumulated in the river channel over some period of time. In the Paria River, the two primary sand input periods are July through October and January through March (Figure 1). During these two periods, sand is being accumulated at a higher rate than in other months. In order to accommodate the decision process and to address other resource needs or concerns, the sediment-triggered HFE windows are two-months long (October–November and March–April).

The sand budget model will use the sediment inputs and estimate the outputs for three river reaches where sand is tracked: (1) Lees Ferry/Paria River (RM 0) to RM 30, (2) RM 30 to Little Colorado River (RM 61), and (3) Little Colorado River to RM 87. The first two reaches will be used to estimate the maximum possible magnitude and duration of an HFE that will not create a negative sand mass balance in Marble Canyon (RM 0 to RM 61).

Hydrologic data for implementation will be based on forecasted monthly inflow volumes from the National Weather Service's Colorado Basin River Forecast Center and Reclamation's 24-month study projected storage conditions. The 24-month study computer model projects future reservoir conditions and potential dam operations for the system reservoirs given existing reservoir conditions; inflow forecasts and projections; and a variety of operational policies and guidelines. Monthly volumes will be apportioned to daily dam releases by WAPA. Water supply forecasts and models will be needed to make these projections and uncertainty associated with these projects will need to be considered in the decision-making process (Grantz and Patno 2010). The sediment data used will be real-time accumulated inputs estimated from the Paria River streamflow gages.

Sand availability at the onset of each release window is determined by the amount of sand received from the Paria River during the accumulation period less the amount transported downstream to the Little Colorado River as estimated by the sand routing model. Sand in Grand Canyon received from the Little Colorado River is viewed as an added benefit to the amount received from the Paria River. The Little Colorado River input cycle largely follows the same accrual periods as the Paria River; however, only sand inputs from the Paria River will be used in HFE modeling recommendations.

Each run is evaluated against 16 different HFE magnitudes and durations to determine their possible occurrence in the sediment-triggered HFE window months (Table 1). The magnitude and duration of an HFE will be determined from the stored sand mass available on October 1 and March 1 of each water year, and the forecasted hydrology. The model evaluates each of the 16 sediment-triggered HFE types sequentially starting with the highest magnitude and duration of release. For example, the initial run determines if there is enough sediment available to achieve a positive sand mass balance in Marble Canyon for a release of 45,000 cfs for 250 hours. A positive sand mass balance is defined as a condition in which the amount of sediment being delivered by tributaries into the system exceeds the amount being exported from the system by ongoing dam operations and HFEs in the accounting period under consideration.

If the model run concludes that enough sediment is not available to achieve a positive sand mass balance, the next lower magnitude or duration sediment-triggered HFE is evaluated by the model. This is repeated until a sediment-triggered HFE scenario is reached that can be implemented with the available sediment or it is determined that a sediment-triggered HFE cannot be implemented. If it is determined that a sediment-triggered HFE cannot be implemented and the projected annual volume is greater than or equal to 10 maf, a proactive spring HFE will be triggered.

TABLE 1 List of HFEs Available for Sediment-Triggered Experiments (fall, extended-duration fall and spring) under the Selected Alternative

HFE ID	Peak Discharge (cfs)	Duration at Peak (hours)
1	45,000	250
2	45,000	192
3	45,000	144
4	45,000	96
5	45,000	72
6	45,000	60
7	45,000	48
8	45,000	36
9	45,000	24
10	45,000	12
11	45,000	1
12	41,500	1
13	39,000	1
14	36,500	1
15	34,000	1
16	31,500	1

The modeling component is based on four key analysis phases associated with the two sand budget accounting periods and the two sediment-triggered HFE windows:

Phase 1: Fall Accounting Period. The fall accounting period is from July 1 to November 30. Beginning on July 1 of each year, monitoring data will be used to track the sand storage from Paria River inputs in Marble Canyon.

Phase 2: October-November HFE Window. Beginning October 1, sand storage and forecast hydrology will be evaluated using the sediment budget model to determine whether conditions are suitable for an HFE. The model determines what magnitude and duration of the HFE, if any, would produce a positive sand mass balance at the end of the accounting period. If the model produces a positive result, the largest HFE that would result in a positive sand mass balance is forwarded to the decision and implementation component (see below), which also allows for other factors to be considered in the planning process (see Section 1.1). During the decision process, sediment input will continue to be measured, the model will continue to be run and results or output will be forwarded to decision-makers to allow for refinement of the previously recommended magnitude and duration of the HFE. If the model produces a negative result, the model will be rerun using more recent sediment input to determine whether a positive sand mass balance will be reached in time to have an HFE in the release window.

Phase 3: Spring Accounting Period. The spring accounting period is December 1 to June 30. As with the fall accounting period, monitoring data will be used to track the sand storage conditions in Marble Canyon during this time period. This accounting will be conducted regardless of whether or not a previous October or November HFE was conducted such that two HFEs could theoretically occur in the same year. The exception to this would be following an extended-duration fall HFE, as there would be no spring HFE following an extended-duration fall HFE. The accounting will continue to consider sand storage conditions present at the end of Phase 2, whether or not an HFE has occurred.

Phase 4: March-April sediment-triggered HFE Window. The evaluation in this phase is the same for the October-November HFE window (see Phase 2) with the model output being forwarded to the decision and implementation component. The model output will be used in the same way as for the October-November determination. Whether or not a spring HFE is scheduled, sediment inputs will continue to be monitored through the end of the spring accounting period for use in the next accounting period. Note that proactive spring HFEs (see Section 3.2), which are triggered by water volume and not sediment inputs, could occur in April, May, or June. In addition, spring HFEs will not be tested in years when there had been an extended-duration fall HFE earlier in the same water year.

1.3 DECISION AND IMPLEMENTATION

The third component of the HFE protocol is decision and implementation. This component could span a portion or most of the HFE window, depending on when conditions are deemed suitable for an HFE. The output from the model runs described above is used to determine if sediment and hydrology conditions are suitable for an HFE of a given magnitude and duration. For example, if the scenario that is identified by the model cannot be implemented because of facility limitation (e.g., if one or more turbines are out of service), managers will assess the need to modify the range of magnitude and duration of the HFE. Because this EIS has considered the effects of 45,000 cfs HFEs for 1 to 250 hours, it also serves to analyze the effects of HFEs at lower magnitudes and equivalent durations.

Because the model only considers water and sediment, an added purpose of the decision and implementation component is to consider potential effects on other resources. To determine whether conditions are suitable for implementing or discontinuing HFEs, the DOI will schedule implementation meetings or calls with the DOI bureaus (USGS, NPS, FWS, BIA, and Reclamation), WAPA, AZGFD, and one liaison from each Basin State and from the UCRC, as needed or requested by the participants. The implementation group will strive to develop a consensus recommendation to bring forth to the DOI regarding resource issues as detailed at the beginning of this section as well as including WAPA's assessment of the status of the Basin Fund. The Secretary of the Interior will consider the consensus recommendations of the implementation/planning group, but retains sole discretion to decide how best to accomplish operations and experiments in any given year pursuant to the ROD and other binding obligations.

DOI also will continue separate consultation meetings with the Tribes, AZGFD, the Basin States, and UCRC upon request, or as required under existing RODs.

If the decision is made to conduct an HFE, staff of the USGS's Grand Canyon Monitoring and Research Center (GCMRC) will prepare to conduct monitoring and research in cooperation with other agencies. If not, the process will be repeated during the next accounting window. For each HFE, GCMRC staff will analyze results and integrate information from other HFEs for use in future HFE decisions.

The decision process could result in a sediment triggered HFE being considered whether or not a positive sand mass balance is projected for that release, since the decision must be made in advance of the actual sediment-triggered HFE release and there is an admitted uncertainty in the modeled forecast for both sediment input and dam releases. Caution will be exercised; however, because the sand mass balance only accounts for the difference between inputs and outputs, and does not adequately portray the erosion of sand in the river channel. Successive HFEs or intervening periods of erosion without HFEs could negatively affect the ability of future HFEs to form sandbars and beaches. Furthermore, this erosion could impact other resources and it is advisable to ensure that the net amount of sand in the river channel not be depleted so as to compromise other ecosystem components and functions. The output of the model will be integrated with an assessment of the status and trend of other resources, as an acknowledgement that the decision cannot be focused solely on the condition of the sediment to ensure that the decision encompasses the impacts on the resources identified above in P-1.1.

2 OPERATION OF GLEN CANYON DAM UNDER THE HFE PROTOCOL

The scenarios considered below describe how Reclamation will modify the operation of Glen Canyon Dam to reallocate monthly volumes when necessary to achieve HFEs as called for under this protocol. Implementation of the protocol will be done in concert with coordinated river operations. Since 1970, the annual volume of water released from Glen Canyon Dam has been made according to the provision of the Criteria for Coordinated Long-Range Operation of Colorado River Reservoirs (LROC) that includes a minimum objective release of 8.23 maf.

The 2007 Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Power and Lake Mead (Reclamation 2007a) for lower basin shortages and the coordinated reservoir operations (Reclamation 2007b) implements relevant provisions of the LROC for an interim period through 2026. This allows Reclamation to modify these operations by allowing for potential annual releases both greater than and less than the minimum objective release under certain conditions. A more thorough description of Reclamation's process for determining and implementing annual release volumes is available in the 2007 EIS and Record of Decision (Reclamation 2007a, 2007b).

Pursuant to the 2007 Colorado River Interim Guidelines, the annual release volume from Lake Powell is projected and updated each month in response to the monthly 24-month study model run. This projected annual release volume is allocated to produce projected monthly release volumes and becomes the basis for scheduled monthly releases from Glen Canyon Dam. It is important to note that, regardless of the timing of releases, implementation of the HFE protocol will not affect annual release volumes.

HFEs could require more water than what is scheduled for release through the coordinated operation process described above. In order to perform these HFEs, reallocation of monthly releases from Glen Canyon Dam may be necessary. Monthly reallocations for an HFE will not affect annual release volumes.

2.1 POTENTIAL OPERATION OF GLEN CANYON DAM DURING THE FALL HFE IMPLEMENTATION WINDOW

Reclamation will attempt to implement fall HFEs by lowering the remaining days within the fall HFE period to the degree practicable up to as low as allowed under the LROC and LTEMP ROD in order to release the projected October and November volumes in the 24-month study. If a fall high-HFE could be achieved within the release volumes projected for October and November, no reallocation of the monthly volumes from other months will need to be performed.

If, however, a fall HFE could not be achieved within the release volumes projected for October and November, Reclamation will reduce the projected monthly release volumes as necessary through the remainder of the water year. The reallocation will be determined in consultation with WAPA to minimize adverse impacts on hydropower. Reallocation will only be conducted up to the amount necessary to result in the projected monthly volume for October and November being sufficient to conduct the HFE.

2.2 POTENTIAL OPERATION OF GLEN CANYON DAM DURING THE SPRING HFE IMPLEMENTATION WINDOW

Reclamation will attempt to achieve spring HFEs by lowering the remaining days within the spring HFE period to the degree practicable up to as low as allowed under the LROC and LTEMP ROD in order to release the projected March and April volumes in the 24-month study. If the sediment-triggered spring HFE could be achieved within the release volumes projected for March and April, no reallocation of the monthly volumes from other months would need to be performed. Note that proactive spring HFEs (see Section 3.2) would not require reallocation of water outside of the month in which they occurred because they would be 24 hours or less in duration.

If, however, Reclamation determined that it will not be possible to achieve the sediment-triggered HFE within the monthly release volumes projected for March and April, Reclamation will reduce the projected monthly release volumes as necessary through the remainder of the water year. The reallocation will be determined in consultation with WAPA to minimize adverse impacts on hydropower. The reallocation process will only be conducted up to the amount necessary to result in the projected monthly volume for March and April being sufficient to conduct the sediment-triggered HFE. If additional reallocation of the monthly volumes is required to achieve the sediment-triggered HFE, Reclamation would attempt to do so while maintaining the projected July and August release volumes in the 24-month study.

3 HIGH-FLOW EXPERIMENTS TO BE EVALUATED UNDER THE PREFERRED ALTERNATIVE

Sediment-related experiments under the selected alternative include (1) sediment-triggered spring and fall HFEs up to 96-hr duration; (2) short-duration (24-hr) proactive spring HFEs in high-volume equalization years (>=10 maf) prior to equalization releases; and (3) implementation of up to four extended-duration (>96 hr) HFEs, up to 250 hr long, depending on sediment conditions. The pattern of transferring water volumes from other months to make up the HFE volume will be discussed in the monthly Glen Canyon Dam operational coordination meetings described in Section 1.

If sediment resources are stable or improving, the combination of base operations, HFEs, and other treatments will continue as prescribed for the selected alternative. If sediment resource conditions decrease to unacceptable levels during the LTEMP period, operations may be modified to the extent allowable under the LTEMP ROD or will be evaluated and considered under a separate NEPA process, potentially including additional studies of sediment augmentation or other actions.

For all sediment experiments, testing will be modified or temporarily or permanently suspended if (1) experimental treatments were ineffective at accomplishing their objectives, or (2) there were unacceptable adverse impacts on resources. Monitoring results will be evaluated to determine whether additional tests, modification of experimental treatments, or discontinuation of experimental treatments were warranted.

Implementation of HFEs will consider resource condition assessments and resource concerns using the annual processes described in Section 1. HFEs may not be tested when there appears to be the potential for unacceptable impacts on the resources listed in Section 1. In addition, there is uncertainty associated with cumulative impacts from sequential HFEs. These cumulative impacts will be considered before implementing an HFE.

3.1 SEDIMENT-TRIGGERED SPRING HFES

Under the selected alternative, sediment-triggered spring HFEs will be implemented after an initial 2-year delay in order to enable testing of the effectiveness of trout management flows and address concerns raised by the apparent positive response of trout to the 2008 spring HFE (Korman et al. 2011; Melis et al. 2011). After the first 2 years of the LTEMP period, spring HFEs will be implemented when triggered by sediment conditions, except in water years when an extended-duration fall HFE (see description in Section 3.4) was conducted. Modeling indicates that there may be sufficient sediment input for spring HFEs in about 26% of the years in the LTEMP period. Sediment-triggered spring HFEs will be implemented when triggered during the entire LTEMP period unless new information indicated they were not effective in building sandbars, or there were unacceptable adverse effects on resources (Section 1).

Implementation of sediment-triggered spring HFEs will consider resource condition assessments and resource concerns using the processes described in Section 1. Spring HFEs may not be tested when there appears to be the potential for unacceptable adverse impacts on the resources listed in Section 1. In addition, there is uncertainty associated with the cumulative impacts of sequential HFEs on sediment, aquatic, and potentially other resources. These cumulative impacts will be considered before implementing a spring HFE particularly if a fall HFE had been implemented in the same water year.

3.2 PROACTIVE SPRING HFES

GCMRC scientists identified proactive spring HFEs as a potential experimental treatment to transport and deposit in-channel sand at elevations above those of equalization flows. Proactive spring HFEs will be tested only in years with high annual release volume (i.e., ≥10 maf). A first test will be a 24-hr 45,000-cfs release conducted in April, May, or June. Duration in subsequent tests could be shortened depending on the observed effects during the first tests. It would be preferable to test proactive spring HFEs at least two to three times in the 20 year LTEMP period, but being able to do so will be dependent upon annual hydrology. Modeling indicates that proactive spring HFEs would be triggered in about 10% of the years in the LTEMP period.

Proactive spring HFEs will not be tested in the first 2 years of the LTEMP. In addition, proactive spring HFEs will not be tested in years when there had been a sediment-triggered spring HFE or an extended-duration fall HFE earlier in the same water year. Proactive spring HFEs could be performed in the same water year as a 96-hr or shorter sediment-triggered fall HFE, although prior to implementation, the potential effects of these HFEs will be carefully evaluated using the processes described in Section 1. The first test will be carefully evaluated to determine whether additional tests were warranted based on the efficacy of building and maintaining sandbars. If initial tests show positive results without unacceptable adverse effects on the resources listed in Section 1, proactive spring HFEs will be implemented when triggered during the entire LTEMP period.

Implementation of proactive spring HFEs will consider resource condition assessments and resource concerns using the processes described in Section 1. Proactive spring HFEs may not be tested when there appears to be the potential for unacceptable impacts on the resources identified in Section 1. The cumulative impacts of sequential HFEs will be considered before implementing a proactive spring HFE.

3.3 SEDIMENT-TRIGGERED FALL HFES

Under the selected alternative, sediment-triggered fall HFEs could be implemented throughout the 20-year LTEMP period unless new information indicated fall HFEs were not effective in building sandbars, or there were unacceptable adverse effects. Modeling indicates fall HFEs would be triggered in about 77% of the years in the LTEMP period.

Implementation of sediment-triggered fall HFEs will consider resource condition assessments and resource concerns using the processes described in Section 1. Fall HFEs may not be tested when there appears to be the potential for unacceptable impacts on the resources listed in Section 1. The cumulative impacts of sequential HFEs will be considered before implementing a sediment-triggered fall HFE.

3.4 EXTENDED-DURATION FALL HFES

The HFE EA (Reclamation 2011) had a limit of 96-hr duration HFEs at various release levels. Under the selected alternative, sediment-triggered fall HFEs with durations longer than 96 hr (up to 250 hr) will be tested. The duration of these extended-duration fall HFEs will be based on the amount of sediment delivered from the Paria River during the fall accounting period and will be no more than the maximum magnitude and duration of HFE that will achieve a positive sand mass balance in Marble Canyon, as determined by modeling. Based on examination of the observed historical sediment input from the Paria River, it was determined that HFEs up to 10.4 days in length (250 hr) could be supported before exhausting seasonal sediment inputs and affecting water delivery requirements. GCMRC scientists have suggested that increasing the duration of HFEs when sediment supply can support a longer duration may lead to more sand being deposited at higher elevations, resulting in bigger sandbars. Modeling indicates the sediment trigger for this treatment may be reached in 25% of the years in the LTEMP period. There will be no more than four extended-duration fall HFEs allowed over the 20-year LTEMP period.

The duration of the first implementation of an extended-duration HFE will be limited to no more than 192 hr (twice as long as the 96-hr limit). This duration is considered long enough to produce a measurable result if the treatment represents an effective approach to building sandbars under enriched sediment conditions. The duration of all tests will be based on available sediment, current hydrology, reviews of available information, the expert opinion of GCMRC and other Grand Canyon scientists, and consideration of potential effects on other resources listed in Section 1. If feasible, monitoring will include real-time observations of sediment concentrations to determine if sediment deposition continues throughout the duration of the extended HFEs.

Implementation of extended-duration fall HFEs will consider resource condition assessments and resource concerns using the processes described in Section 1. Extended-duration fall HFEs may not be tested when there appears to be the potential for unacceptable impacts on the resources listed in Section 1. Because the effects of extended-duration HFEs on Lake Mead water quality are a concern, DOI will coordinate with relevant water quality monitoring programs or affected agencies prior to implementing any test of extended-duration HFEs. The cumulative impacts of sequential HFEs will be considered before implementing an extended-duration fall HFE.

Another important concern that results from the large volume of water bypassed during an extended-duration HFE is water delivery. Water delivery issues will be considered before deciding to implement an extended-duration fall HFE. An extended-duration HFE will not be implemented if annual release volume would be affected. It is possible that in lower volume years there would not be sufficient water available to support an extended-duration HFE. A 250-hr extended-duration HFE would result in a monthly total release of approximately 1.2 maf. In lower volume release years (e.g., 7.0 maf or 7.48 maf), the maximum duration may be less than 250 hr. In addition, a sediment-triggered spring HFE or proactive spring HFE will not be conducted in the same water year as an extended-duration fall HFE. If an extended-duration fall HFE was triggered but not implemented for any of the reasons described above, a fall HFE 96 hr or less in duration could be implemented instead. Implementation will necessitate reducing water volume in other months of the same water year.

In order to fully test the efficacy of these longer HFEs, several replicates would be desirable in the 20 year LTEMP period. Extended-duration HFEs will be considered successful and will be continued up to a total of four times in the 20-year LTEMP period as part of an adaptive experimental treatment if there was a widespread increase in bar size relative to ≤96-hr HFEs, and if sand mass balance was not significantly compromised relative to the ability to maintain a long-term equilibrium. Extended-duration HFEs will not continue to be tested if they were not effective in building sandbars, if resulting total sandbar volumes were no bigger than those created by shorter-duration HFEs, or if unacceptable adverse impacts on resources listed in Section 1 were observed.

ATTACHMENT C REFERENCES

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ATTACHMENT D:

RESPONSES TO COMMENTS ON FEIS

Colorado River Basin States Representatives of Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming and the Upper Colorado River Commission (Basin States)

In their comment letter on the FEIS, the Basin States noted that they continue to concur with implementing the preferred alternative (Alternative D) as described in the LTEMP FEIS with the following considerations: (1) implementation must comply with existing law including those governing water allocation and delivery; (2) the implementation process and consultation and communication process described in Sections 2.2.4.3 and 2.2.4.4, respectively, of the FEIS, which specifically includes the Basin States' involvement in the assessment of resources and evaluation of potential experiments, are critical to the Basin States' support of the LTEMP FEIS and the preferred alternative; (3) careful consideration should be given to how the LTEMP objectives and goals are integrated into GCDAMP processes; (4) the Basin States do not support the use of GCDAMP funds for experiments and management activities that extend beyond the areas that are directly affected by dam operations; (5) HFEs should continue to be considered experimental; (6) experimental low summer flow should only be implemented when they are needed to address immediate concerns with the humpback chub population and only upon careful consideration of all potentially affected resources; and (7) hydropower resources should be maximized consistent with the preferred alternative and in compliance with existing law.

Response: Comments and considerations identified in the Basin States' letter are generally consistent with the preferred alternative identified in the FEIS and in this ROD and its implementation through GCDAMP. In terms of hydropower, as stated in the LTEMP goals and objectives, the hydropower goal is to "maintain or increase Glen Canyon Dam electric energy generation, load following capability, and ramp rate capability, and minimize emissions and costs to the greatest extent practicable, consistent with improvement and long-term sustainability of downstream resources."

Colorado River Energy Distributors Association (CREDA)

CREDA comments focused on changes made following the DEIS, issues of concern that according to CREDA had not been adequately addressed previously, and new information that was not previously available for public review and comment (e.g., Appendices O and P). Specific comments included: (1) issues with the wording of the purpose and need of the LTEMP, scope of resource goals and objectives, and description of the experimental framework of the preferred alternative; (2) legal sufficiency of the LTEMP Biological Assessment and need to include testing of a wider range of flow conditions; (3) objection to maintaining the 8,000 cfs cap on within-day fluctuation levels; and (4) non-inclusion of new information on non-use valuation of Glen Canyon Dam operations.

Response: The joint-lead agencies do not agree with CREDA's assessment of the purpose and need statement as too broad to be of use. The quotes identified by CREDA leave out key elements of the purpose and need statements that further clarify the scope and intent. DOI disagrees with the statement that experiments or other proposed actions are not adequately defined or analyzed. The LTEMP FEIS described experiments to be conducted under different alternatives in sufficient detail to allow for a full analysis of their effects. Extensive modeling of the effects of these alternatives on a full set of resources was conducted and formed the basis of the assessment presented in the FEIS. In addition, the FEIS includes safeguards that would prevent unacceptable adverse impacts on key resources. As stated in Section 2.2.4.3 of the FEIS, an unacceptable adverse impact, at a minimum, would include significant negative impacts on resources as a result of experimental treatments that have not been analyzed for Alternative D in the LTEMP EIS. Further details of monitoring and experiments will be provided as needed in the Science Plan developed by GCMRC and in triennial work plans developed as part of the GCDAMP.

The Biological Assessment was written to evaluate and state the effects of the "proposed action," which, for purposes of ESA consultation, is Alternative D as described in the FEIS. The subsequent Biological Opinion is the FWS' opinion on the effects of the proposed action (i.e., Alternative D) on threatened and endangered species and designated critical habitat. Unless considered necessary based on a jeopardy call, FWS does not typically suggest modifications to the proposed action. In their Biological Opinion on the LTEMP, the FWS stated "it is our biological opinion that the LTEMP, as proposed, is not likely to jeopardize the continued existence of these species [humpback chub, razorback sucker, and Kanab ambersnail], and is not likely to destroy or adversely modify designated critical habitat for the humpback chub and razorback sucker [no critical habitat has been designated for the Kanab ambersnail]." The FWS did not include reasonable and prudent measures to minimize take of these species because "all reasonable measures to minimize take have been incorporated into the project description." Alternative D did not include hydropower improvement flows, therefore those were not part of the ESA consultation and are not part of the Biological Opinion.

The 8,000 cfs maximum daily fluctuation cap has been in place since 1996, and was established to address safety, recreation, and sediment concerns. The LTEMP EIS analysis has found that the same concerns still apply. The 8,000 cfs maximum daily fluctuation is based on Bishop et al. (1987), which was reviewed by DOI experts and found to still be the best available information and appropriate for this EIS. The Bishop study surveyed both the river guides and the general public regarding preferences and the river guides reported a preference for a maximum of 8,000 cfs daily change for a "tolerable recreation experience" under relatively high average daily flows. DOI received over 1,000 comment letters on the DEIS from river guides, members of conservation groups, and the general public specifically stating their preference for retaining the 8,000 cfs maximum daily fluctuation in the preferred alternative.

The new referenced report from Jones et al. on non-use valuation of alternative Glen Canyon Dam operations appears to be a project report, and it is unclear if it has been peer reviewed. The referenced report was not provided until November 4, 2016, after the FEIS was completed. This information was reviewed by a team of DOI subject matter experts and was considered for potential implications to FEIS or Record of Decision. The subject matter experts concluded that this study did not represent significant new information relevant to the LTEMP that would require changes to the FEIS or change DOI's selection of the preferred alternative in the Record of Decision. Additionally, some of the information used in this new report was found in earlier studies from Jones et al. which were considered and referenced in the FEIS in Sections 3.14 and 4.14.

U.S. Environmental Protection Agency (EPA)

EPA's comment letter reiterated their findings on the DEIS including their rating of Lack of Objections-Adequate (LO-1). The EPA commended NPS and Reclamation for "conducting a rigorous analysis of the proposed actions, and clearly communicating the projected impacts to important resources in the project area." EPA noted that the FEIS incorporated the Council on Environmental Quality's *Final Guidance for Federal Departments and Agencies on Consideration of Greenhouse Gas Emissions and the Effects of Climate Change in National Environmental Policy Act Reviews* and included a comprehensive table that utilized standardized and comparable metrics to quantify the effects of a changing climate on each of the presented alternatives.

Response: Comments noted.

International Federation of Fly Fishers and Trout Unlimited (IFFF/TU)

As acknowledged in the introduction to their comments on the FEIS, all of the comments submitted by IFFF/TU were submitted previously on the DEIS. IFFF/TU raised the following concerns: (1) the aquatic food base should be a priority in the LTEMP and experiments should be initiated early in the 20-year program; (2) objectives and adaptive management strategies in the Arizona Game and Fish Department's Fishery Management Plan should be considered in the FEIS; (3) the rainbow trout fishery should be given priority status; (4) trout management flows should be used to improve the quality of the trout fishery; and (5) extended-duration HFEs should not be implemented until the impacts to the aquatic food base, native fish, rainbow trout, and invasive species in both Glen and Marble canyons are more fully understood.

Response: Reponses to comments from IFFF/TU were provided in Appendix Q of the FEIS. These responses are summarized here.

DOI acknowledges the importance of testing experimental macroinvertebrate production flows to determine their effectiveness in improving the aquatic food base. Implementation of this experiment in any given year would be determined based on the processes described in Sections 2.4.4.3 and 2.2.4.4 of the FEIS.

The AZGFD management plan and NPS's Comprehensive Fisheries Management Plan are independent of the LTEMP EIS. Currently, there are aspects of the AZGFD plan that are not in agreement with the LTEMP or with the Comprehensive Fisheries Management Plan. The NPS is continuing to work with AZGFD to work toward agreement on these concerns.

The rainbow trout fishery was listed as 1 of 7 key issues in Section 1.2 of the FEIS and was one of the resource goals in Section 1.4 of the FEIS.

Section 2.2.4.6 of the FEIS and Section 2.2.4 in Attachment B of this ROD clarify that the implementation processes of TMFs will include consideration of resource condition assessments, and the resource concerns identified in the FEIS included impacts on trout. Early tests of TMFs will be used to determine the effectiveness of TMFs and a best approach to trout management. Experimentally, the best conditions for testing TMFs are when high trout recruitment is expected, such as during a high release volume/equalization year or after a spring HFE, however the conditions for both of these are somewhat unpredictable and infrequent.

The effects of HFEs on aquatic resources were fully analyzed in Section 4.5 of the FEIS. This section reports that fall HFEs have not been found to have negative impacts on the food base, trout recruitment, or native or nonnative fish. Prior to the implementation of any HFEs, there would be consideration of conditions related to humpback chub, trout, and aquatic food base. The HFE implementation process includes meetings with the GCMRC, FWS, AZFGD and other partners to take into consideration annual conditions as well as any new information. If unacceptable adverse impacts are predicted or observed, then experiments may be discontinued or additional NEPA processes may be conducted. The extended-duration fall HFEs would be phased in with the first test being no longer than 192 hours.

National Parks Conservation Association (NPCA)

NPCA reiterated general support of the preferred alternative and stated that they believe that the preferred alternative represents the best compromise in meeting the intent of the GCPA while minimizing negative impacts to other societal considerations. NPCA expressed their opinion that the hydropower objective should be reworded from “maintaining or improving” hydropower generation to “minimiz[ing] impacts on or improv[ing]” hydropower generation, and that the status of the Basin Fund should not be a primary consideration in the decision making process. NPCA stated concern that equalization flows implemented under the 2007 Interim Guidelines can have detrimental effects on sediment and that modification of the guidelines should have been considered in the LTEMP EIS.

Response: DOI believes the hydropower objective and goal as written are consistent with NPCA’s proposed wording because “maintaining and improving” hydropower generation is to be achieved “to the greatest extent practicable, consistent with improvement and long-term sustainability of downstream resources.” The implementation process described in the FEIS includes the status of the Basin Fund among a number of other resource considerations and does not assign primary or secondary status to any. The process is designed to be responsive to specific conditions in any given year. Adherence to the Interim Guidelines and other components of the Law of the River was an important objective and goal of the LTEMP, and was fully analyzed in the FEIS.

Salt River Project (SRP)

SRP referenced concerns they had expressed about the LTEMP EIS process, and asserted that none of those issues were addressed by the joint-lead agencies. In addition, they expressed support for the comments submitted by CREDA on the FEIS; recommended that experiments to improve hydropower performance should be included in drier years, and that these experiments would potentially benefit the endangered humpback chub, help control trout, and supplement the Basin Fund; and that some method should be included to limit the impacts of HFEs on air emissions.

Response: The joint leads are aware of concerns that SRP raised related to their involvement in development of the LTEMP EIS, but disagree with the characterization of SRP's level of involvement. SRP indicated they had not been consulted sufficiently or consistently and that they were not consulted on the analytical approach or data used in the hydropower analysis. As documented in Chapter 1 and Section 2.1 of the FEIS, the joint leads held numerous meetings with Cooperating Agencies throughout the EIS process including monthly conference calls for over four years (more than 50 calls or meetings); numerous workshops and webinars (more than 15) to gather input and present preliminary results; and opportunities to review and comment on purpose and need, resource goals and objectives, performance metrics, alternatives, assessment methodologies, and preliminary drafts of EIS sections.

The joint-lead agencies evaluated the referenced hydropower improvement operations in drier years and found a number of potentially adverse impacts on sediment transport, aquatic food base, vegetation, and recreation.

Placing a limit on air emissions related to implementation of HFEs is not likely to result in improvements to air quality because of the expected very small impact of HFEs on emissions.

Save the Colorado

In their comments on the FEIS, Save the Colorado stated that the FEIS (1) fails to take climate change seriously and does not represent the most current and best available science on climate change and its likely impacts on the Colorado River; (2) does not include the most current economic analysis of the impact of removing hydropower at Glen Canyon Dam; (3) fails to use the most current science to adequately consider, account for, and mitigate climate change emissions from operations of Glen Canyon Dam; (4) fails to take the required hard look at the impacts of the LTEMP alternatives on climate change and economic impacts; and (5) fails to consider an adequate range of alternatives that meet the purpose, needs, and objectives of the proposed project.

Response: DOI believes that Reclamation's 2012 Basin Study, which was used as the basis for the climate analysis in the LTEMP FEIS, represents the most current comprehensive look at the effects of climate change on water supply in the Colorado River Basin, and is still relevant to the analysis of the impacts of the LTEMP over the next 20 years. The analysis presented in the FEIS was specifically intended to determine the sensitivity of the alternatives to different climate outcomes and determined that uncertainty in climate futures would not change the relative performance of the alternatives; therefore, it would not change the selection of Alternative D for implementation.

The FEIS presents a thorough and comprehensive evaluation of the impacts of alternatives on hydropower generation and economics in Appendix K of the FEIS. That analysis looked at the system-wide response of changes in Glen Canyon Dam output related to operations under each LTEMP alternative. That analysis did not evaluate the complete loss of power generation at Glen Canyon Dam, because decommissioning the dam would not meet the purpose, need, and objectives of the LTEMP.

DOI disagrees with the assertion that the LTEMP FEIS fails to comply with NEPA guidelines and with the CEQ guidance for estimating or addressing greenhouse gas emissions, and note that the EPA commended DOI on the thoroughness of the FEIS and incorporation of the latest CEQ guidance for addressing GHG emissions and the effects of climate change in NEPA reviews.

Section 4.16 of the FEIS presented a detailed systemwide evaluation of the effects of LTEMP alternatives on air emissions and GHG emissions in the 11-state region. Reservoirs such as Lake Powell would be expected to produce some amount of GHG emissions consistent with levels reported for reservoirs in the semiarid Western U.S. (Tremblay et al. 2004 and http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_p_Ap3_WetlandsCH4.pdf). The values presented in the referenced PLOS One article were not used for the FEIS, because that article was published after the FEIS was completed, and the article's estimates of GHG emissions from Lake Powell are based on simplifying assumptions that add uncertainty to those estimates. The authors of that study stated that their estimates were highly variable and that site-specific studies would be needed to determine actual emissions for a specific reservoir. Such studies have not been performed on Lake Powell. Additionally, GHG emissions from reservoirs are related to surface area, and the selected alternative would only change monthly, daily and hourly dam releases and has only temporary and slight changes to reservoir elevations or surface area. These changes are much less than the typical annual variation in reservoir level due to inflows and regulated by other processes outside of the scope of the LTEMP.

The LTEMP team developed a set of alternatives that represented the full range of reasonable experimental and management actions; met the purpose, need, and objectives of the proposed action; and were considered within the constraints of existing laws, regulations, and existing decisions and agreements. Other alternatives such as the "Fill Mead First," "Run-of-the River" and "Decommissioning the Dam" proposals were not included in the FEIS because they would not meet the purpose, need, or objectives of the proposed action (see Sections 2.3.9 and 2.3.10 of the FEIS). These alternatives would not allow compliance with water delivery requirements including the Law of the River and 2007 Interim Guidelines, and would not comply with other federal requirements and regulations, including the GCPA.

Sierra Club

In their comment letter, the Sierra Club appealed the analysis and decision of the LTEMP because they claimed it violates the GCPA, the analysis is incomplete, and the decision is arbitrary and capricious. The Sierra Club comments identified the following specific points: (1) the purpose and need does not reflect legal obligations; (2) LTEMP must aim to restore the full suite of species that existed before Glen Canyon Dam; (3) LTEMP must analyze an alternative that is based on peer-reviewed science; and (4) NPS and Reclamation must plan for future climate uncertainty and should analyze the "Fill Mead First" alternative.

Response: As stated in Appendix Q of the FEIS, the purpose and need statement articulates the responsibilities of the Secretary of the Interior under the GCPA, the goal of which is to preserve, mitigate adverse impact to and improve the values for which GCNP and GCNRA were established, including, but not limited to natural and cultural resources and visitor use. The purpose and need and alternatives evaluated in the EIS take direction from the GCPA and attempt to develop an alternative that meets the requirements of the GCPA and applicable Federal laws, regulations, and policies. In addition to Section 1802 of GCPA, the Secretary is required to follow numerous other federal laws, including the 1956 Colorado River Storage Project Act that addresses hydropower generation. Therefore, removal of power generation from the purpose and need statement in the EIS would be inconsistent with other parts of the GCPA.

As stated in Section 1.5.3 of the FEIS, the reintroduction of extirpated species was considered outside the scope of the EIS, but was addressed for fish within the NPS Comprehensive Fisheries Management Plan. LTEMP alternatives include experiments that are intended to improve conditions for ESA-listed species, other native special status species, vegetation communities and wildlife within the Colorado River Ecosystem. Included in all but the No-Action Alternative are non-flow vegetation treatments that would include the control of nonnative plant species and revegetation with native plant species. Alternative D includes experimental flows to improve the aquatic food base by providing conditions that would improve macroinvertebrate production. DOI worked closely with FWS throughout the 5-year EIS process to ensure that the appropriate experiments, dam operations, and non-flow actions were identified as conservation measures for ESA-listed species. Formal consultation with FWS has resulted in a Biological Assessment and Biological Opinion on the effects of the proposed action on listed species and designated critical habitat.

Because of Glen Canyon Dam infrastructure, it is not possible to design an alternative that provides the variability in flow that existed before the construction of the dam. Without infrastructure modification, especially sediment augmentation, sustained very high flows could cause irreparable harm to ecological and sediment resources. Alternative F, fully analyzed in the EIS, provides many of the elements in the hydrograph proposed by the Sierra Club including low summer, autumn, and winter flows, and multiple, variable peaks within the spring and early summer when peaks in inflow are most likely. It was designed with the elements proposed by the Sierra Club in mind. Flows under this alternative would not be the same in each year, and could vary significantly from year-to-year based on hydrologic conditions. As for any alternative, implementation under an adaptive management framework would allow fine-tuning to accomplish specific species or community goals.

For the reasons stated in Section 2.3.9 of the FEIS, DOI does not believe that the "Fill Mead First" alternative would meet the purpose, need, and objectives of the LTEMP, which include water delivery. One of the LTEMP objectives is to "ensure the LTEMP does not affect water delivery to the communities and agriculture that depend on Colorado River water consistent with applicable determinations of annual water release volumes from Glen Canyon Dam made pursuant to the LROC for Colorado River Basin Reservoirs, which are currently implemented through the 2007 Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead." The FEIS further states: "Overlying these goals is the understanding that operations under LTEMP will continue to deliver water in a manner that is fully consistent with and subject to the Colorado River Compact, the Upper Colorado River Basin Compact, the Water Treaty of 1944 with Mexico, the decree of the Supreme Court in Arizona v. California, and the provisions of CRSPA and the Colorado River Basin Project Act of 1968 that govern allocation, appropriation, development, and exportation of the waters of the Colorado River Basin, and consistent with applicable determinations of annual water release volumes from Glen Canyon Dam made pursuant to the LROC for Colorado River Basin Reservoirs, which are currently implemented through the 2007 Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead. As such, water delivery is an overarching consideration for dam operations that will necessarily inform the actions that can be taken to achieve the resource goals set forth above."

Southern Nevada Water Authority (SNWA)

In their comment letter, SNWA referenced their comments on the DEIS and those provided by the Basin States (within which the State of Nevada is represented). In addition, SNWA emphasized the importance of considering water quality in Lake Mead in the implementation process for the LTEMP. SNWA acknowledged that the FEIS included Lake Mead water quality as a resource consideration in the FEIS.

Response: Comments noted. The FEIS includes communication and coordination related to Lake Mead water quality.

State of Colorado (Colorado)

Colorado's comments reaffirmed their continued support for Alternative D as the preferred alternative, and largely echoed the comments provided by the Basin States. There were, however, several elements include in the comment letter that were unique to Colorado's comments including the following recommendations: (1) provide clarification on the scope of LTEMP activities and limit these to only those actions that address issues directly related to the effects of dam operations within the Colorado River Ecosystem; (2) pre-dam conditions should be presented for contextual purposes only; (3) resource goals and objectives should be limited to conditions within the Colorado River Ecosystem and should apply to activities that can be accomplished only through regulation of flow at Glen Canyon Dam; (4) the GCPA does not provide DOI the authority to conduct non-flow actions that are not related to dam operations or directly mitigating those dam operations; (5) the list of laws and regulations presented in the FEIS is well beyond what is necessary for the LTEMP; (6) the roles and hierarchy of federal agency involvement in operation of Glen Canyon Dam do not reflect the appropriate balance; (7) HFEs should continue to be considered experimental; (8) impacts of LTEMP on Hoover Dam operations fall outside the scope of considerations when implementing the LTEMP activities; and (9) all LTEMP experiments or management actions during the LTEMP period must carefully consider and minimize negative impacts to the Basin Fund; (10) the ROD should include appropriate disclaimer language regarding the various components of the Law of the River to prevent stakeholders from disputing or contesting legal characterizations.

Response: There is an important distinction between the scope of LTEMP activities and the scope of the effects analysis. Although the EIS identified some indirect impacts that could occur over a broader geographic range, LTEMP activities would focus only on resource effects of dam operations within the Colorado River Ecosystem.

In the introduction to Chapter 3 of the FEIS, the intention of presenting information on pre-dam conditions is clearly stated as for contextual purposes and is not intended to form the basis for comparison of the alternatives or to provide goals for achieving resource conditions. In the FEIS, the action alternatives are compared to the No-Action Alternative (Alternative A), as is the standard practice for NEPA compliance.

In the FEIS, the wording of resource goals and objectives were revised to make it clear that these targeted resource conditions within the Colorado River Ecosystem. While most LTEMP activities are related to flow regulation, there are some non-flow actions that are also considered (e.g., mechanical removal of trout, translocation of humpback chub, and vegetation treatment). The vegetation treatment experiment is limited to the CRE, and the science and monitoring activities would be expected to occur primarily within the CRE.

The list of laws and regulations presented in Section 1.9 of the FEIS includes those which are related to operations of Glen Canyon Dam, management of National Park units, and protection of the resources that could be affected by the LTEMP. This list is broad and not all of the laws and regulations relate to day-to-day implementation of the LTEMP, but were important considerations in conducting the assessments presented in the FEIS.

The LTEMP FEIS states that HFEs will be experimental.

Impacts of LTEMP operations on Hoover Dam hydropower operations were presented in the FEIS based on the need to fully evaluate the consequences of the proposed action. Although potential impacts on Hoover Dam operations were identified, consideration of these impacts was intentionally not included in the list of resources to be considered during implementation of experiments.

The LTEMP FEIS includes the Basin Fund as one of the resources for which there would be consideration of potential unacceptable adverse impacts prior to implementing experiments.

A disclaimer relating to interpretation of specific provisions of the Law of the River, similar to that recommended by Colorado, has been added to the ROD.

ATTACHMENT D REFERENCES

Bishop, R.C., K.J. Boyle, M.P. Welsh, R.M. Baumgartner, and P.R. Rathbun, 1987, *Glen Canyon Dam Releases and Downstream Recreation: An Analysis of User Preferences and Economic Values*, Glen Canyon Environmental Studies, Flagstaff, Ariz., Jan.

Tremblay, A., L. Varfalvy, C. Roehm, and M. Garneau, 2004, "The Issue of Greenhouse Gases from Hydroelectric Reservoirs: From Boreal to Tropical Regions," *United Nations Symposium on Hydropower and Sustainable Development*, Beijing, China, Oct. 27–29, 2004. Available at http://www.un.org/esa/sustdev/sdissues/energy/op/hydro_tremblaypaper.pdf.

ATTACHMENT E:

U.S. FISH AND WILDLIFE SERVICE BIOLOGICAL OPINION FOR THE GLEN CANYON DAM LONG-TERM EXPERIMENTAL AND MANAGEMENT PLAN

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Fish and Wildlife Service
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In reply refer to:
AESO/SE
02EAAZ00-2012-F-0059
02EAAZ00-2014-CPA-0029

November 28, 2016

Memorandum

To: Regional Director, Bureau of Reclamation, Upper Colorado Regional Office, Salt Lake City, Utah

From: Field Supervisor, Arizona Ecological Services Office, U.S. Fish and Wildlife Service

Subject: Biological Opinion for the Glen Canyon Dam Long-Term Experimental and Management Plan, Coconino County, Arizona

Thank you for your request for formal consultation/conference with the U.S. Fish and Wildlife Service (FWS) pursuant to section 7 of the Endangered Species Act of 1973 (16 U.S.C. § 1531-1544), as amended (Act). Your request was dated August 16, 2016, and received by us via electronic mail the same day. At issue are impacts that may result from the proposed Glen Canyon Dam Long-Term Experimental and Management Plan (LTEMP) located in Coconino County, Arizona. The proposed action may affect the endangered humpback chub (*Gila cypha*) and its critical habitat, the endangered razorback sucker (*Xyrauchen texanus*) and its critical habitat, and the endangered Kanab ambersnail (*Oxyloma kanabensis*).

In your memorandum, you requested our concurrence that the proposed action is not likely to adversely affect the endangered southwestern willow flycatcher (*Empidonax traillii extimus*) and the endangered Yuma Ridgway's rail (*Rallus obsoletus yumanensis*). We concur with your determinations. The basis for our concurrences is found in Appendix A.

This biological opinion (BO) replaces the 2008 Final Biological Opinion on the Operation of Glen Canyon Dam (USFWS 2008, 2009, consultation number 22410-1993-F-167 and the court ordered supplements to that opinion, 22410-1993-F-167-R1). This BO also replaces the 2011 Final Biological Opinion on the Operation of Glen Canyon Dam including High Flow Experiments and Non-Native Fish Control (USFWS 2011a, consultation numbers 22410-2011-F-0100 and 22410-2011-F-0112). Since we issued these BOs, the status of the humpback chub, razorback sucker, and their critical habitat have improved, and the proposed LTEMP action includes conservation actions for these species and their habitats beyond what was included in past operations and BOs.

This BO is based on information provided in the August 16 and September 27, 2016, biological assessments (BAs), the 2016 draft environmental impact statement (DEIS) and final EIS (FEIS), telephone conversations, field investigations, and other sources of information. Literature cited in this biological opinion is not a complete bibliography of all literature available on the species of concern, the proposed action and its effects, or on other subjects considered in this opinion. A complete record of this consultation is on file at this office.

Consultation History

Details of the consultation history are summarized in Table 1.

Table 1. Summary of Consultation History

Date	Event
September 2012-December 2015	We participated in serval meetings and conference calls to discuss preparation of the DEIS and conservation measures for the proposed action.
January 2016-August 2016	We participated in several coordination calls to discuss the DEIS, proposed action, conservation measures, and draft BA.
March 4, 2016	We met with the U.S. Bureau of Reclamation (Reclamation) Western Area Power Authority (Western), National Park Service (NPS), and the U.S. Geological Survey Grand Canyon Monitoring and Research Center (GCMRC) to discuss the effects of low summer flow to humpback chub and razorback suckers.
March 16, 2016	We received a copy of the draft BA from Reclamation.
March 30, 2016	We provided comments to Reclamation on the draft BA.
May 20, 2016	We had a meeting with Western, NPS, GCMRC, and Reclamation to discuss our comments on the draft BA.
June 6, 2016	We received a second draft BA from Reclamation.
June 22, 2016	We provided comments to Reclamation on the second draft BA.
August 16, 2016	We received Reclamation's August 16, 2016, request for formal consultation and the BA.

August 18, 2016	We issued a thirty-day letter initiating formal consultation.
September 27, 2016	We received the final updated BA from Reclamation.
November 8, 2016	We submitted a draft BO to Reclamation for review.
November 18, 2016	We received Reclamation's comments on the draft BO.

BIOLOGICAL OPINION

DESCRIPTION OF THE PROPOSED ACTION

The complete description of the proposed action can be found in your August 16, 2016, BA, the updated September 27, 2016, BA, the 2016 DEIS and FEIS, and other supporting information in the administrative record. These documents are included herein by reference. We have included a summary of the proposed action from the September 27, 2016, BA (pages 4-42).

The U.S. Department of the Interior (DOI), through Reclamation and NPS proposes to develop and implement a Long-Term Experimental and Management Plan (LTEMP) for operations of Glen Canyon Dam, the largest unit of the Colorado River Storage Project (CRSP). The LTEMP provides a framework for adaptively managing Glen Canyon Dam operations over the next 20 years consistent with the Grand Canyon Protection Act of 1992 (GCPA) and other provisions of applicable federal law. The proposed action will help determine specific dam operations and actions that could be implemented to improve conditions and continue to meet the Grand Canyon Protection Act's (GCPA) requirements and to minimize adverse impacts on the downstream natural, recreational, and cultural resources in the two park units, including resources of importance to American Indian Tribes. LTEMP supersedes existing operational plans for Glen Canyon Dam.

The DOI has identified several primary objectives of operating Glen Canyon Dam under the LTEMP, as well as more specific goals to improve resources within the Colorado River ecosystem (primarily from Glen Canyon Dam downstream to the headwaters of Lake Mead) through experimental and management actions. These goals and objectives are listed in the BA (pages 6-8). The preferred alternative in the LTEMP EIS and proposed action under analysis in this BO is Alternative D.

The Glen Canyon LTEMP involves the effects of implementation of flow (operations at Glen Canyon Dam) and non-flow actions that would be triggered by resource conditions over a 20-year period at Glen Canyon Dam and in the Colorado River downstream of Glen Canyon Dam within Glen Canyon National Recreation Area (GCNRA) and Grand Canyon National Park (GCNP), Coconino County, Arizona, to Lake Mead National Recreation Area (LMNRA).

A wide range of possible hydrologic conditions will occur over the LTEMP implementation time frame in response to intra-annual and inter-annual variability in basin-wide precipitation cycles.

Within a year, monthly operations are typically adjusted (increased or decreased) based on changing annual runoff forecasts, and, since 2007, the application of the Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (Reclamation 2007).

Base Operations and Operational Flexibility

Base operations consist of dam operations when no condition dependent or experimental actions are triggered. The proposed action for base operations (Alternative D in the DEIS and FEIS) influences the amount of monthly, daily, and hourly water releases from Glen Canyon Dam, but does not affect the total amount of annual water release determinations. Under the proposed action, the total monthly release volume in October, November, and December would be equal to current operations (Reclamation 2007). The August release volume in the proposed action is set to a moderate volume level (800 thousand acre-feet [kaf] in an 8.23 million acre-feet [maf] release year) to balance sediment conservation needs prior to a potential fall high flow event (HFE), and power production and capacity concerns. The January through July monthly release volumes were set at levels that roughly track Western's contract rate of power delivery. This water release schedule results in a redistribution of monthly release volumes and a relatively even distribution of flows compared to current operations.

Under the proposed action, the allowable within-day fluctuation range of releases from Glen Canyon Dam would be proportional to the volume of water scheduled to be released during the month (10 × monthly volume in kaf in the high-demand months of June, July, and August and 9 × monthly volume in kaf in other months), with a maximum daily fluctuation of 8,000 cubic feet/second (cfs). The down-ramp rate (the rate of river stage or water level reduction) would be increased to 2,500 cfs per hour (hr), but the up-ramp rate (the rate at which the river stage or water level increases) would remain unchanged from current operations at 4,000 cfs/hr. Figure 2 in the BA (p. 15) shows the minimum, mean, and maximum daily flows under the proposed action in an 8.23 maf year.

Reclamation retains the authority to utilize operational flexibility at Glen Canyon Dam because hydrologic conditions of the Colorado River Basin (or the operational conditions of Colorado River reservoirs) cannot be completely known in advance. Consistent with current operations, Reclamation, in consultation with WAPA, would make specific adjustments to daily and monthly release volumes during the water year. Monthly release volumes may be rounded for practical implementation or for maintenance needs. In addition, when releases are actually implemented, minor variations may occur regularly for a number of operational reasons that cannot be projected in advance.

Reclamation also would make specific adjustments to daily and monthly release volumes, in consultation with other entities as appropriate, for a number of reasons, including operational, resource-related, and hydropower-related issues. Examples of these adjustments may include, but are not limited to, the following:

- For water distribution purposes, volumes may be adjusted to allocate water between the Upper and Lower Basins, consistent with the Law of the River as a result of changing hydrology;

- For resource-related issues that may occur uniquely in a given year, release adjustments may be made to accommodate nonnative species removal, to assist with aerial photography, or to accommodate other resource considerations separate from experimental treatments under the LTEMP; and,

- For hydropower-related issues, adjustments may occur to address issues such as electrical grid reliability, actual or forecasted prices for purchased power, transmission outages, and experimental releases from other Colorado River Storage Project dams.

These potential "adjustments" are all part of the general operation of the dam and fall within the context of normal operations and are part of the action under consultation.

In addition, Reclamation may make modifications under circumstances that may include operations that are prudent or necessary for the safety of dams, public health and safety, other emergency situations, or other unanticipated or unforeseen activities arising from actual operating experience (including, in coordination with the Basin States, actions to respond to low reservoir conditions as a result of drought in the Colorado River Basin). Also, the Emergency Exception Criteria established for Glen Canyon Dam will continue unchanged under the proposed action (e.g., Section 3 of the Glen Canyon Operating Criteria at 62 FR 9448, March 3, 1997). The emergency exception criteria allow for the proposed action to be altered temporarily in order to respond to an emergency (e.g., flooding, search and rescue operation, transmission power emergencies). When the emergency exception criteria are invoked, normal operations are suspended until the emergency has ended, or Western has discharged its North American Energy Reliability Council (NERC) responsibility regarding the emergency. Emergency exception criteria are further defined in the operating criteria and in the Memorandum of Understanding (MOU) on Glen Canyon operations signed by Western and Reclamation.

Experimental Elements of LTEMP

The proposed action identifies condition-dependent flow and non-flow actions intended to safeguard against unforeseen adverse changes in resource impacts, and to prevent irreversible changes to those resources. These condition-dependent treatments would be implemented experimentally during the LTEMP period unless they prove ineffective or result in unacceptable adverse impacts on other resources. Prior to implementation of any experiment, the relative effects of the experiment on the following resource areas would be evaluated and considered: (1) water quality and water delivery; (2) humpback chub; (3) sediment; (4) riparian ecosystems; (5) historic and traditional cultural properties; (6) tribal concerns; (7) hydropower production and Western's assessment of the status of the Basin Fund; (8) the rainbow trout (*Oncorhynchus mykiss*) fishery; (9) recreation; and, (10) other resources. Although these key resources are listed for consideration on a regular basis, the DOI intends to retain sufficient flexibility in implementation of experiments to allow for response to unforeseen circumstances or events that involve any other resources not listed here. For example, the 2015 and 2016 discovery of nonnative green sunfish (*Lepomis cyanellus*) reproducing in a slough in the Glen Canyon reach of the project area illustrates the need to be responsive to unforeseen conditions.

The implementation criteria and triggers for experimental flow actions under the proposed action are detailed in Table 3 of the BA (pages 20-23). Triggers for experimental changes in operations, implementation considerations for determining if an experimental treatment should proceed, conditions that would cause the treatment to be terminated prior to completion (i.e., off-ramps), and the number of replicates that are initially considered needed are discussed in Table 3. In many cases, two to three replicates of an experimental treatment would be necessary in order to understand the effects of the action on target and non-target resources. The results of these tests would be used to determine if these condition-dependent treatments should be retained as part of the suite of long-term actions implemented under LTEMP. In other cases, implementation of experimental treatments would continue throughout the LTEMP period if triggered (e.g., spring and fall HFEs), except in years when it was determined that the proposed experiment could result in unacceptable adverse impacts on resource conditions. For these conservation experiments, effectiveness would be monitored and the experiments would be terminated or modified only if sufficient evidence suggested the treatment was ineffective or had unacceptable adverse impacts on other resources. "Sufficient evidence" would be defined through data analysis and discussion through the formal stakeholder process defined in the FEIS. All experimental treatments would be closely monitored for adverse effects to important resources. At a minimum, an unacceptable adverse impact would include significant negative impacts on resources as a result of experimental treatments that have not been analyzed for the proposed action in the LTEMP FEIS. DOI would exercise a formal process of stakeholder engagement to ensure decisions are made with sufficient information regarding the condition and potential effects on important resources (see BA, pages 19 and 24, for a complete description of the process).

Experimental treatments are grouped under three categories: (1) Sediment-Related Experimental Treatments; (2) Aquatic Resource-Related Experimental Treatments; and, (3) Native and Non-native Plant Management and Experimental Actions. The specific types of experimental treatments included under each category are described below.

1. <u>Sediment-Related Experimental Treatments</u> (BA, pages 24-30): Spring and fall HFEs would be implemented when triggered, based on the estimated sand mass balance resulting from Paria River sediment inputs during the spring and fall accounting periods, to rebuild sandbars. These HFEs include sediment-triggered HFEs in spring or fall, proactive spring HFEs as triggered by high annual release volume (> 10 maf), and extended duration (>96 hr) fall HFEs.

2. <u>Aquatic Resource-Related Experimental Treatments</u> (BA, pages 30-41): Nonnative fish control actions would be implemented if the Little Colorado River humpback chub population declined and proactive conservation actions failed to reverse declining populations.
    a. Mechanical removal of nonnative species is a controversial issue in the Colorado River through Glen and Grand Canyons. A spring 2015 meeting of Grand

Canyon biologists (NPS, FWS, AGFD, GCMRC) to assess current trout removal triggers resulted in a concept of early conservation measure intervention to maximize conservation benefit to humpback chub and minimize the likelihood of mechanical predator removal. Under the preferred alternative, mechanical removal of nonnative rainbow and brown trout (and other nonnative predators) would be implemented through a triggered, tiered approach (see Appendix D in BA) near the confluence of the Little Colorado River and the Colorado River if conservation actions designed to reverse declines in the Little Colorado River humpback chub aggregation were ineffective. Two different tiers of population metrics would be used to trigger responses such as actions to increase growth and survival of humpback chub (Conservation Actions, Tier 1), or mechanical nonnative fish control (Tier 2), which would only be implemented when Tier 1 conservation actions (actions would focus on increasing growth, survival and distribution of chub in the Little Colorado River and LCR mainstem aggregation area) fail to slow or reverse the decline in the humpback chub population (see Appendix D in BA, Young et al. 2015). In addition, if humpback chub decline and the identified actions are not working, the FWS, in coordination with action agencies and traditionally associated Tribes, will identify future appropriate actions (among other caveats specified in Young et al. 2015).

b. Experimental Trout Management Flows (TMFs) could be used to control annual rainbow trout production in the Glen Canyon reach for the purposes of managing the rainbow trout fishery and for limiting emigration to Marble Canyon and the Little Colorado River reach. TMFs would be tested early in the experimental period, preferably in the first 5 years.

c. Low summer flows may be tested in the second 10 years of the LTEMP period, for the purpose of achieving warmer river temperatures (> 14°C) to benefit humpback chub and other native species. Under low summer flows, daily fluctuations would be less than under base operations (e.g., approximately 2,000 cfs). Investigating the anticipated effects of and options for providing warmer water temperatures in the mainstem Colorado River through Grand Canyon is an identified management action in the Humpback Chub Recovery Goals (USFWS 2002a).

d. Low steady weekend flows ("bug flows") would be conducted to test whether the flows would increase insect abundance. On an experimental basis, for example, flows would be held low and steady for two days per week (weekends) from May through August to attempt to improve the productivity of the aquatic food base, and increase the diversity and abundance of mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera), which are collectively referred to as EPT.

3. Native and Nonnative Plant Management and Experimental Treatments (BA, pages 41-42): Experimental riparian vegetation treatment activities would be implemented by NPS under the proposed action and would modify the cover and distribution of riparian plant

communities along the Colorado River. All activities would be consistent with NPS Management Policies (NPS 2006) and would occur only within the Colorado River Ecosystem in areas that are influenced by dam operations. NPS would work with tribal partners and GCMRC to experimentally implement and evaluate a number of vegetation control and native replanting activities on the riparian vegetation within the Colorado River Ecosystem in GCNP and GCNRA. These activities would include ongoing monitoring and removal of selected nonnative plant species, systematic removal of nonnative vegetation at targeted sites, and native replanting at targeted sites, which may include complete removal of tamarisk (both live and dead) and re-vegetation with native plants. Treatments would include the control of nonnative plant species and re-vegetation with native plant species.

Conservation Measures

Conservation measures identified in the 2011 BO on operations of Glen Canyon Dam (USFWS 2011a) included the establishment of a humpback chub refuge, evaluation of the suitability of habitat in the lower Grand Canyon for the razorback sucker, and establishment of an augmentation program for the razorback sucker, if appropriate. Other measures include humpback chub translocation; Bright Angel Creek brown trout (*Salmo trutta*) control; Kanab ambersnail monitoring; determination of the feasibility of flow options to control trout, including increasing daily down-ramp rates to strand or displace age-0 trout, and high flow followed by low flow to strand or displace age-0 trout; assessments of the effects of actions on humpback chub populations; sediment research to determine effects of equalization flows; and Asian tapeworm (*Bothriocephalus acheilognathi*) monitoring. Conservation measures that were not completed are ongoing and are included in the proposed action (e.g., brown trout control, humpback chub translocation, and sediment research to determine the effects of equalization flows), while new conservation measures or adjustments to the existing ones have been developed for the proposed action. These conservation measures are designed to minimize or reduce the effects of the proposed action or benefit or improve the status of listed species as part of the LTEMP and are listed below. The conservation measures were developed by FWS, Reclamation, NPS, and GCMRC. Further planning and compliance may be needed to implement components of the new conservation measures listed below. Decisions regarding the need for further planning and compliance would be made by Reclamation in consultation with the FWS and NPS.

<u>Humpback Chub</u>

Ongoing actions:

- Reclamation would continue to support the NPS, FWS, GCMRC, and GCDAMP in funding and implementing translocations of humpback chub into tributaries of the Colorado River in Marble and Grand Canyons, and in monitoring the results of these translocations, consistent with agencies' plans and guidance (e.g., NPS Comprehensive Fisheries Management Plan [CFMP], FWS Humpback Chub Genetics Management Plan and Translocation Framework, and GCMRC Triennial Work Plan). Translocations allow for opportunities to expand the area occupied by humpback chub and improve the overall status of the species. Specifically, the following would occur:

  - Humpback chub would be translocated from the lower reaches of the Little Colorado River to areas above Chute Falls in an effort to increase growth rates and survivorship.
  - Monitoring would be conducted annually, or as needed, depending on the data required, to determine survivability, population status, or genetic integrity of the Havasu Creek humpback chub population. Intermittent translocations of additional humpback chub in Havasu Creek would be conducted if the FWS and NPS determine it is necessary to maintain genetic integrity of the population.

- Reclamation would continue to fund a spring and fall population estimate annually, or at a different frequency as deemed appropriate in consultation with FWS, using a mark recapture based model for the Little Colorado River or the most appropriate model developed for the current collecting techniques and data. Monitoring the chub population allows us to determine its status (whether it is stable, increasing, or decreasing).

- Reclamation would continue to fund control or removal of nonnative fish in tributaries prior to chub translocations depending on the existing fish community in each tributary. Reclamation, NPS, and FWS would lead any investigation into the possibility of using a chemical piscicide, or other tools, as appropriate. Tributaries and the appropriate control methods would be identified by the FWS, NPS, Reclamation, and GCMRC, in consultation with the Arizona Game and Fish Department (AGFD). Depending on the removal methods identified, additional planning and compliance may be necessary. Removal of nonnative fishes improves the status of chub and other native fishes by reducing competition and predation. The regulation and control of nonnative fish is a management action identified in the Humpback Chub Recovery Goals (USFWS 2002a) and Razorback Sucker Recovery Goals (USFWS 2002b).

- Reclamation would continue to fund the FWS in maintenance of a humpback chub refuge population at a federal hatchery (Reclamation has assisted the FWS in creating a humpback chub refuge at the Southwestern Native Aquatic Resources and Recovery Center [SNARRC]) or other appropriate facility by providing funding to assist in annual maintenance (including the collection of additional humpback chub from the Little Colorado River for this purpose). In the unlikely event of a catastrophic loss of the Grand Canyon population of humpback chub, the refuge would provide a permanent source of sufficient numbers of genetically representative stock for repatriating the species.

- Reclamation would continue to assist the FWS, NPS and the GCDAMP to ensure that a stable or upward trend of humpback chub mainstem aggregations can be achieved by:
  - Continuing to conduct annual monitoring of the Little Colorado River humpback chub aggregation (e.g., juvenile chub monitoring parameters). Periodically, an open or multistate model should be run to estimate abundance of the entire Little Colorado River aggregation inclusive of mainstem fish.

- Supporting annual monitoring in the mainstem Colorado River to determine status and trends of humpback chub and continuing to investigate sampling and analytical methods to estimate abundance of chub in the mainstem.
- Conducting periodic surveys to identify additional aggregations and individual humpback chub.
- Evaluating existing aggregations and determining drivers of these aggregations, for example, recruitment, natal origins, spawning locations, and spawning habitat (e.g., consider new and innovative methods such as telemetry or the Judas-fish approach) (Kegerries et al. 2015).
- Exploring means of expanding humpback chub populations outside of the Little Colorado River Inflow aggregation. Evaluate the feasibility of mainstem augmentation of humpback chub that would include larval collection, rearing, and release into the mainstem at suitable areas outside of or within existing aggregations.

- Reclamation would, through the GCDAMP, conduct disease and parasite monitoring in humpback chub and other fishes in the mainstem Colorado. The GCMRC is currently conducting parasite monitoring in the Little Colorado River. However, in order to better understand how/if disease and parasites (primarily Asian tapeworm) are affecting chub and how temperature differences may affect parasite occurrence, this work would be expanded to include investigations of parasites in humpback chub (and surrogate fish if necessary) in the mainstem. Ensuring adequate protection from diseases and parasites is an identified management action needed in the Humpback Chub Recovery Goals (USFWS 2002a) and Razorback Sucker Recovery Goals (USFWS 2002b).

New actions:

- Reclamation would collaborate with the FWS, GCMRC, NPS, and the Havasupai Tribe to conduct preliminary surveys and a feasibility study for translocation of humpback chub into Upper Havasu Creek (above Beaver Falls). The implementation of surveys and translocations, following the feasibility study, would be dependent on interagency discussions, planning and compliance, and resulting outcomes of tribal consultation. As stated above, translocations of chub into currently unoccupied habitat aid in expanding the area occupied by the species. In addition, using a tributary to the Colorado River, such as Upper Havasu Creek, protects translocated fish from the effects of dam operations in the mainstem, but still allow for chub in Havasu Creek to contribute to the mainstem population.

- Reclamation would, in cooperation with the FWS, NPS, GCMRC, and AGFD, explore and evaluate other tributaries for potential translocations.

<u>Razorback Sucker</u>

Ongoing actions:

- Reclamation would continue to assist the NPS, FWS, and the GCDAMP in funding larval and small-bodied fish monitoring in order to:
    - Determine the extent of hybridization in flannelmouth and razorback sucker collected in the western Grand Canyon.
    - Determine habitat use and distribution of different life stages of razorback sucker to assist in future management of flows that may help conserve the species. Sensitive habitats to flow fluctuations could be identified and prioritized for monitoring.
    - Assess the effects of TMFs and other dam operations on razorback sucker.

<u>Actions to benefit all native aquatic species</u>

Ongoing actions:

- Reclamation, in collaboration with the NPS and FWS, and in consultation with the AZGFD, would investigate the possibility of renovating Bright Angel and Shinumo Creeks with a chemical piscicide, or other tools, as appropriate. Additional planning and compliance, and tribal consultation under Section 106 of the NHPA, would be required. This feasibility study is outlined in the NPS CFMP (2013; see "Feasibility Study for Use of Chemical Fish Control Methods"). The action benefits humpback chub and other native fish by removing nonnative fish that can predate upon and compete with humpback chub. The regulation and control of nonnative fish is a management action identified in the Humpback Chub Recovery Goals (USFWS 2002a) and Razorback Sucker Recovery Goals (USFWS 2002b).

- Reclamation would continue to fund efforts of the GCMRC and NPS to remove brown trout (and other nonnative species) from Bright Angel Creek and the Bright Angel Creek Inflow reach of the Colorado River, and from other areas where new or expanded spawning populations develop, consistent with the NPS CFMP. After 5 years of removal efforts are completed (in 2017), an analysis of success would be conducted. Piscicides may be considered for removal of nonnative species if determined to be appropriate and following completion of the necessary planning and compliance actions. The regulation and control of nonnative fish is a management action identified in the Humpback Chub Recovery Goals (USFWS 2002a) and Razorback Sucker Recovery Goals (USFWS 2002b).

New actions:

- Reclamation would explore the efficacy of a temperature control device at the dam to respond to potential extremes in hydrological conditions due to climate conditions that could result in nonnative fish establishment. Evaluations would be ongoing for all current and evolving technological advances that could provide for warming and cooling the river in both high- and low-flow discharge scenarios, and high and low reservoir levels. These studies should include evaluating and pursuing new technologies, an analysis of the feasibility, and a risk assessment and cost analysis for any potential solutions. The regulation and control of nonnative fish is a management action identified in the Humpback Chub Recovery Goals (USFWS 2002a) and Razorback Sucker Recovery Goals (USFWS 2002b).

- Reclamation would pursue means of preventing the passage of deleterious invasive nonnative fish through Glen Canyon Dam. Because Glen Canyon Dam release temperatures are expected to be warmer under low reservoir elevations that may occur through the LTEMP period, options to hinder expansion of warmwater nonnative fishes into Glen and Grand Canyons would be evaluated. Potential options to minimize or eliminate passage through the turbine or bypass intakes, or minimize survival of nonnative fish that pass through the dam would be assessed (flows, provide cold water, other). While feasible options may not currently exist, technology may be developed during the LTEMP period that could help achieve this goal. The regulation and control of nonnative fish is a management action identified in the Humpback Chub Recovery Goals (USFWS 2002a) and Razorback Sucker Recovery Goals (USFWS 2002b).

- Reclamation would, in consultation with the FWS and AGFD, fund the NPS and GCMRC on the completion of planning and compliance to alter the backwater slough at River Mile (RM) 12 (commonly referred to as "Upper Slough"), making it unsuitable or inaccessible to warmwater nonnative species that can compete with and predate upon native fish, including humpback chub. Depending on the outcome of NPS planning and compliance, Reclamation would implement the plan in coordination with the FWS, AGFD, NPS and GCMRC. Additional coordination would be conducted to determine and access any habitats that may support warmwater nonnatives. The regulation and control of nonnative fish is a management action identified in the Humpback Chub Recovery Goals (USFWS 2002a) and Razorback Sucker Recovery Goals (USFWS 2002b).

- Reclamation would support the GCMRC and NPS in consultation with the FWS and AGFD on the completion of planning and compliance of a plan for implementing rapid response control efforts for newly establishing or existing deleterious invasive nonnative species within and contiguous to the action area. Control efforts may include chemical, mechanical, or physical methods. While feasible options may not currently exist, new technology or innovative methods may be developed in the LTEMP period that could help achieve this goal. Rapid response to new warmwater fish invasions may become a more frequent need in the future with lower reservoir elevations and warmer dam releases. The regulation and control of nonnative fish is a management action identified in the Humpback Chub Recovery Goals (USFWS 2002a) and Razorback Sucker Recovery Goals (USFWS 2002b).

- Reclamation, will consider, in consultation with the GCDAMP, the experimental use of TMFs to inhibit brown trout spawning and recruitment in Glen Canyon, or other mainstem locations. Inhibiting brown trout spawning and recruitment will benefit chub by reducing the potential for brown trout to predate upon humpback chub. The regulation and control of nonnative fish is a management action identified in the Humpback Chub Recovery Goals (USFWS 2002a) and Razorback Sucker Recovery Goals (USFWS 2002b).

Southwestern willow flycatcher and Yuma Ridgway's rail

- Reclamation would partially assist in funding NPS to conduct Yuma Ridgway's rail surveys once every three years for the life of the LTEMP.

- Reclamation would partially assist in funding NPS to conduct southwestern willow-flycatcher surveys once every two years for the life of the LTEMP.

ANALYTICAL FRAMEWORK FOR THE JEOPARDY AND ADVERSE MODIFICATION DETERMINATIONS

Jeopardy Determination

In accordance with policy and regulation, the jeopardy analysis in this BO relies on four components: (1) the *Status of the Species*, which evaluates the humpback chub, razorback sucker, and Kanab ambersnail range-wide conditions, the factors responsible for these conditions, and their survival and recovery needs; (2) the *Environmental Baseline*, which evaluates the condition of these species in the action area, the factors responsible for their condition, and the relationship of the action area to the survival and recovery of these species; (3) the *Effects of the Action*, which determines the direct and indirect impacts of the proposed Federal action and the effects of any interrelated or interdependent activities on these species; and (4) *Cumulative Effects*, which evaluates the effects of future, non-Federal activities in the action area on these species.

In accordance with policy and regulation, the jeopardy determination is made by evaluating the effects of the proposed Federal action in the context of the species' current status, taking into account any cumulative effects, to determine if implementation of the proposed action is likely to cause an appreciable reduction in the likelihood of either the survival and recovery of the species in the wild. The jeopardy analysis in this BO considers the range-wide survival and recovery needs of the species and the role of the action area in its survival and recovery as the context for evaluating the significance of the effects of the proposed Federal action, taken together with cumulative effects, for purposes of making the jeopardy determination.

Adverse Modification Determination

This BO relies on the regulatory definition of "destruction or adverse modification" of critical habitat at 50 CFR 402.02[8]. In accordance with policy and regulation, the adverse modification analysis in this Biological Opinion relies on four components: 1) the *Status of Critical Habitat*, which evaluates the range-wide condition of designated critical habitat for the humpback chub and razorback sucker in terms of physical and biological features[9], the factors responsible for that

[8] See 81 FR 7214.

[9] The term "primary constituent elements" was introduced in critical habitat designation regulations (50 CFR 424.12) to describe aspects of "physical or biological features", which are referenced in the statutory definition of critical habitat. The Services have removed the term "primary constituent elements" and returned to using the statutory term "physical or biological features" (81 FR 7414). Existing critical habitat designations will not be republished to reflect this change; however, in future rules we will discontinue using the term "primary constituent elements" and instead will use "physical and biological features".

condition, and the intended value of the critical habitat for survival and recovery of these species; 2) the *Environmental Baseline*, which evaluates the condition of the critical habitat in the action area, the factors responsible for that condition, and the value of the critical habitat for survival and recovery of the species in the action area; 3) the *Effects of the Action*, which determines the direct and indirect impacts of the proposed Federal action and the effects of any interrelated or interdependent activities on the physical and biological features and how that will influence the value of affected critical habitat units for survival and recovery of these species; and 4) the *Cumulative Effects*, which evaluates the effects of future, non-Federal activities in the action area on the physical and biological features and how that will influence the value of affected critical habitat units for survival and recovery of these species.

For purposes of the adverse modification determination, the effects of the proposed Federal action on the species' critical habitat are evaluated in the context of the range-wide condition of the critical habitat, taking into account any cumulative effects, to determine if the critical habitat range-wide would remain functional (or would not preclude or significantly delay the current ability for the physical and biological features to be functionally established in areas of currently unsuitable but capable habitat) such that the value of critical habitat for the conservation of the species is not appreciably diminished.

STATUS OF THE SPECIES AND CRITICAL HABITAT

The information in this section summarizes the rangewide status of each species that is considered in this BO. Further information on the status of these species can be found in the administrative record for this project, documents on our web page (https://www.fws.gov/southwest/es/arizona/) under Document Library, Document by Species, and in other references cited in each summary below.

Humpback chub and critical habitat

The humpback chub, an endemic fish to the Colorado River Basin of the southwestern United States, was listed as endangered on March 11, 1967 (32 FR 4001) and the FWS designated critical habitat in 1994 (USFWS 1994). The first recovery plan for the humpback chub was approved in 1979 (USFWS 1979), the plan was revised in 1990 (USFWS 1990). Recovery Goals that amended and supplemented the 1990 revised plan were approved in 2002 (USFWS 2002a), but were withdrawn and declared of no force and effect by court order on January 18, 2006 (Grand Canyon Trust et al., vs. Gale Norton et al., United States District Court for the District of Arizona, Order No. 04-CV-636-PHX-FJM).

The humpback chub is native to the states of Wyoming, Colorado, Utah, and Arizona and there are six recognized populations that occur in mid- and low-elevation, canyon-confined, deep-water regions, including five in the upper basin and one in the lower basin (Lees Ferry is the demarcation line between upper and lower Colorado River basins). The upper basin populations occur in (1) the Colorado River in Cataract Canyon, Utah; (2) the Colorado River in Black Rocks, Colorado; (3) the Colorado River in Westwater Canyon, Utah; (4) the Green River in Desolation and Gray Canyons, Utah; and (5) the Yampa River in Yampa Canyon, Colorado. The only population in the lower basin occurs in the Colorado River in Marble Canyon, the Grand

Canyon, and Little Colorado River. The five upper basin populations occupy from 1.4 to 113 km (0.9 to 70 mi) of river with a current abundance of about 500 to 1,600 adult chub. The lower basin population, the Grand Canyon and Little Colorado population of chub, consists of about 12,000 adults in the Little Colorado River and six mainstem aggregations of about 250 adults that occupy about 290 km (180 mi) of the Colorado River in Grand Canyon.

Historically, the humpback chub occurred throughout much of the Colorado River and its larger tributaries from below Hoover Dam upstream into Arizona, Utah, Colorado, and Wyoming (USFWS 2002a). Historic range and abundance levels are unknown. In 1994, the FWS estimated that historical range may have included 2,179 km (1,354 mi) of river (USFWS 1994), but estimates in 2002 and 2011 have been modified to include only canyon-bound reaches of this previously estimated area, estimating an historic range of approximately 756 km (~470 mi) (USFWS 2002a, 2011a). Regardless of the actual historic range, the chub is currently restricted to six population centers that encompass approximately 537 km (334 mi) of river, with only the lower basin population (the population that occurs from Glen Canyon Dam downstream through western Grand Canyon) consisting of a widespread and relatively stable population. The FWS is currently developing a Species Status Assessment (SSA) and revising the recovery plan for the humpback chub, but these documents, which will include a rangewide assessment of species viability, are not completed and are still under review (K. Young 2016, pers. comm.).

The humpback chub is a large, long-lived species endemic to the Colorado River system. This member of the minnow family may attain a length of 20 inches, weigh 2 pounds or more, and live for 20 to 40 years (Andersen 2009). The humpback chub evolved in seasonally warm and turbid water and is highly adapted to the unpredictable hydrologic conditions. Adult humpback chub occupy swift, deep, canyon reaches, but also use eddies and sheltered shoreline habitat (Valdez and Clemmer 1982, Valdez et al. 1990, Valdez and Ryel 1995). Spawning occurs on the descending limb of the spring hydrograph at water temperatures typically between 16 and 22°C. Young require low-velocity shoreline habitats, including eddies and backwaters.

The main spawning area for the humpback chub within the Grand Canyon is the Little Colorado River, which provides warm temperatures suitable for spawning and shallow low-velocity pools for larvae (Gorman 1994). The species spawns primarily in the lower 13.6 km of the Little Colorado River, but spawning likely occurs in other areas of the Colorado River as well (Valdez and Masslich 1999, Anderson et al. 2010). Gorman and Stone (1999) found ripe adults aggregated in areas of complex habitat structure associated with clean gravel deposits among large boulders mixed with travertine masses in or near runs and eddies. Mainstem spawning is suspected near 30 Mile Spring, or in other areas in the western Grand Canyon following the detection of larval humpback chub in recent years (Albrecht et al. 2014, Kegerries et al. 2015).

Young humpback chub seek areas that provide physical cover and contain some low velocity refuges, including shoreline talus, vegetation, and backwaters typically formed by eddy return current channels (AGFD 1996, Converse et al. 1998, Dodrill et al. 2015). Backwaters can have warmer water temperatures than other habitats, and native fish, including the humpback chub, are frequently observed in backwaters, leading to a common perception that this habitat is critical for juvenile native fish conservation. However, backwaters are rare and ephemeral habitats, so they contain only a small portion of the overall population. Dodrill et al. (2015) showed the total abundance of juvenile humpback chub was much higher in talus than in backwater habitats, which could be a factor of availability of talus habitats versus backwaters. The Near Shore Ecology project concluded that backwaters are likely not important to the Little Colorado River chub aggregation because they are not a significant habitat component in that area (Pine 2011).

As young humpback chub grow, they shift toward deeper and swifter offshore habitats. Valdez and Ryel (1995, 1997) found that young humpback chub remain along shallow shoreline habitats throughout their first summer, at low water velocities and depths less than 1 m (3.3 ft). They shift as they grow larger and by fall and winter move into deeper habitat with higher water velocities and depths up to 1.5 m (4.9 ft). Stone and Gorman (2006) found similar results in the Little Colorado River discovering that as humpback chub physically develop their behavior changes from diurnally active, vulnerable, nearshore-reliant, to nocturnally active, large-bodied adults, which primarily reside in deep mid-channel pools during the day and move inshore at night.

The humpback chub is primarily an insectivore, with larvae, juveniles, and adults all feeding on a variety of aquatic insect larvae and adults, including dipterans (primarily chironomids and simuliids), Thysanoptera (thrips), Hymenoptera (ants, wasps, bees), and amphipods (such as *Gammarus lacustris*) (AGFD 2001). Donner (2011) found that 65% of humpback chub production in the Grand Canyon was attributed to chironomids and simuliids, and that the potential for competition between humpback chub and nonnative fish was high when nonnative fish abundance was high. Feeding by all life stages may occur throughout the water column as well as at the water surface and on the river bottom. Spurgeon et al. (2015) also found that humpback chub consumed and assimilated native fish, and that they occupied a high trophic position in the food web in a Grand Canyon tributary, similar to rainbow trout.

Primary threats to the species include streamflow regulation and habitat modification (including coldwater dam releases and habitat loss), competition with and predation by nonnative fish species, parasitism, hybridization with other native *Gila*, and pesticides and pollutants (USFWS 1990, 2002a). Upper basin habitat, including channel geomorphology and water temperature have not changed appreciably, but spring peak flow has been reduced and summer and winter base flows have increased. Habitat in the Grand Canyon has been modified by the presence and operation of Glen Canyon Dam, including altered flow and temperature regimes and sediment budget. Predation and competition by nonnative fishes is likely the greatest threat to both upper basin and lower basin populations.

Recovery for the humpback chub is defined by the FWS Humpback Chub Recovery Goals (Recovery Goals) (USFWS 2002a). The Recovery Goals consist of actions to improve habitat and minimize threats. The success of those actions is measured by the status and trend (i.e., the demographic criteria) of the population. In 2006, a U.S. District Court ruling set aside the Recovery Goals, because they lacked time and cost estimates for recovery. The court did not fault the recovery goals as deficient in any other respect, thus the FWS, the GCDAMP, and the Upper Colorado River Endangered Fish Recovery Program (UCRRP), the program that addresses conservation of all of the upper Colorado River basin populations of humpback chub, continue to utilize the underlying science in the Recovery Goals. A 5-Year Review conducted in 2011, relied on the information provided in the recovery goals and provides supplemental information on the species' distribution and status (USFWS 2011b). A change in the status of the humpback chub was not recommended in the 5-Year Review because five of six demographic recovery criteria and four of 22 downlisting criteria had not been met. However, this is mostly due to status of humpback chub in the Upper Basin Recovery Unit; the humpback chub in the Lower Basin Recovery Unit (the population under consultation in this BO that occurs in the mainstem Colorado River in Marble and Grand Canyons and the Little Colorado River) partially met recovery criteria 1a and 1b, and has met criteria 1c (USFWS 2011b)/

Critical Habitat

Critical habitat for humpback chub was designated in 1994 in seven reaches for a total of 610 kilometers (km) (379 miles [mi]) (USFWS 1994). There are 319 km (198 mi) of critical habitat in the upper basin (Colorado and Utah) and 291 km (181 mi) in the lower basin (Arizona). In Arizona, critical habitat includes 278 km (173 mi) of the Colorado River through Marble and Grand Canyons (Reach 7) from Nautiloid Canyon (RM 34) to Granite Park (RM 208), and the lower 13 km (8 mi) of the Little Colorado River (Reach 6). The entire Colorado River reach in Arizona and the bottom portion of the Little Colorado River are within the action area for LTEMP.

Critical habitat was designated for the four big river fishes (Colorado Pikeminnow [*Ptychocheilus lucius*], humpback chub, bonytail chub [*Gila elegans*], and razorback sucker) concurrently in 1994, and the primary constituent elements (PCEs) were defined for the four species as a group (USFWS 1994). However, the PCEs vary somewhat for each species on the ground, particularly with regard to physical habitat, because each of the four species has different habitat preferences. The PCEs are:

- Water: Consists of water of sufficient quality (i.e., temperature, dissolved oxygen, lack of contaminants, nutrients, turbidity, etc.) that is delivered in sufficient quantity to a specific location in accordance with a hydrologic regime that is required for the particular life stage for each species.

- Physical Habitat: This includes areas of the Colorado River system that are inhabited by fish or potentially habitable for use in spawning, nursery, feeding, or corridors between these areas. In addition to river channels, these areas include bottomlands, side channels, secondary channels, oxbows, backwaters, and other areas in the 100-year floodplain, which when inundated provide spawning, nursery, feeding, and rearing habitats, or access to these habitats.

- Biological Environment: Food supply, predation, and competition are important elements of the biological environment and are considered components of this constituent element. Food supply is a function of nutrient supply, productivity, and availability to each life stage of the humpback chub. Predation, although considered a normal component of this environment, is out of balance due to introduced fish species in some areas. This is also true of competition from nonnative fish species.

The PCEs are all integrally related and must be considered together. For example, the quality and quantity of water affect the food base directly because changes in water chemistry, turbidity, temperature, and flow volume all affect the type and quantity of organisms that can occur in the habitat that are available for food. Likewise, river flows and the river hydrograph have a significant effect on the types of physical habitat available. Changes in flows and sediment loads caused by dams may have affected the quality of nearshore habitats utilized as nursery areas for young humpback chub. Increasingly the most significant PCE seems to be the biological environment, and in particular predation and competition, from non-native species. Even in systems like the Yampa River, where the water and physical PCEs are relatively unaltered, non-native species have had a devastating effect on the ability of that critical habitat unit to support conservation (Finney 2006, Fuller 2009). It is likely that the future conservation of humpback chub may depend on our ability to control nonnative species, and manipulating the water and physical PCEs of critical habitat to disadvantage non-natives may play an important role. It is for this reason that Reclamation has agreed as part of LTEMP to explore the efficacy of a temperature control device at the dam to respond to potential extremes in hydrological conditions due to climate change that could result in warmwater nonnative fish establishment.

Previous Consultations

Section 7 consultations on humpback chub have evaluated large-scale water-management activities. For the upper basin, UCRRP tracks the effects of such consultations on the species and provides conservation measures to offset the effects. Several consultations have occurred on the operations of Glen Canyon Dam, including one in 1995 that resulted in a jeopardy and adverse modification opinion. Subsequent consultations in 2008, 2009, and 2010 reached non-jeopardy/non adverse modification conclusions. Finally, the consultation on Sport Fish Restoration Funding evaluated the USFWS sport fish stocking program in Arizona (USFWS 2011c). Biological opinions on actions potentially affecting humpback chub in Arizona may be found at our website https://www.fws.gov/southwest/es/arizona/ in the Section 7 Biological Opinion page of the Document Library.

Razorback sucker and critical habitat

The razorback sucker was listed as endangered in 1991 (USFWS 1991). The Razorback Sucker Recovery Plan was released in 1998 (USFWS 1998) and Recovery Goals were approved in 2002 (USFWS 2002b). Critical habitat for the fish was designated in 1994 (USFWS 1994).

The species is endemic to large rivers of the Colorado River Basin from Wyoming to Mexico; however, the species range has been substantially reduced (Marsh et al. 2015). The razorback sucker was once abundant in the Colorado River and its major tributaries throughout the basin, occupying 3,500 miles of river in the United States and Mexico (USFWS 2002b). Records from the late 1800s and early 1900s indicated the species was abundant in the lower Colorado and Gila River drainages (Kirsch 1889, Gilbert and Scofield 1898, Minckley 1983, Bestgen 1990). Within the Grand Canyon, it is likely that razorback suckers historically occurred throughout the Colorado River to Lake Mead (after Hoover Dam construction), with several documented captures in the mainstem (near Bright Angel and Shinumo Creeks), at the Little Colorado River inflow in 1989 and 1990, and from the Paria River mouth (in 1963 and 1978, as reported in NPS

2013). Until recently, the last razorback sucker collected from the Grand Canyon (RM 39.3) was caught in 1993, and the species was considered extirpated from the Grand Canyon. However, in the 2012 and 2013, adult razorback suckers were captured in western Grand Canyon (NPS 2013, GCMRC 2013). In addition, sampling of channel margin habitats has also documented razorback sucker larvae as far upstream as RM 173 (just upstream of Lava Falls) in 2014 (Albrecht et al. 2014) and 2015 (Kegerries et al. 2015), respectively, indicating that spawning is occurring in the mainstem river in the western Grand Canyon (Albrecht et al. 2014, Kegerries et al. 2015). This is the farthest upstream razorback sucker spawning has been documented in the Grand Canyon (Albrecht et al. 2014). The razorback sucker also occurs in the Green River, upper Colorado River, and San Juan River subbasins; the lower Colorado River between Lake Havasu and Davis Dam; Lake Mead and Lake Mohave; and tributaries of the Gila River subbasin (USFWS 2002b) and Lake Powell (Francis et al. 2015).

Razorback suckers are actively stocked into occupied habitats in the upper and lower basins to prevent extirpation of the species from the wild. The stocking efforts rely on the captive broodstocks in the basins, and the capture of wild-born larvae from Lake Mead and Lake Mohave to provide sub-adult fish for stocking programs. Most populations in the upper Colorado River Basin are maintained by stocking, and in the lower basin, with the exception of Lake Mead, razorback sucker are also maintained through stocking, including populations in Lakes Mohave and Havasu (Marsh et al. 2015). Recruitment has been occurring since the 1970s, sustaining the small population remaining in Lake Mead (Albrecht et al. 2010, USFWS 2012, Mohn et al. 2015); rangewide, however, recruitment is rare or nonexistent in other populations (Marsh et al. 2015).

The razorback sucker is a large river sucker (Catostomidae) with adults reaching lengths up to 3.3 feet and weigh 11 to 13 pounds (Minckley 1973). Razorback suckers are long-lived, reaching the age of at least the mid-40s (McCarthy and Minckley 1987). Adult razorback suckers use most of the available riverine habitats, although there may be an avoidance of whitewater type habitats. Main channel habitats used tend to be low velocity ones such as pools, eddies, nearshore runs, and channels associated with sand or gravel bars (Bestgen 1990). Adjacent to the main channel, backwaters, oxbows, sloughs, and flooded bottomlands are also used by this species. From studies conducted in the upper basin, habitat selection by adult razorback suckers changes seasonally. They move into pools and slow eddies from November through April, runs and pools from July through October, runs and backwaters during May, and backwaters, eddies, and flooded gravel pits during June. In early spring, adults move into flooded bottomlands. They use relatively shallow water (approximately three feet) during spring and deeper water (five to six feet) during winter (McAda and Wydoski 1980, Tyus and Karp 1989, Osmundson and Kaeding 1989).

Much of the information on spawning behavior and habitat comes from fishes in reservoirs where observations can readily be made. They typically spawn over mixed cobble and gravel bars on or adjacent to riffles or in shallow shorelines in reservoirs in water 3 to10 feet deep (Minckley et al. 1991). Spawning takes place in the late winter to early summer depending upon local water temperatures. Suitable water temperatures for spawning, egg incubation, and growth range from 14 to 25°C (USFWS 2002b), with estimated optimal temperatures of 18°C for spawning, 19°C for egg incubation, and 20°C for growth (Valdez and Speas 2007). Hatching success is temperature dependent, with the potential for complete mortality occurring at temperatures less than 10°C (USFWS 2002b).

Habitat needs of larval and juvenile razorback sucker are reasonably well known. Young razorback suckers require nursery areas with quiet, warm, shallow water such as tributary mouths, backwaters, and inundated floodplains along rivers, and coves or shorelines in reservoirs (USFWS 2002b). During higher flows, flooded bottomland and tributary mouths may provide these types of habitats.

Razorback suckers are somewhat sedentary; however, considerable movement over a year has been noted in several studies (USFWS 1998). Spawning migrations have been observed or inferred in several locales (Jordan 1891, Minckley 1973, Osmundson and Kaeding 1989, Bestgen 1990, Tyus and Karp 1990).

Razorback sucker diet varies depending on life stage, habitat, and food availability. Larvae feed mostly on phytoplankton and small zooplankton and, in riverine environments, on midge larvae. Diet of adults taken from riverine habitats consisted chiefly of immature mayflies, caddisflies, and midges, along with algae, detritus, and inorganic material (USFWS1998).

Since the arrival of Euro-Americans in the Southwest, the range and abundance of razorback sucker have been significantly decreased due to water manipulations, habitat degradation, and importation and invasion of nonnative species. Construction of dams, reservoirs, and diversions destroyed, altered, and fragmented habitats needed by the sucker. Channel modifications reduced habitat diversity, and degradation of riparian and upland areas altered stream morphology and hydrology. Finally, invasion of these degraded habitats by a host of nonnative predacious and competitive species has created a hostile environment for razorback sucker larvae and juveniles. Although the suckers can bring off large spawns each year and produce viable young, in many areas the larvae are largely eaten by nonnative fish species (Minckley et al. 1991). The range-wide trend for the razorback sucker is a continued decrease in wild populations due to a lack of sufficient recruitment due to predation by non-native species on the eggs and larvae and the loss of old adults due to natural mortality.

The UCRRP has implemented considerable research, habitat management, nonnative species removal, and stocking actions to benefit the razorback sucker in Colorado, Utah, and Wyoming. The San Juan Program works in the San Juan River in New Mexico and Utah. The Lower Colorado River Multi-Species Conservation Plan (LCR MSCP) is also engaged in research and stocking actions to benefit the razorback in the lower Colorado River of Arizona, California, and Nevada. The razorback sucker is also a covered species in the Bartlett-Horseshoe Habitat Conservation Plan (HCP) on the Verde River.

The 5-year status review for the razorback sucker was completed in 2012 (USFWS 2012). The recovery of the species is based on whether the reduction or removal of threats has occurred, and on whether improvement in the demographic criteria has been achieved. Based on the review, only one of the 10 demographic criteria had been met, two had been partially met, and seven criteria were unmet. In addition, the majority of the most meaningful threats to the species were not mitigated, as only nine of the 29 recovery factor criteria were met. As a result, the FWS determined that a change in the species' endangered status was not warranted (USFWS 2012).

Critical habitat

As stated above, critical habitat was designated for the four big river fishes (Colorado Pikeminnow, humpback chub, bonytail chub, and razorback sucker) concurrently in 1994, and the PCEs were defined for the four species as a group (USFWS 1994). However, the PCEs vary somewhat for each species on the ground, particularly with regard to physical habitat, because each of the four species has different habitat preferences. The biological support document (Maddux et al. 1993) discusses in depth how each designated reach met the PCEs. The PCEs for razorback sucker are:

- Water: This includes a quantity of water of sufficient quality (i.e., temperature, dissolved oxygen, lack of contaminations, nutrients, turbidity, etc.) that is delivered to a specific location in accordance with a hydrologic regime that is required for the particular life stage.

- Physical habitat: This includes areas of the Colorado River system that are inhabited by razorback suckers or potentially habitable for use in spawning, nursery, feeding, rearing, or corridors between these areas. In addition to river channels, these areas also include bottomlands, side channels, secondary channels, oxbows, backwaters, and other areas in the 100-year floodplain, which, when inundated, provide spawning, nursery, feeding, and rearing habitats.

- Biological environment: Food supply, predation, and competition are important elements of the biological environment and are considered components of this constituent element. Food supply is a function of nutrient supply, productivity, and availability to each life stage of the razorback sucker. Predation, although considered a normal component of this environment, may be out of balance due to introduced fish species in some areas. This may also be true of competition, particularly from non-native fish species.

Critical habitat was designated in 15 river reaches in the historical range of the razorback sucker and includes portions of the Colorado, Duchesne, Green, Gunnison, San Juan, White, and Yampa rivers in the upper basin, and the Colorado, Gila, Salt, and Verde rivers in the lower basin (USFWS 1994).

Previous Consultations

Section 7 consultations on razorback sucker include programmatic efforts for the Upper Basin and San Juan recovery programs and Lower Colorado River Multi-Species Conservation Program for new water diversions or changes in points of diversion. Information on these programs is available at their websites. Biological opinions on actions potentially affecting razorback suckers in Arizona may be found at our website https://www.fws.gov/southwest/es/arizona/ in the Section 7 Biological Opinion page of the Document Library.

Kanab ambersnail

The Kanab ambersnail was listed as endangered in 1992 (USFWS 1992) with a recovery plan completed in 1995 (USFWS 1995). No critical habitat is designated for this species. The 5-year status review for the Kanab ambersnail was completed in 2011 (USFWS 2011d). The FWS found that no change in the status of the species was warranted due to the ongoing, existing threats due to private land development, controlled flooding in the Colorado River, climate change, and inadequate existing regulatory mechanisms. However, Arizona and Utah ambersnail populations identified as "Kanab ambersnail" and "Niobrara ambersnail" are based primarily on morphological distinctions. Recent genetic analysis and morphological evaluation by Culver et al. (2013) on ambersnail specimens suggests that the Arizona and Utah populations, including Vasey's Paradise, are genetically and morphologically similar to other *Oxyloma* populations in the study, and their taxonomic identity may be revised in the future. The consensus appears to be that this snail is part of a much larger population that has higher numbers and distribution. The FWS did recognize that genetic, anatomical, and morphological information resulted in conflicting views on the taxonomy of the species.

The species occurs in Utah and at two populations in Grand Canyon National Park: one at Vasey's Paradise, a spring and hanging garden at the right bank at RM 31.8, and a translocated population at Upper Elves Chasm, at the left bank at RM 116.6 (Gloss et al. 2005). The Elves Chasm population is located above an elevation that could be inundated by HFEs of up to 45,000 cfs. Intensive searches at more than 150 springs and seeps in tributaries to the Colorado River between 1991 through 2000 found no additional Kanab ambersnail (Sorensen and Kubly 1997, Meretsky and Wegner 1999, Meretsky et al. 2000, Webb and Fridell 2000). Stevens et al. (1997) defined primary habitat at Vasey's Paradise as crimson monkey-flower (*Mimulus cardinalis*) and non-native watercress (*Nasturtium officinale*), and secondary, or marginal, habitat as patches of other species of riparian vegetation that are little or not used by Kanab ambersnail.

The Kanab ambersnail lives approximately 12–15 months and is hermaphroditic and capable of self-fertilization (Pilsbry 1948). Mature Kanab ambersnail mate and reproduce in May–August (Stevens et al. 1997, Nelson and Sorensen 2001). Fully mature snail shells are translucent amber with an elongated first whorl, and measure about 23 mm (0.9 inches) in shell size. Adult mortality increases in late summer and autumn leaving the overwintering population dominated by subadults. Young snails enter dormancy in October–November and typically become active again in March–April. Over-winter mortality of Kanab ambersnail can range between 25 and 80 percent (USFWS 2011d, Stevens et al. 1997). Populations fluctuate widely throughout the year due to variation in reproduction, survival, and recruitment (Stevens et al. 1997). Current climate change science predicts decreases in precipitation and water resources in areas occupied by Kanab ambersnail. Because Kanab ambersnail populations are restricted to small wet vegetated habitat areas, we consider climate change and associated reduction in water resources a threat to Kanab ambersnail (USFWS 2011d). Surveys conducted by AGFD have noted drying and reductions in habitat at Vasey's Paradise due to drought (Sorensen 2016, pers. comm.)

Previous Consultations

Section 7 consultations on Kanab ambersnail have occurred on the operations of Glen Canyon Dam in 2007, 2008, 2009, and 2011 and all reached non-jeopardy/non adverse modification conclusions. Biological opinions on actions potentially affecting Kanab ambersnail in Arizona may be found at our website https://www.fws.gov/southwest/es/arizona/ in the Section 7 Biological Opinion page of the Document Library.

ENVIRONMENTAL BASELINE

The environmental baseline includes past and present impacts of all Federal, State, or private actions in the action area, the anticipated impacts of all proposed Federal actions in the action area that have undergone formal or early section 7 consultation, and the impact of State and private actions which are contemporaneous with the consultation process. The environmental baseline defines the current status of the species and its habitat in the action area to provide a platform to assess the effects of the action now under consultation.

Description of the Action Area

The action area is defined as all areas to be affected directly or indirectly by the federal action and not merely the immediate area involved in the action (50 CFR § 402.02). In delineating the action area, we evaluated the farthest reaching physical, chemical, and biotic effects of the action on the environment.

The action area for this proposed federal action is the Colorado River corridor from Glen Canyon Dam in Coconino County, Arizona, downstream to the Colorado River Inflow in Lake Mead. The action area includes the area potentially affected by implementation of the LTEMP (normal and experimental operations of Glen Canyon Dam and non-flow actions). This area includes Lake Powell, Glen Canyon Dam, the river downstream to Lake Mead and the lower 0.25 mi of the Little Colorado River. More specifically, the scope primarily encompasses the Colorado River Ecosystem, which includes the Colorado River mainstream corridor and interacting resources in associated riparian and terrace zones, located primarily from the forebay of Glen Canyon Dam to the western boundary of Grand Canyon National Park. It includes the area where dam operations impact physical, biological, recreational, cultural, and other resources. Portions of Glen Canyon National Recreational Area, Grand Canyon National Park, and Lake Mead National Recreational Area are included within this area.

The Colorado River Ecosystem is complex and formed in a sediment-laden, seasonally flooded environment and virtually all of the resources are associated with or dependent upon water and sediment. The construction and operation of Glen Canyon Dam altered the natural dynamics of the Colorado River through the collection and storage of water for beneficial purposes in a process which traps sediment and associated nutrients that previously traveled down the Colorado River. The regulated releases from Glen Canyon Dam and Lake Powell have resulted in an altered aquatic and terrestrial ecosystem compared to that which existed before Glen Canyon Dam, and this environment is what defines the environmental baseline for this biological opinion.

The major function of Glen Canyon Dam (and Lake Powell) is water storage to support a multitude of uses. The amount of water and its pattern of release directly or indirectly affect the physical, biological, cultural, and recreational resources within the Colorado River Ecosystem and establish the environmental baseline in which the humpback chub, razorback sucker, and Kanab ambersnail inhabit. As described in the proposed action and FEIS, water releases from Glen Canyon Dam fluctuate on a daily and hourly basis to maximize the value of generated power by providing peaking power during high-demand periods. More power is produced by releasing more water through the dam's generators. Daily releases can range from 5,000 to 31,500 cfs, but actual daily fluctuations are constrained to less than this maximum range as a result of implementing the 1996 Record of Decision for the Operation of Glen Canyon Dam (Reclamation 1996). These constrained fluctuations result in a downstream "fluctuation zone" between low and high river stages (i.e., the water level associated with a given flow) that is inundated and exposed on a daily basis.

Glen Canyon Dam also affects downstream water temperature and clarity. Historically, the Colorado River and its larger tributaries were characterized by heavy sediment loads, variable water temperatures, large seasonal flow fluctuations, extreme turbulence, and a wide range of dissolved solids concentrations. The dam has altered these characteristics in the Colorado River between Glen Canyon Dam and Lake Mead. Before the dam, water temperature varied on a seasonal basis from highs around 27°C (80°F) to lows near freezing. Now, water released from Glen Canyon Dam averages 9°C (48°F) year round, although release temperatures vary depending on the water level in Lake Powell and other factors, and water temperature warms by about 1°C (1.8°F) for every 30 mi traveled downstream during warmer months of the year (Reclamation 1999). Lake Powell traps sediment that historically was transported downstream. The dam releases clear water, and the river becomes muddy when downstream tributaries contribute sediment, as during summer monsoon storms.

In summary, the regulated releases from Glen Canyon Dam and Lake Powell have resulted in an altered aquatic and terrestrial ecosystem compared to that which existed before Glen Canyon Dam. Cold, clear water releases from the dam support an important rainbow trout fishery in the Glen Canyon reach, while native fish, including the endangered humpback chub and razorback sucker, occur further downstream. Vegetation has become established closer to the river's edge due to the elimination of annual flood scouring, and has increasingly become dominated by nonnative plant species.

Humpback chub and critical habitat

A. Status of the species and critical habitat within the action area

The Colorado River/Little Colorado River population of humpback chub is the largest of the six population centers of the humpback chub (USFWS 2011b). Within the Grand Canyon, this species is most abundant in the vicinity of the confluence of the Colorado River and Little Colorado River (Kaeding and Zimmerman 1983, Douglas and Marsh 1996, Valdez and Ryel 1995). This population is specifically referred to as the Little Colorado River aggregation of humpback chub and includes those fish residing in the Little Colorado River and in the mainstem within proximity of a few miles to the Little Colorado River mouth. In addition, there are eight other areas (aggregation areas) where humpback chub are, or have been, regularly collected within the action area. These aggregation areas are located in the mainstem at 30 Mile, Lava Chuar-Hance, Bright Angel Creek inflow, Shinumo Creek inflow, Stephen Aisle, Middle Granite Gorge, Havasu Creek inflow, and Pumpkin Spring (Valdez and Ryel 1995, Ackerman 2008, Persons et al., *In review*). In addition, since 2009, translocations of humpback chub have been made by the FWS to upstream of Chute Falls in the Little Colorado River, and by the NPS, with assistance provided by Reclamation and FWS, to introduce juvenile fish into Shinumo and Havasu Creeks, with the goal of establishing additional spawning populations within the Grand Canyon (NPS 2013). Surveys conducted in 2013, 2014, and 2015 suggest that translocated humpback chub have successfully spawned in Havasu Creek (NPS 2013). Humpback chub occupy approximately the lower 5.6 km (3.5 mi) of Havasu Creek, from the mouth to Beaver Falls, which is a barrier to upstream movement of fish. The most recent humpback chub population estimate in Havasu Creek was approximately 280 individuals as of May 2015. While reproduction has been documented, the population has increased primarily as a result of continued translocations.

Sampling conducted between October 2013 and September 2014 in western Grand Canyon between Lava Falls (RM 180) and Pearce Ferry (RM 280) captured 144 juvenile humpback chub during sampling of the small-bodied fish community. In addition, 209 humpback chub larvae were collected during sampling of the larval fish community in randomly selected sites (Albrecht et al. 2014). Results were similar in larval and small-bodied fish sampling in 2015: 285 juvenile and 67 age-0 humpback chub were captured during small-bodied and larval fish sampling, respectively, from throughout the study area (Kegerries et al. 2015). These results suggest that young humpback chub are using widespread nursery and rearing habitats between RM 180 and RM 280 in the western Grand Canyon. This information indicates that humpback chub are reproducing and recruiting throughout the project area, which is an improvement in the environmental baseline for the species since our last BO on Glen Canyon Dam operations.

The Little Colorado River population (aggregation) of humpback chub is measured with closed and open population models. Closed models estimate the annual spring and the annual fall abundance of various size classes of chub within the Little Colorado River (Van Haverbeke et al. 2013, 2016). As such, the closed models do not account for chub that are not residing in the Little Colorado River during any particular year (i.e., there is always a portion of the Little Colorado River aggregation that is residing in the nearby mainstem each year). Initial closed mark-recapture population efforts in the Little Colorado River were conducted in the early 1990s (Douglas and Marsh 1996), after which there was a hiatus until they were resumed again in 2000 (Van Haverbeke et al. 2013, 2016). Results from both of these studies indicate that sometime in the mid- to late-1990s, humpback chub underwent a significant decline in the Little Colorado River. This was followed by a period of relatively low, but stable abundance between 2000 and 2006, and by a period (2007–2014) of significantly increased abundance levels (Van Haverbeke et al. 2013). The post-2006 increase in humpback chub ≥150 mm and ≥200 mm was visible during both spring and fall seasons, but it was more apparent during spring months. Spring 2015 monitoring showed significant decrease in abundance of humpback chub ≥150 mm and ≥200 mm compared to the previous several years. The cause of this decline is unknown, but there is evidence from sampling in the mainstem during 2015 that many chub may have simply remained or emigrated into the mainstem during 2015 (i.e., the portion of the Little Colorado River aggregation of chub residing in the nearby mainstem was higher than usual).

In summary, population estimates indicate that the number of adult humpback chub in the Grand Canyon has been increasing since 2000 or 2001 and has been relatively stable for about the last five years. A number of factors have been suggested as being responsible for the observed increases, including experimental water releases, rainbow and brown trout removal, and drought-induced warming (Andersen 2009, Coggins and Walters 2009). In addition, translocations of juvenile humpback chub to Shinumo and Havasu Creeks have resulted in increased numbers of adult humpback chub captured in the mainstem aggregations (Persons et al., *In review*). Translocations to tributaries have been shown to provide an adequate mechanism for rearing juvenile humpback chub that may later disperse to the Colorado River and augment aggregations (Spurgeon et al. 2015).

Critical habitat

Critical habitat for humpback chub in the action area includes a portion of Critical Habitat Reach 6, the Little Colorado River, and Critical Habitat Reach 7, the Colorado River in Marble and Grand Canyons. Reach 6 consists of the lowermost 8 miles (13 km) of the Little Colorado River to its mouth with the Colorado River; however, only about 0.25 mile of this reach is affected by mainstem flow. Reach 7, consists of a 173-mile (278-km) reach of the Colorado River in Marble and Grand Canyons from Nautiloid Canyon (RM 34) to Granite Park (RM 208).

The current condition of critical habitat in the Little Colorado River (Reach 6) is probably similar to historical conditions in many ways. All of the PCEs are provided for in this reach of humpback chub critical habitat, and this segment supports the majority of the Grand Canyon population, the largest of the humpback chub populations.

Critical habitat in Reach 7, in Marble and Grand canyons, has been altered significantly from historical conditions, primarily due to the construction and operation of Glen Canyon Dam (see discussion in USFWS 2011a). The flow of the Colorado River in Marble and Grand canyons has been modified by Glen Canyon Dam since 1964, and the dam and its operation is the primary factor in the function of PCEs in this reach. However, humpback chub use a variety of riverine habitats, with adults found in canyon areas with fast current, deep pools, and boulder habitat, and at least some of the PCEs are functional as demonstrated by the persistence of mainstem aggregations of humpback chub. Reach 7 provides an important role in support of the Grand Canyon population (the largest of the humpback chub populations) although the relationship with the Little Colorado River and the overall importance of habitats in the mainstem to recovery is not well known. This is because most of the humpback chub population occurs in the Little Colorado inflow aggregation, which utilizes the Little Colorado River to a large degree.

Dam discharge and river flow regimes can both destroy and build shoreline rearing habitat, thus affecting juvenile chub survival (Converse et al. 1998). Fluctuating flows can destabilize backwater habitats and may negatively impact aquatic macroinvertebrate production (Kennedy et al. 2016). However, dam releases, such as HFEs, can create shallow backwater habitats associated with sandbars and are thought to provide rearing habitat for native fish, because they may be warmer than the mainstem river water temperature during the summer months due to solar radiation (Behn et al. 2010, Dodrill et al. 2015). Although HFE water releases from Glen Canyon Dam between 2000 and 2008 may have improved some habitat characteristics (e.g., backwaters) for humpback chub, the limited availability of suitable warmwater temperatures in the mainstem may have constrained the potential for positive population responses (Kennedy and Ralston 2011). Additional factors affecting the PCEs of critical habitat are discussed below.

The PCEs, as described in the Status of the Species section, are: Water of sufficient quality (i.e., temperature, dissolved oxygen, lack of contaminants, nutrients, turbidity) that is delivered to a specific location in accordance with a hydrologic regime required for the particular life stage for each species; Physical Habitat, areas for use in spawning, nursery, feeding, and movement corridors between these areas; and Biological Environment, food supply, predation, and competition. In summary, the conditions of the PCEs in Reach 7 are:

- The physical PCE for spawning is present within critical habitat Reach 7. During the early 1990s, nine aggregations of humpback chub were described in Grand Canyon (Valdez and Ryel 1995). These comprised the aggregations at 30-Mile, Little Colorado River, Lava-Hance, Bright Angel, Shinumo, Stephen's Aisle, Middle Granite Gorge, Havasu, and Pumpkin Spring. Except for the Little Colorado River aggregation, population estimates for the additional aggregations were small, ranging from 5-98 adult humpback chub per aggregation, with no population estimation provided for some of the aggregations because of too few recaptured fish (Valdez and Ryel 1995). This trend of low catch in aggregations outside of the Little Colorado River aggregation continued during 2002-2006, although the pattern was reported as low relative abundance (catch per unit effort, CPUE) rather than absolute abundance (Ackerman 2008). Since 2010, annual sampling of the aggregations has again resumed. Major findings have been that relative abundances of adult humpback chub in the aggregations have increased since sampling events during the earlier time periods (Persons et al., *In review*). Additionally, a group of adult chub likely consisting of between 300-600 individuals has been found near 34-Mile in Marble Canyon (D. Van Haverbeke 2016, pers. comm.), and there appears to have been a dramatic increase in the absolute abundances of humpback chub in western Grand Canyon (roughly Havasu Creek downriver), with all size classes being represented. For example, while the number of adults estimated at the Pumpkin Springs aggregation (~RM 213) was only 5 adult fish during the early 1990s, 69 humpback chub were captured in this aggregation during a single day in 2016; 31 of these being adults. Finally, translocations of humpback chub into Shinumo and Havasu creeks have significantly augmented those respective mainstem aggregations.

- Nursery habitat for juvenile humpback chub may be limited by fluctuating flows that alternately flood and dewater mainstem near shore habitats important to early life stages of humpback chub and by the loss of sediment-formed habitats. Feeding areas are available to all life stages, especially for adult fish as indicated by condition factor of adult fish in the mainstem compared to those in the Little Colorado River (Hoffnagle et al. 2006), although feeding areas in the mainstem may be limiting for juvenile humpback chub due to the effect of fluctuations on nearshore habitats (AGFD 1996).

- Movement corridors appear to be adequate based on movements of humpback chub throughout the system (Valdez and Ryel 1995, Paukert et al. 2006).

- Food supply is a function of nutrient supply, productivity, and availability to each life stage of the humpback chub. River regulation by Glen Canyon dam decreases turbidity in the tailwaters (the water immediately downstream of a dam) and permits increased algae growth on bottom substrates (Angradi 1994, Shannon et al. 1994), leading to an increased expansion of macroinvertebrate populations in the tailwater reach of Glen Canyon Dam (Blinn et al. 1992, Stevens et al. 1997). Algae biomass and production decrease downstream as water clarity decreases (Carothers and Brown 1991, Stevens et al. 1997, Hall et al. 2010). This drives a downstream decrease in aquatic invertebrate biomass (e.g., midges, snails, and aquatic worms) (Carothers and Brown 1991, Stevens et al. 1997, Kennedy and Gloss 2005, Rosi-Marshall et al. 2010). Cold water temperatures and daily fluctuations in discharge associated with hydropower production are likely responsible for the low diversity and abundance of aquatic insects downstream of the Paria River (Stevens et al. 1997, Kennedy et al. 2016).

- Nonnative fish species that prey on and compete with humpback chub affect the PCEs of the biological environment aspect of critical habitat. Catfish (channel catfish and black bullhead), trout (rainbow and brown trout), and common carp are well established in the action area and will continue to function as predators or competitors of humpback chub. Minckley (1991) hypothesized that non-native fish predation and competition may be the single most important threat to native fishes in Grand Canyon (Valdez and Ryel 1995, Marsh and Douglas 1996, Coggins 2008, Yard et al. 2008). In 2015 and 2016 green sunfish established in a slough in the Lee's Ferry reach of Glen Canyon and brown trout appear to be increasing in this reach as well. The partner agencies (AGFD, FWS, NPS, Reclamation, and USGS) treated the slough with piscicides in 2015 and 2016 to remove the green sunfish, but it is likely invasions of nonnative, predatory fish will continue.

- The water quality and quantity PCEs in Reach 7 have been modified by Glen Canyon dam by altering water temperatures and flow regimes. However, since 1996, water releases from Glen Canyon Dam have been adaptively managed to improve water quality and quantity for humpback chub in the Colorado River through Grand Canyon (Reclamation 1996). These modified flows reduced daily fluctuations in river flow from peak power plant releases, and allowed for higher spring releases to restore some aspects of the natural hydrograph. These flow actions appear to be assisting with maintenance of this PCE, with the caveat that the requirements necessary for all life stages of humpback chub in the mainstem to support a recovered Grand Canyon population are still under investigation (USFWS 2011b).

B. Factors affecting species environment and critical habitat within the action area

Primary factors affecting humpback chub and critical habitat within the action area include habitat alterations associated with dams and reservoirs that have modified water temperature, and the introduction of nonnative fishes (USFWS 2011b), which act as competitors and/or predators of the humpback chub (Andersen 2009, Yard et al. 2011, Kennedy et al. 2013).

- Temperatures, particularly in the upper reaches of the action area, even in warmer years, are not optimal for humpback chub spawning and growth. The coldwater temperatures in most places of the main channel are below the temperature needed for spawning, egg incubation, and growth of the humpback chub. Survival of humpback chub young in the mainstem near the Little Colorado River is thought to be low because of cold mainstem water temperatures (Clarkson and Childs 2000, Robinson and Childs 2001), which may limit hatching success, reduce larval survival and larval and juvenile growth, reduce swimming ability, and increase predation vulnerability (Ward and Bonar 2003, Ward 2011). Water temperatures in the mainstem Colorado River have generally been warmer over the last decade, and warming over the summer increases downstream, due to solar radiation. These warmer water temperatures in the mainstem over the last decade may be providing some temporary benefit and contributing to the improving status of the humpback chub (Reclamation 2011a). For example, maximum daily temperatures exceeded 20°C (68°F) in the lower river (RM 180–RM 280), and daily average temperature was 18.3°C (65°F) in early July (Kegerries et al. 2015). There is some evidence of recruitment at the 30-mi aggregation possibly due to the presence of warm springs. Adult chub captured near RM 35 suggests the possibility of a new aggregation or expansion of the 30-mi aggregation, and during 2013 and 2014, three female humpback chub were captured near the 30-mi aggregation that expressed eggs.

- Predation by rainbow and brown trout at the Little Colorado River confluence has been identified as an additional mortality source affecting humpback chub survival, reproduction, and recruitment (Valdez and Ryel 1995, Marsh and Douglas 1997, Yard et al. 2011). The incidence of piscivory by brown trout has been found to be much higher than for rainbow trout in the Grand Canyon (Yard et al. 2011, Whiting et al. 2014), but rainbow trout are much more abundant in the Colorado River, and thus may impact native fish at a similar magnitude (Yard et al. 2011). Predation by channel catfish and black bullhead are also thought to impact humpback chub in the Grand Canyon, particularly if warmer water conditions occur (NPS 2013). Because of their size, adult humpback chub are less likely to be preyed on by trout; however, emergent fry, young-of-year (YOY), and juvenile humpback chub are susceptible to predation in the Little Colorado River and mainstem Colorado River (Yard et al. 2011).

In addition, the Colorado River now includes nonnative fish parasites, such as the Asian tapeworm and anchor worm, which may infect some humpback chub and affect survival (Clarkson et al. 1997, Andersen 2009). Recent studies also indicated that toxic mercury (Hg) and selenium (Se) concentrations in native fish were elevated in the Grand Canyon (Walters et al. 2015). While humpback chub were not tested in the study, elevated levels of Hg in the food web, and in particular, primary prey items, including blackfly larvae (Simuliidae), may result in negative impacts to humpback chub (Walters et al. 2015).

Razorback sucker and critical habitat

A. Status of the species and critical habitat within the action area

Within the Grand Canyon, it is likely that razorback sucker historically occurred throughout the Colorado River to Lake Mead (after Hoover Dam construction), with several documented captures in the mainstem (near Bright Angel and Shinumo Creeks), at the Little Colorado River inflow in 1989 and 1990, and from the Paria River mouth (in 1963 and 1978, as reported in NPS 2013). Until recently, the last razorback sucker collected from the Grand Canyon (RM 39.3) was caught in 1993, and the species was considered extirpated from the Grand Canyon.

Recent efforts to better understand the use of the western Grand Canyon by razorback sucker has revealed that the species is present, but likely rare, in Grand Canyon. Adult razorback suckers have recently been captured from the western Grand Canyon. Four fish that were sonic-tagged in Lake Mead in 2010 and 2011 were detected in the spring and summer of 2012 in GCNP up to Quartermaster Canyon (RM 260) (NPS 2013). An additional untagged adult razorback sucker was captured in GCNP near Spencer Creek (RM 246) in October 2012 (NPS 2013), and another adult was captured in late 2013 (GCMRC 2014). Sampling of channel margin habitats has also documented 462 and 81 razorback sucker larvae as far upstream as RM 173 (just upstream of Lava Falls) in 2014 (Albrecht et al. 2014) and 2015 (Kegerries et al. 2015), respectively, indicating that spawning is occurring in the mainstem river in the western Grand Canyon (Albrecht et al. 2014, Kegerries et al. 2015). This is the farthest upstream razorback sucker spawning has been documented in the Grand Canyon (Albrecht et al. 2014). Unfortunately, small-bodied fish sampling designed to detect juvenile razorback sucker in western Grand Canyon has failed to detect any older larval or juvenile fish. The capture of YOY suckers indicates that there is the potential for razorback sucker spawning in Lower Grand Canyon and in-river recruitment (Albrecht et al. 2014). However, based on the presence of larger, older sucker species (i.e., flannelmouth suckers [*Catostomus latipinnis*]) and the lack of predatory nonnative fish species in the lower river, it is possible that razorback suckers could (or do) recruit into the action area. There is also evidence that at the Colorado River inflow to Lake Mead, where six razorback suckers, seven razorback sucker-flannelmouth sucker hybrids, and 251 flannelmouth suckers were captured in 2014, hybridization is occurring between razorbacks and flannelmouth suckers. Although the extent and effect of this hybridization on razorback suckers in the lower Grand Canyon is unknown, it may be that with so many flannelmouth and so few razorback sucker adult fish apparently present (based on capture data), hybridization between the two species is common.

Tagged adult razorback suckers have also been located as far upstream as RM 184.4 near Lava Falls, and along with the collection of larvae, these indicate that the species utilizes the Colorado River above the Lake Mead inflow area more than previously thought (Albrecht et al. 2014). In 2015, submersible ultrasonic receivers (SURs), devices used to detect sonic-tagged razorback suckers, were installed upstream of Lava Falls, to an area below Bright Angel Creek. No detections of razorback sucker were recorded above Lava Falls through September 2015; however, the continued collection of larval fish upstream of Lava Falls indicates spawning is occurring in at least one unknown location in the mainstem or tributaries (Kegerries et al. 2015).

In summary, razorback sucker are located within the project area, from the Colorado River inflow of Lake Mead upstream, as far as an area above Lava Falls in Grand Canyon. The upstream distribution of adult razorback sucker is unknown, but they have been found upstream of Lava Falls. These occurrences since 2013 of adult and larval razorback sucker in Lake Mead and the lower Grand Canyon downstream of RM 180 indicate that the connectivity of the lake to the riverine reaches may be important to maintenance of razorback sucker in the action area.

Critical habitat

Critical habitat within the action area includes the Colorado River and its 100-year floodplain from the confluence of the Paria River downstream to Hoover Dam (a distance of about 500 mi), including Lake Mead to full pool elevation (USFWS 1994). Therefore, the entire Colorado River within the action area is razorback sucker critical habitat.

In the riverine portion of the reach (Paria River to Separation Canyon), the PCEs for water, physical habitat, and biological environment have been altered by creation of Glen Canyon Dam as described earlier for the humpback chub. The suitability of the physical habitat conditions for razorback sucker in this reach were likely significantly less even before closure of the dam as razorback suckers are generally not found in whitewater habitats that are home to humpback chub (Bestgen 1990).

Recent warming river temperatures due to lower Lake Powell elevations, attributed to drought and consumptive water use, may have resulted in more suitable habitat in the western Grand Canyon for razorback suckers. In 2015, river temperatures were within the acceptable range needed for razorback sucker spawning and successful hatching, particularly farther downstream (Kegerries et al. 2015). In addition, fish community composition in the lower river below Diamond Creek has changed dramatically from one dominated by nonnative species, to native species (Kegerries et al. 2015). However, the cause of the change in fish community composition is unknown. The drop in nonnative predator abundance, combined with periodically warmer water temperatures, may have allowed for the expansion of razorback sucker into the western Grand Canyon. Additional research and monitoring are needed to better understand the management implications of these habitat changes for recovery of razorback sucker in Grand Canyon (Albrecht et al. 2014).

B. Factors affecting species environment and critical habitat within the action area

The historical decline of the razorback sucker and its critical habitat in the Grand Canyon has been attributed primarily to habitat modification due to dam construction (including coldwater dam releases, habitat loss, and migration impediments), streamflow regulation, and predation by nonnative fish species, which have resulted in a lack of recruitment (USFWS 2002b, Gloss and Coggins 2005).

- Similar to the humpback chub, cold hypolimnetic releases from Glen Canyon Dam have likely contributed to reproductive failure in razorback sucker (Gloss and Coggins 2005). Flow regulation has decreased the magnitude of spring peak runoff, which is closely linked to reproduction of the razorback sucker. The loss or drastic reduction in peak flows, along with channelization or disconnection of floodplain nursery habitats with the main channel (as a result of loss of peak flows), have resulted in the reduction of reproduction and recruitment as it likely occurred historically (USFWS 2002b). The flow regimes necessary to maintain razorback sucker populations in the action area, including flows that provide adequate spawning cues and spawning and nursery habitat, are presumably present as some razorback suckers have been detected in western Grand Canyon and there is evidence of spawning (Albrecht et al. 2014). However, the low numbers of adults detected and lack of recruitment indicate that habitat may not be adequate for suckers to maintain themselves within the action area at this time.

- Competition with and predation by nonnative fishes have also been identified as important factors in the decline of the razorback sucker (Minckley et al. 1991, USFWS 2002b). The reduced sediment supply and resulting clear water due to dam operations also is thought to favor sight-feeding nonnative predators, over razorback sucker and other native fish that evolved in highly turbid conditions (Gloss and Coggins 2005).

Similar to impacts on humpback chub, elevated Hg and Se described by Walters et al. (2015) may be another factor that affects razorback sucker in the Colorado River. While razorback suckers were not tested, other native suckers with similar diets were found to have high levels of Hg and Se in the Grand Canyon (Walters et al. 2015).

Kanab ambersnail

A. Status of the species within the action area

The Kanab ambersnail (at least as it is currently recognized) is only found in three locations. Two of these are within the Grand Canyon: the riparian vegetation at Vasey's Paradise and Elves Chasm. Vasey's Paradise is at RM 31.5, and Upper Elves Chasm is at RM 116.6. The latter population was created from snails translocated from Vasey's Paradise (USFWS 2008).

Based on annual survey data, live counts of Kanab ambersnails at Vasey's Paradise declined in 2011 from previous years, although the ambersnail habitat at Vasey's Paradise was in overall good condition in 2011. At Elves Chasm, live counts of Kanab ambersnails remained higher in 2011 than previous years, and habitat at this location was in good condition in 2011 (Sorensen 2012). The population at Vasey's Paradise generally occurs at elevations above 33,000-cfs flows. However, as much as 7.3% of the Vasey's Paradise population occurs below the elevation of 33,000-cfs flow, and as much as 16.4% of the population occurs below the elevation of 45,000 cfs flow. The Elves Chasm population is located above the elevation of 45,000-cfs flow (Reclamation 2011b).

Recent monitoring surveys of the Kanab ambersnail population at Vasey's Paradise in Grand Canyon were conducted in May and June 2013, September 2014, and May 2015 (Sorensen 2016). The results from timed presence/absence count surveys at Vasey's Paradise, compared to past years, are summarized in Table 2. The low CPUE in 2014 and 2015 may be due to drought (see factors affecting species environment, below). Monitoring was also conducted on September 12, 2016, where surveyors found one live, mature Kanab ambersnail in all of the lower habitat patches they surveyed (not all habitat patches were surveyed). Total search time for those patches was 126 minutes (CPUE of 0.01 snails/10min search). This count and CPUE estimate is the lowest ambersnail count AGFD has ever tallied at Vasey's Paradise.

Table 2. Kanab ambersnail counts, search effort, and catch-per-unit-effort (CPUE) from timed presence/absence sampling at Vasey's Paradise, 2007-2015 (Sorensen 2016).

Survey Date	# Live Kanab Ambersnails Observed	Minutes of Search Effort	CPUE (# snails per 10 min search)
May 2007	186	526	3.54
April 2009[1]	52	214	2.43
April 2010[1]	51	164.5	3.10
May 2011[1]	28	358	0.78
May 2012[1]	38	303.5	0.80
May 2013[1]	17	339	0.50
May 2014	No survey		
May 2015[1]	44	229.5	1.92
July 2009[1]	106	169.5	6.25
June 2010	141	314.5	4.48
June 2011	82	277	2.96
July 2011[1]	34	223	1.52
June 2012	34	239.5	1.42
June 2013	51	277.5	1.84
June 2014	No survey		
Sept 2006	16	219	0.73
Sept 2007	35	217.5	1.61
Sept 2008	22	225.5	0.97
Sept 2009	66	215.5	3.06
Sept 2010	139	292	4.75
Sept 2011	51	308.5	1.65
Sept 2012	11	268	0.41
Sept 2013	No survey		
Sept 2014	10	270.5	0.37

[1] AGFD Supervised Citizen Science Trip.

Traditional 20-cm diameter plot sampling was only conducted in June 2013 at Vasey's Paradise, but no live Kanab ambersnails were detected in the six sample plots; however, a few live Kanab ambersnails were observed in suitable habitat outside of the sample plots.

AGFD also supervised small teams of citizen science volunteers to conduct monitoring surveys of the translocated Kanab ambersnail population at Upper Elves Chasm in May 2013 and May 2015. Results from this timed presence/absence count survey, compared to past years, are summarized in Table 3. The estimated CPUE for both the 2013 and 2015 surveys were nearly identical, at 1.51 and 1.50 snails per 10 minute search, respectively.

Table 3. Kanab ambersnail counts, search effort, and CPUE from timed presence/absence sampling at Upper Elves Chasm, 2009-2015 (Sorensen 2016).

Survey Date	# Live Kanab ambersnails Observed	Minutes of Search Effort	CPUE (# snails per 10 min search)
April 2009	13	113.5	1.14
April 2010	8	69	1.16
May 2011	20	97.5	2.05
May 2012	7	82	0.85
May 2013	15	99	1.51
May 2014	No survey		
May 2015	7	46.5	1.50
June 2009	30	184.5	1.62
June 2010	27	154	1.75
June 2011	27	65	4.15

B. Factors affecting species environment within the action area

There has likely been some loss of Kanab ambersnails and habitat from the highest flow actions conducted under previous dam operations and flow actions. Kanab ambersnail habitat only begins to be affected by flows at about 17,000 cfs (Sorensen 2009), and flows only exceeded this level in 2011. Meretsky and Wegner (2000) noted that even at flows from 20,000 to 25,000 cfs (current operation allows flows up to 25,000 cfs), only one patch of snail habitat is significantly affected (Patch 12), and a second patch is impacted to a lesser extent at flows above 23,000 cfs (Patch 11). Very few Kanab ambersnail have been found in these two patches historically, likely because the habitat is of low quality (Sorensen 2009). The abundance of Kanab ambersnail has not returned to levels seen before the drought of 2002-2003 that severely reduced the amount of available habitat and likely reduced the population that year (USFWS 2011d).

The habitat at Vasey's Paradise remains somewhat stable from year-to-year, but is scoured by high floods and likely is affected by microclimatic conditions such as higher humidity and lower air temperatures. The surrounding environments and high vegetative cover may be important habitat features related to Kanab ambersnail survival (Sorenson and Nelson 2002). Long-term, climate change has the potential to affect Kanab ambersnail habitat. The water source at Vasey's Paradise consists of waterfalls emanating from groundwater and emerging from the cliff face. In 2014, 2015, and 2016, the flow was reduced, likely as a result of basin-wide drought (and CPUE of snails decreased, see Table 2 and September 12, 2016, survey results above). Consequently, the usually dense vegetation at Vasey's Paradise is notably diminished. Drought associated with climate change will likely diminish the water source supporting Vasey's Paradise and consequently the vegetation and habitat available to the Kanab ambersnail.

The translocated population at Elves Chasm is not affected by dam operations. The population also seems to have recovered from drought conditions, as surveys in 2009 found more snails than in previous years, and surveys in 2010-2013 and 2015 continue to locate snails.

EFFECTS OF THE ACTION

Effects of the action refer to the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated and interdependent with that action, which will be added to the environmental baseline. Interrelated actions are those that are part of a larger action and depend on the larger action for their justification. Interdependent actions are those that have no independent utility apart from the action under consideration. Indirect effects are those that are caused by the proposed action and are later in time, but are still reasonably certain to occur.

Hydrology directly affects the amount of water and water quality variables in the downstream river environment such as temperature, salinity, and turbidity, which in turn have effects to humpback chub, razorback sucker, and Kanab ambersnail. Sediment transport and channel and floodplain morphology (e.g., pools, rapids, sandbars, and terraces) are controlled and shaped by the river's hydrologic properties and implementation of the proposed action. The water volumes, flow rates, and timing of sediment transport, as well as other aspects of Colorado River hydrology are directly affected by the proposed action. In addition, an extensive suite of ongoing and new conservation measures are included in LTEMP (see proposed action) that will collectively work to minimize the negative effects of the proposed action on listed species, enhance the survival and recovery of the humpback chub; monitor the status and effects to the humpback chub, razorback sucker, and Kanab ambersnail in the action area; and, and allow for Reclamation and their partners to use adaptive management to respond to any changes in listed species status or habitat over time. Since razorback sucker have only recently re-occupied the project area, we are still learning about their use of the area; however, there are conservation actions included in the proposed action that will allow us to better understand how the proposed action may also aid in sucker recovery.

The direct and indirect effects of the proposed action include impacts from base operations and operational flexibility; experimental elements (includes sediment-related, aquatic resource-related, and native/nonnative plant management experimental treatments), and, implementation of ongoing and new conservation measures. We summarize the expected effects of each of these groups of actions and evaluate the impacts to the humpback chub and critical habitat, razorback sucker and critical habitat, and Kanab ambersnail.

Humpback chub and critical habitat

There are several aspects of the proposed action that may affect humpback chub through direct impacts to individuals or habitat or by indirectly influencing the abundance and distribution of nonnative fish (that prey upon or compete with chub), or by influencing macroinvertebrate production (food base). Dam operations have the potential to influence water flow, water temperatures, the quantity and quality of nearshore rearing habitats (e.g., backwaters), aquatic insects (food base), and nonnative species presence and abundance. These operations may also result in direct fatality to juvenile native fish through stranding. Other non-flow actions that may have direct and indirect effects to humpback chub include conservation measures (including actions in Appendix D of the BA, mechanical removal of nonnative fish, etc.) and continued fisheries research and monitoring under the GCDAMP.

Effects of Base Operations and Operational Flexibility

Base dam operations will change with the implementation of the proposed action. The distribution of monthly release volumes under the proposed action results in a more even distribution of flows over the course of a water year relative to existing, or baseline, flows. The daily fluctuation in release volumes will be proportional to the Lake Powell reservoir volume (i.e., lower fluctuations during lower flows), with a maximum release volume fluctuation range of 8,000 cubic feet/second, which would be the same as the current maximum fluctuation range, which has been in place since 1996 (Reclamation 1996). The daily downramp rate would be increased, compared to the current condition, by 67% (from 1,500 cfs/hr to 2,500 cfs/hr). Therefore, it is anticipated that year-round, fluctuating flows during the 20-year life of LTEMP may have long-term adverse effects on humpback chub by increasing the risk of stranding juvenile chub, damaging nearshore rearing habitats, degrading aquatic invertebrate prey production, and maintaining cold water temperatures. Conservation measures that allow for recruitment, such as ongoing and proposed expanded translocations in Havasu Creek, would likely reduce the overall effect of this potential loss of young chub, by providing chub with additional habitat that is unaffected by base operations.

The potential for, and the effect of, stranding on individual humpback chub survival caused by Glen Canyon Dam operations in the action area has not been directly investigated; however, fish stranding as a result of hydroelectric and irrigation projects is well-documented (Nagrodski et al. 2012). Stranding of fish, particularly juvenile fish, is a potential outcome of daily hydropeaking (rapid changes in discharge) as a result of hydropower generation (Bunn and Arthington 2002, Nagrodski et al. 2012). Increasing downramp rates under the proposed action may increase the risk of stranding juvenile humpback chub using nearshore habitats. Stranding could include fish being temporarily restricted to isolated habitats away from the main channel until water levels come back up, or complete desiccation. Desiccation of these isolated habitats would result in fatality of any juvenile humpback chub present. Factors that may influence the probability of stranding fish during daily hydropeaking include the rate of flow reduction, water temperature, channel geomorphology, and substrate composition, as well as biotic factors including fish life stage and size (Nagrodski et al. 2012). Increasing drawdown rates under the proposed actions may increase the potential for isolating and/or desiccating nearshore habitats.

Daily fluctuating flows under base operations would also likely continue to degrade nearshore habitats, particularly cobble shoals, riffles, and backwaters in wider sections of the canyon, and where low-angle shorelines susceptible to flow fluctuations are prevalent. For example, cobble riffles and shoals, which are important spawning areas for fish and invertebrate production areas, would be dewatered daily. Generally, based on catch rates, few larval and small-bodied juvenile native fish have been observed in these types of habitats below Lava Falls (Albrecht et al. 2014, Kegerries et al. 2015). However, during a low steady flow experiment, humpback chub were found at higher densities in these habitats than in others (Dodrill et al. 2015).

Hydropeaking has also been demonstrated to have long-term detrimental impacts on aquatic invertebrates (the chub food base) below hydroelectric dams in the western United States (Kennedy et al. 2016). Kennedy et al. (2016) found that hydropeaking was a primary factor implicated in reduced aquatic insect diversity, and the Grand Canyon was found to have the lowest insect diversity and the highest hydropeaking index among 16 dammed rivers in the study. A diverse source of invertebrates is available to colonize the Colorado River from tributary streams (Oberlin et al. 1999, Whiting et al. 2014). However, the proposed action's hydropeaking, along with the existing altered temperature and flow regime, would continue to result in decreased invertebrate production, hence a reduced prey production for humpback chub, over the life of the LTEMP. Implementation of the experimental low steady weekend flows for macroinvertebrate production may improve this situation over time, but until this flow experiment is executed and monitored, we do not know how it will improve the prey base for humpback chub.

Under base operations, river temperatures would continue to be more suitable for coldwater nonnative species (brown and rainbow trout) than for warmwater native and nonnative fish. The estimated average main channel temperatures modeled for LTEMP indicated that temperature conditions would be most suitable for warmwater nonnative species at locations farther downstream from Glen Canyon Dam (e.g., RM 157 and RM 225) compared to upstream locations (e.g., RM 0 and RM 61), where temperatures would be more suitable for coldwater fish, specifically nonnative brown and rainbow trout. However, main channel temperatures at and downstream of RM 61 would be more suitable for both trout species than at locations closer to the dam. The abundance of trout is lower in those locations because other habitat characteristics (e.g., substrate composition and water clarity) are less suitable there.

Previous studies have shown that rainbow trout recruitment and population size within the Glen Canyon reach of the action area appear to be largely driven by dam operations (AGFD 1996; McKinney and Persons 1999; McKinney et al. 2001a,b; Makinster et al. 2011; Wright and Kennedy 2011; Korman et al. 2011, 2012; Avery et al. 2015). Increases in rainbow trout abundance have been attributed to the changes in flows beginning with interim flows in 1991 and later the implementation of Modified Low Fluctuating Flows (MLFF) in 1996. These changes both increased minimum flows and reduced fluctuations in daily flows, which created more stable and productive nursery habitats for rainbow trout in Glen Canyon (McKinney and Persons 1999). More recent declines in rainbow trout abundance (such as those observed from 2001 to 2007) have been attributed to the combined influence of warmer water releases from Glen Canyon Dam, high abundance of rainbow trout resulting in increased intraspecific competition, and periodic dissolved oxygen deficiencies, along with possible limitations in the food base (Makinster et al. 2011). Episodic emigration from the Lees Ferry reach toward the Little Colorado River was likely related to increased trout density, trout condition, and turbidity (Korman et al. 2015).

In addition to providing habitat for nonnative rainbow and brown trout, colder water temperatures (≤12°C) result in negative effects to humpback chub from decreased growth and increased time young chub are susceptible to predation. The effects of cold water on chub include increased egg incubation time (Hamman 1982), reduced egg and fry survival (Hamman 1982), increased larval-to-juvenile transition time (Clarkson and Childs 2000), and reduced growth rates of all other life stages (Clarkson and Childs 2000, Coggins et al. 2011). Essentially, juvenile humpback chub do not grow at temperatures under 12°C. From Glen Canyon Dam to the Little Colorado River inflow, water temperatures are generally <12°C. Consequently, there will be little or no humpback chub reproduction and recruitment in this reach of the mainstem, unless it occurs at isolated locations such as 30-mile springs (RM 30) or springs at RM 34. There is also little opportunity for larval fish to grow in Marble Canyon, unless the limited backwaters provide some thermal opportunities. In the Little Colorado River to Diamond reach, backwaters are more prevalent due to the more open geomorphology, and temperatures have reached or exceeded 16°C near RM 160 during September. The increased water temperature in the lower river reach may provide the conditions necessary for mainstem spawning activity and growth. Restricting the growth of young humpback chub also prolongs the time during which individuals are vulnerable to trout predation (Yackulic et al. 2014). Larger, older juvenile humpback chub may be able to avoid, withstand, or escape predation by rainbow trout under warmer and turbid water conditions; however, temperature and size did not afford the same advantage in escaping brown trout predation (Ward and Morton-Starner 2015).

Operational flexibility in dam operations is necessary to account for unforeseen changes in basin-wide hydrologic conditions, dam maintenance needs, water distribution, resource-related issues, or hydropower-related issues. The degree of flexibility in dam operations would not change from the current conditions, and no additional effects are expected to occur as a result of this need to respond to changing conditions and operational needs.

In summary, under LTEMP base operations, continued hydropeaking flows with increased downramp rates would increase the risk of stranding juvenile humpback chub, degrade nearshore rearing habitats, and limit the establishment of aquatic invertebrates. In addition, implementation of the LTEMP proposed action would continue to result in river temperatures that are more suitable for coldwater nonnative species than for warmwater native and nonnative fish, particularly closer to the dam. As described above, although the coldwater environment does not provide habitat for humpback chub growth and survival, it may assist in reducing the potential for nonnative warmwater fishes to establish in sections of the river.

Effects of Experimental Actions

Glen Canyon Dam has had a negative impact on the aquatic and terrestrial habitats of the Colorado River ecosystem from lower Lake Powell downstream to Lake Mead. In order to minimize these effects (including the previously mentioned effects discussed above) and improve conditions for listed species and their habitats, LTEMP includes experimental conservation actions meant to achieve the following desired future conditions:

- High-elevation open riparian sediment deposits along the Colorado River in sufficient volume, area, and distribution so as to provide habitat to sustain native biota and desired ecosystem processes that include nearshore habitats for native fish and marsh and riparian habitats for food chain maintenance.

- Water quality with regard to dissolved oxygen, nutrient concentrations and cycling, turbidity, and temperature, sufficient to support natural ecosystem functions, visitor safety, and visitor experience to the extent feasible and consistent with the life history requirements of humpback chub and other focal aquatic species including ecosystem-sustaining nutrient distribution, flux, and cycling, and hydro-physical conditions and characteristics necessary to sustain aquatic biota.
- The aquatic food base will sustainably support viable populations of humpback chub and other desired species at all trophic levels.
- Assure that an adequate, diverse, productive aquatic food base exists for humpback chub and other aquatic and terrestrial species that depend on those food resources.
- Sustainably maintain native fish species and their habitats (including critical habitats) throughout each species' natural ranges in the Colorado River ecosystem.
- Achieve healthy, self-sustaining populations of other remaining native fish with appropriate distribution (flannelmouth sucker, bluehead sucker, and speckled dace).
- Achieve humpback chub recovery in accordance with the Act and the humpback chub comprehensive management plan with the assistance of collaborators within and external to the GCDAMP.
- Achieve a self-sustaining humpback chub population in its natural range in the Colorado River ecosystem.
- Maintain spawning habitat for humpback chub in the Lower Little Colorado River.
- Establish additional humpback chub spawning habitat and spawning aggregations within the Colorado River ecosystem, where feasible and appropriate.
- Promote adequate survival of young-of-year or juvenile humpback chub that enter the mainstem to maintain reproductive potential of the population and achieve population sizes consistent with recovery goals.

These experimental conservation actions are grouped under three categories: (1) Sediment-Related Experimental Treatments; (2) Aquatic Resource-Related Experimental Treatments; and, (3) Native and Non-native Plant Management and Experimental Actions. If these experimental actions are found to benefit humpback chub, then they will be continued as appropriate and if triggered throughout the course of the next 20 years.

An adaptive management approach is being taken to implement all experimental elements of the LTEMP. This is being done in order to refine existing information regarding the effects of dam operations on affected resources. Information gathered through the adaptive and experimental process may be used to adjust operations within the range of the impacts analyzed in the FEIS. Prior to the implementation of any experimental action, potential impacts on humpback chub (and other resources) would be considered by the DOI, and deliberations would include the FWS and other DOI subject experts. This would help to identify and minimize the potential for adverse effects to humpback chub as a result of the implementation of an experimental conservation action. The following section summarizes the expected or hypothesized effect of the experimental actions on humpback chub. However, we acknowledge that monitoring and research following these experiments will provide more information regarding effects to chub (and other resources) as the LTEMP is implemented.

(1) Effects of Sediment-Related Experimental Treatments

Experimental flows under the proposed action include: sediment-triggered spring and fall HFEs through the entire 20 year LTEMP period; 24-hour proactive spring HFEs in high volume years (≥10 maf release volume); and, extension of the duration of fall HFEs up to 45,000 cfs for as many as 250 hrs depending on sediment availability.

HFEs under the proposed action were designed to increase and retain fine sediment for ecological purposes in Grand Canyon. Sediment is a fundamental component of the riverine ecosystem, and the sediment regime has been drastically altered by Glen Canyon Dam. HFEs have been shown to build sandbars that substantially increased the total area and volume of backwater habitat (Grams et al. 2010). The increased elevation of backwaters also increased the degree of isolation from the main channel, which would likely result in a higher degree of warming in backwater habitats (Trammell et al. 2002, Vernieu and Anderson 2013), which may be important to native fish growth in the summer (Albrecht et al. 2014, Kegerries et al. 2015). However, as discussed in the Status of the Species, studies of habitat used by juvenile humpback chub have been mainly limited to the Little Colorado River inflow reach, and it is unclear how important backwater or embayment habitats are to humpback chub throughout other reaches of the Grand Canyon (Pine 2011, Dodrill et al. 2015).

Under the proposed action, we would expect there to be 19.3 to 21 HFEs (maximum of 38 HFEs) during the 20-year LTEMP period. The more frequent HFEs are expected to favor blackfly and midge production (food base for humpback chub); however, spring and fall HFEs may differ in their effects, so it is unclear what long-term impacts of annual HFEs may have on the food base. Up to four of the fall HFEs implemented could be long-duration HFEs (lasting up to 250 hrs). These extended-duration HFEs would be of higher magnitude and could increase benthic scouring (the removal of aquatic invertebrates from the river bottom), compared to short-duration HFEs. Aquatic invertebrate drift from an extended-duration fall HFE may be elevated due to increased biomass of benthic (sediment-dwelling) invertebrates that may develop over the summer months. This could result in an increase in food supply for humpback chub. However, the four to five months between a fall and spring HFE could preclude full recovery of most benthic invertebrate assemblages. A spring HFE following a fall HFE, particularly a long-duration fall HFE, could scour the remaining primary producers (plants, cyanobacteria, and unicellular organisms that can produce their own food) and susceptible invertebrates and further delay the recovery of the aquatic food base. For this reason, implementation of a spring HFE in years that follow an extended-duration fall HFE would be carefully evaluated prior to carrying out the action.

Proactive spring HFEs would occur in high volume years with planned equalization releases (≥10 maf) in order to protect the sand supply. Fall HFEs longer than 96 hrs in duration will be implemented when there is sufficient Paria River sediment input in the fall accounting period (July–October) to achieve a positive sand mass balance in Marble Canyon. Spring HFEs and high and steady flows (Avery et al. 2015), have both demonstrated an increase in rainbow trout production in the Colorado River, especially in the Lees Ferry reach (16 mi reach below the dam). This increase in survival of juvenile rainbow trout was attributable to an improvement in habitat conditions and food availability in Glen Canyon for recently emerged trout (Korman et al. 2011). Flows and temperature were modeled over the LTEMP period to assess how rainbow trout recruitment and the potential for emigration downstream toward the Little Colorado River may be impacted by flow experiments. Under the preferred alternative, emigration of rainbow trout is estimated to be 11% higher than under the current dam operations, which could increase the likelihood of negative impacts on humpback chub through competition and predation, particularly in cold water release years. To provide a means of controlling trout recruitment following tests of HFEs, TMFs would be experimentally implemented and tested for efficacy as early in the LTEMP period as possible (see discussion of TMFs below). However, if TMFs did not result in decreases in rainbow trout predation of chub at the Little Colorado River, if Tier 1a (adult chub numbers) or 1b(subadult recruitment) of the *Proposed Action Triggers for the Management of Humpback chub* (Appendix D in BA [Young et al. 2015]) are not met, conservation actions defined in that document would be implemented. If the Tier 1 conservation actions are insufficient to stop a humpback chub population decline, then the Tier 2 Trigger (mechanical removal of aquatic predators [e.g., rainbow trout]) would ensue at the Little Colorado River inflow. Although both TMFs and mechanical trout control are considered experimental actions (see below), they are expected to offset risks of trout predation upon juvenile chub at the Little Colorado River because both are designed to reduce trout and/or trout recruitment. In addition, during the ongoing drought in the 2000s, Lake Powell levels generally declined and release temperatures gradually began to warm (Vernieu et al. 2005). Since this time, water release temperatures have continued on a general warming trend compared to the early 1990s. It is expected that basin-wide drought will continue resulting in lower Lake Powell levels over the next 20 years. These conditions are expected to result in warmer dam releases, which could also mitigate the effects of rainbow trout predation upon juvenile humpback chub (Ward and Morton-Starner 2015).

Nonnative brown trout, or warmwater species occurrence or abundance, may also be influenced by the HFEs. Brown trout spawning occurs mostly in tributaries, primarily in Bright Angel Creek (Reclamation 2011a,b); consequently, reproduction is not expected to be significantly affected by the flow operations of the dam. However, recent increases in brown trout recruitment in 2014-2015 have occurred in the Lees Ferry reach of the Colorado River in Glen Canyon (Stewart 2016). Brown trout were observed to be spawning near the 4-mile bar in Glen Canyon during the fall of 2014, and an increase in age-1 brown trout was observed in 2015 (Korman et al. 2015). Spawning of brown trout was also observed during October and November of 2015 near the 4-mile bar in Glen Canyon (Korman et al. 2015). It is unclear if flow operations, including recent fall HFEs, may have caused an increase in brown trout in recent years or if other factors are supporting the rise in brown trout recruitment. The YOY of fall-spawning brown trout would benefit from increased food availability, similar to rainbow trout, if the fall HFE effects on benthic invertebrates are similar to those of the spring HFEs (Cross et al. 2011). The proposed action would include continued monitoring and potential research regarding the effects of fall HFEs on brown trout populations, particularly in the Glen Canyon reach of the action area.

Although increases in brown trout recruitment are not known to be related to HFEs, it is possible that the establishment of green sunfish in 2015 in a warmwater slough downstream of Glen Canyon Dam may be related to dam operations (Reclamation 2016). If this assumption is correct, combined with expected occasional warmwater flow release periods during drought years, there is potential for warmwater nonnative fish occurrence below Glen Canyon Dam to increase over time. Rapid increases in dam discharge from base flow to up to 45,000 cfs during HFE implementation may increase the chance that abundant warmwater nonnative fish near the intakes become entrained in the bypass tubes. The risk would increase during periods of low Lake Powell levels because when this occurs intakes are closer to the surface and lake littoral zones where smallmouth bass or green sunfish are present. During basin-wide drought years, warmer discharge would increase the risk further, because warmer water could facilitate reproduction of these species in the Grand Canyon, potentially near the Little Colorado River inflow. Conservation measures were developed to address this risk and include investigating the means to prevent warmwater species passage through the dam, planning and implementing actions to make warmwater sloughs less hospitable to warmwater nonnative fish, and developing a rapid response protocol that includes chemical control and other methods not included in the NPS CFMP.

In summary, sediment-related experimental treatments have the potential to negatively affect humpback chub individuals and habitat by increasing rainbow trout emigration to the Little Colorado River reach. This may increase predation or competition effects, alter the food base, or increase the risk of establishment of warmwater nonnative fish. However, these negative impacts may be offset by conservation actions such as humpback chub translocations, monitoring and management of mainstem aggregations (outside of the Little Colorado River aggregation), triggered mechanical removal[10] of nonnative fish (trout or warmwater nonnative fish) to benefit juvenile humpback chub rearing, the development of a rapid response protocol, and warmwater species habitat modification. Further, backwaters created following HFEs may provide warmwater rearing habitat for juvenile humpback chub.

Sediment treatments would not continue to be tested if they are not effective in achieving their purpose or have unacceptable adverse impacts on humpback chub, the rainbow trout fishery, or other resources.

(2) Effects of Aquatic Resource-Related Experimental Treatments

Effects of Triggered Conservation Actions and Mechanical Removal of Nonnative Fish Experiments

Mechanical removal of nonnative species is a controversial issue in the Colorado River through Glen and Grand Canyons. In an attempt to reduce the need for mechanical removal of trout at the confluence of the Colorado and Little Colorado Rivers, Young et al. (2015, Appendix D of the BA) developed a tiered, triggered approach to address mechanical removal of nonnative fish. The purpose of this document is to minimize the need for mechanical predator removal through early implementation of humpback chub conservation measures. The tiered, triggered approach

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10 Reclamation and the NPS are committed to continue to consult with the Tribes regarding nonnative fish control. Reclamation committed in agreements with Tribes in 2012 to consider live removal when feasible; however, the presence of whirling disease prohibits live removal of trout due to the risk of spreading the disease to other waters. Reclamation and the NPS have worked with the Tribes to determine a beneficial use of the removed fish on other projects and understand that what is considered beneficial use may not be the same for all Tribes. Reclamation and the NPS are committed to consult further with the Tribes to determine acceptable mitigation for nonnative fish control.

identifies two tiers of sequential actions. Tier 1 would emphasize conservation actions (i.e., expansion of translocation actions in the Little Colorado River, head-starting larval chub to later translocate) that would take place early during an adult or sub-adult humpback chub population decline (should that happen). Tier 2 would serve as a backstop prescribing mechanical nonnative predator removal (threat reduction) if conservation measures did not mitigate a decline in chub abundance.

As designed, the tiered, adaptive approach to responding to humpback chub declines is expected to reduce the need for mechanical removal of rainbow trout (or other nonnative predatory fishes) at the Little Colorado mainstem aggregation area.

Effects of Trout Management Flows (TMF)

TMFs are a special type of fluctuating flow designed, at least at this time, to reduce the recruitment of rainbow trout by disadvantaging YOY trout, and hence reducing recruitment. The purpose of trout management activities is to enhance the survival of the endangered humpback chub by reducing the numbers of rainbow trout in the river. Reducing the rainbow trout population would reduce competition with and predation on YOY humpback chub near the confluence with the Little Colorado River from trout moving downstream from reaches just below Glen Canyon Dam. TMFs will be implemented when there is predicted high rainbow trout recruitment in the Glen Canyon reach. For the FEIS modeling, a trigger of 200,000 YOY trout was used to determine when TMFs would be implemented. A TMF is a highly variable flow pattern of water releases at Glen Canyon Dam intended to control the number of YOY rainbow trout in the Glen Canyon reach of the Colorado River and, subsequently, the migration of trout to downstream areas such as the confluence of the Little Colorado River. A typical TMF would consist of several days at a relatively high sustained flow (e.g., 20,000 cfs) that would prompt young fish (specifically, rainbow trout) to move into the shallows along the channel margins. The high flows would be followed by a rapid drop to a low flow (e.g., 5,000 cfs), stranding YOY trout and, depending on the time of year, possibly exposing the eggs, thus preventing them from hatching. Under the proposed action, TMFs could be implemented early in the LTEMP period, in as many as four months (May – August), even if not triggered by predicted high trout recruitment. TMFs would initially be conducted as experiments and would be implemented only if they prove to be successful in reducing trout recruitment in the Glen Canyon reach. In general, TMFs would most likely be triggered when spring HFEs, which can stimulate the food base and thus trout production, are followed by relatively high steady summer flows. If TMFs prove successful, it would reduce the number of times mechanical removal would be triggered.

TMFs are designed to cause fatality in YOY rainbow trout by inundating low-angle, nearshore habitats for several days, and then quickly reducing dam discharge, which would strand YOY fish; however, there is also potential for stranding and increased fatality of juvenile humpback chub. Although the Lees Ferry reach trout population is the target of TMFs, an examination of USGS hydrograph data from Lees Ferry (RM 0) and National Canyon (approximately RM 166) indicated there may be little reduction in the peak of the hydrograph as it moves downstream due to flows downstream in the Marble and Grand Canyons. YOY humpback chub are found primarily in the Little Colorado River inflow reach, as well as further downstream, in unknown numbers. Stranding of these small YOY or larval fish may occur as a result of TMFs. It is less likely that TMFs would affect adult or juvenile chub, because they have a greater ability to swim out of confined spaces as flows dropped. TMFs could occur throughout the summer, overlapping with periods when larval humpback chub are found in nearshore habitats (May–August; Albrecht et al. 2014, Kegerries et al. 2015) and would be susceptible to extreme flow fluctuations under TMFs. At this time, TMFs are designed to disadvantage rainbow trout; should brown trout become a focus of TMFs, there may need to be changes to the TMF protocol if flow modification (e.g., increased or reduced flows) were identified as a possible tool to disadvantage brown trout recruitment.

Effects of Low Summer Flow Experiments

Investigating the anticipated effects of and options for providing warmer water temperatures in the mainstem Colorado River through Grand Canyon is a management action identified in the Humpback Chub Recovery Goals (USFWS 2002a).

Low summer flow experiments involve holding flows low (approximately 8,000 cfs) and relatively steady, compared to base operations during warm summer months. A first test of a low summer flow would feature low flow of 8,000 cfs and relatively little fluctuation (±1,000 cfs per day). Depending on the results of the first test with regard to warming and humpback chub response, the magnitude of the low flow could be adjusted up or down (as low as 5,000 cfs), and the level of fluctuation also modified up to the full range allowed under the proposed action (i.e., 10 × monthly volume [in kaf] in July and August, and 9 × monthly volume [in kaf] in September). Lower flows have the potential for more water warming via heat transfer from the air compared to higher flows and would be tested when the water temperature has been <12°C for two consecutive years and a target temperature of ≥14°C can be achieved at the Little Colorado River confluence. The goal of the experiment is to temporarily achieve warmer river temperatures to benefit humpback chub. A secondary benefit that may occur is increased stability in shoreline habitats (due to the steady flow), which could also temporarily improve juvenile humpback chub rearing habitat.

Low summer flows could be considered a potential tool for improving the physical growth and recruitment of young humpback chub if temperature had been limiting these processes for a period of years. Low summer flows may lead to warmer water temperatures in the Little Colorado River reach and farther downstream, as well as contributing to enhanced growth rates of young humpback chub. Low summer flows may also negatively affect humpback chub due to an increase in warmwater nonnative fish or a decrease in the aquatic food base. In moderate or higher water years, the April–June monthly volumes would have to be quite high and would likely be at or near 25,000 cfs. Following these high flows, there would be an abrupt drop to 8,000 cfs or lower (e.g., 5,000 cfs), which would likely leave much or all of the food base in Glen Canyon and downriver up above the new lower water line (Kennedy and Ralston 2011). These values represent declines in midges and Gammarus in the portions of the channel that have been dewatered, and only a small portion of the channel is actually dewatered. Low summer flows would also provide ideal egg laying conditions for aquatic insects, which should facilitate a rapid recovery of the invertebrate prey base to the reduced habitat area associated with this type of experiment. Nonetheless, the potential for low summer flow experiments to negatively impact the food base exist, and measures that seek to minimize any negative impacts would be considered if a low summer flow is implemented. One test of low steady summer flows was conducted below Glen Canyon Dam in 2000; the results, however, relative to humpback chub were not conclusive (Ralston 2011).

However, because of the uncertainty related to the effects of low summer flows on humpback chub, other native fish, warmwater nonnative fish, water quality, and potentially other resources, DOI would ensure that the appropriate baseline data are collected throughout the implementation of LTEMP. In addition, DOI would convene a scientific panel that includes independent experts prior to the first potential use of low summer flows to synthesize the best available scientific information related to low summer flows. The panel may meet periodically to update the information, as needed and information would be shared as part of the Adaptive Management Working Group (AMWG) annual reporting process.

If tested, low summer flows would occur for 3 months (July, August, and September), and only in the second 10 years of the LTEMP period. The duration of low summer flows could be shortened to less than three months in successive experiments if supported by the scientific panel described above or based on the scientific data and observed effects. The probability of triggering a low summer flow experiment is considered low (about 7% of years) because the water temperature conditions that would allow such a test occur infrequently.

Under this design, the effect of the low summer flow experiment upon humpback chub growth, rearing, and recruitment would be difficult to determine, because results are likely to be confounded by other factors (variation in annual precipitation, turbidity, etc.). The low summer flow experiment would not continue if the results of the experiment do not detect an increase in the growth of individual growth and recruitment of humpback chub; if there is an increase in trout or warmwater nonnative species at the Little Colorado River; or, if there are unacceptable adverse impacts on the rainbow trout fishery, humpback chub population, or other resources.

Low summer flows may allow for a prolonged test of the effect of steady flows on the diversity and abundance of aquatic invertebrates, similar to the intent of the low steady weekend flows for macroinvertebrate production experiments (see below). Base operations have been, and would continue to be, characterized as hydropeaking or load-following, which is an operational regime that has been demonstrated to have long-term detrimental impacts on aquatic invertebrates below hydroelectric dams (Kennedy et al. 2016). Consistently more stable flows over the summer could result in successful egg-laying and reproduction by sensitive macroinvertebrate taxa (e.g., mayflies), which are also important prey for humpback chub. However, the experiment may only be implemented 1 to 3 times in the second ten years of LTEMP, which would limit the ability of this experiment to benefit humpback chub food base over the long term. Therefore, only short-term (within the year of the test) beneficial effects to the food base would be expected.

Effects of Low Steady Weekend Flows for Macroinvertebrate Production Experiments

Experimental low steady flows are steady flows that would be provided every weekend from May through August (34 days total) to test the hypothesis that daily flow fluctuations to meet hydropower demand negatively affect habitat quality along the shorelines to improve the invertebrate assemblage within the action area. The duration and other characteristics of experimental macroinvertebrate production flows would be adjusted within the range of the analysis based on the results of initial experiments. Implementing these experimental flows is an attempt to increase invertebrate production and diversity, and may benefit nearshore habitats by providing stability and some warming in habitats that are more isolated from the mainstem (low flows would be held steady plus/minus 1,000 cfs fluctuation on approximately 34 weekend days over the summer). This experiment would not be conducted during the first 2 years of LTEMP. The goal is to replicate it two to three times to determine its effectiveness.

Sustained low flows for benthic invertebrate production may benefit humpback chub and other fish species by providing additional aquatic insect prey. Kennedy et al. (2016) demonstrated that hydropeaking flows in rivers below hydroelectric facilities may prevent the maintenance of viable populations of many aquatic invertebrates (e.g., mayflies, stoneflies, caddisflies) that would constitute important components of the food base for humpback chub. Many shoreline egg-laying invertebrates were absent from western rivers with higher degrees of hydropeaking fluctuations. This experiment may allow some shoreline egg-laying invertebrates to avoid desiccation, which results in a high degree of egg mortality (Kennedy et al. 2016), and potentially would allow for increased production and possibly diversity of aquatic invertebrates.

In addition to potential benefits of increased aquatic food base production, low steady flows on weekends may help to improve the quality of nearshore habitats for juvenile humpback chub two days per week. However, it is unclear whether two days per week of nearshore habitat stability would result in a measureable impact on juvenile growth, rearing, and recruitment. This treatment would be discontinued if there is no observed increase in invertebrate production that results in benefits to native fish or the trout fishery.

(3) Effects of Native and Nonnative Plant Management and Experimental Treatments

Sediment monitoring and research and efforts to manage riparian vegetation are not expected to have impacts on humpback chub individuals or habitat. Riparian vegetation management would occur in only small, localized areas within the project area and will not result in measurable direct or indirect effects to humpback chub or its habitat.

<u>Effects of Conservation Measures</u>

LTEMP includes ongoing and new conservation measures (see Description of the Proposed Action section above) that are designed to minimize or reduce the effects of the proposed action or benefit or improve the survival and recovery of humpback chub as part of the LTEMP. The intention of these conservation measures is to minimize or offset potential impacts to humpback chub and habitat that may result due to the implementation of the LTEMP. These conservation measures were developed in consultation with the FWS and biologists from Reclamation, NPS, and GCMRC.

Conservation measures include actions identified in the Humpback Chub Recovery Goals (USFWS 2002a), such as the control of nonnative species and investigating the effects of parasites. Those conservation measures, as well as others provided for in the proposed action, will assist in increasing the resiliency (sufficiently large populations for the species to withstand stochastic events), redundancy (sufficient number of populations for the species to withstand catastrophic events), and representation (the breadth of genetic makeup of the species to adapt to changing environmental conditions) of the humpback chub. Humpback chub resiliency will be maintained through protection of the Little Colorado River population and enhanced through the possible expansion of the Havasu Creek population (above Beaver Falls, if appropriate). The Little Colorado River continues to support a robust population of humpback chub, but Havasu Creek has the potential to provide for a second large population within the project area. The redundancy of chub populations will be increased through the establishment of or increasing existing chub populations outside of and within the mainstem Colorado River. As a result of the proposed action, translocations of chub will continue above Chute Falls in the Little Colorado River, within tributary habitat in the project area, and mainstem aggregations could be enhanced or expanded, as appropriate. Finally, the conservation measures will also increase humpback chub representation through the continued funding of the refuge population at SNARRC and implementation of the Humpback Chub Genetics Management Plan and Translocation Framework to guide all translocations. Management of the refuge and use of the best science in conducting translocations will ensure that the genetic diversity within and among chub populations is maintained and capable of adapting to environment changes over time.

Although some fatality of individual humpback chub may occur because of these studies, the information gained will be important for understanding population-level impacts on the species due to dam operations and experimental actions under the proposed action. The adaptive management structure of the LTEMP will allow for adjustments in management actions throughout the life of the LTEMP. Thus, negative effects on individuals would likely be offset by population-level benefits that may be expected if adjustments in operations are made as a result of these studies.

Summary

In summary, LTEMP would have both negative and positive effects to humpback chub and their habitat. The stranding of young chub could occur during HFEs, TMFs, and downramp rates, but longer-term beneficial impacts to older age classes may result from actions taken to reduce nonnative predators. Adverse effects to humpback chub habitat include direct, minor, short-term reductions in nearshore habitat that could occur near the Little Colorado River with changes in flow stage, but long-term benefits are expected from flows designed to rebuild and maintain nearshore and backwater nursery habitats. Although base operations would likely continue to degrade the food base, experimental flows are planned to aid in alleviating this impact and increasing the abundance of invertebrates, thus increasing the food base for chub. Continued predation from an expanded population of rainbow trout is expected under cold water discharge, especially with spring or multiple HFEs; the effect of fall HFEs on brown trout recruitment and potential population increases are still unknown. However, implementation of conservation measures, including translocations, nonnative control, triggered mechanical removal, and triggered proactive conservation actions, are designed to minimize and/or offset population level impacts to humpback chub. Implementation of the ongoing and new conservation measures listed in the proposed action will promote the survival and recovery of humpback chub by increasing the redundancy, representation, and resiliency of humpback chub. The proposed action includes continued protection and monitoring of the Little Colorado River chub population; funding and implementation of translocations of chub into tributaries of the Colorado River in Marble and Grand Canyons; managing against existing coldwater nonnatives, where appropriate (e.g., rainbow and brown trout); designing actions to address the future establishment of warmwater nonnative fish or the expansion of brown trout in the Lees Ferry Reach (e.g., modification of habitat at Upper Slough, the possible modification of timeframe for TMFs); and looking to address future climate change threats through exploration of the efficacy of a temperature control device and pursuing means of preventing the passage of invasive nonnative fish through the dam.

Effects of the action on humpback chub critical habitat

In our analysis of the effects of the action on critical habitat, we consider whether or not a proposed action would result in the destruction or adverse modification of critical habitat. In doing so, we must determine if the proposed action would result in effects that appreciably diminish the value of critical habitat for the recovery of a listed species. To determine this, we analyze whether the proposed action would adversely modify any of the PCEs that were the basis for determining the habitat to be critical. To determine if an action results in adverse modification of critical habitat, we must also evaluate the current condition of all designated CHUs, and the PCEs of those units, to determine the overall ability of all designated critical habitat to support recovery. Further, the functional role of each of the CHUs in recovery must also be considered because, collectively, they represent the best available scientific information as to the recovery needs of the species.

Below, we describe the primary constituent elements or “PCEs” for humpback chub critical habitat that we are evaluating and then briefly describe the “effects” to these PCEs within Reach 6 (Little Colorado River) and Reach 7 (Colorado River from Marble through Grand Canyon) from implementation of LTEMP.

Water Quality/Quantity PCE: This PCE calls for water of sufficient quality (i.e., temperature, dissolved oxygen, lack of contaminants, nutrients, turbidity, etc.) that is delivered in sufficient quantity to a specific location in accordance with a hydrologic regime that is required for the each of the life stages of humpback chub.

Effect: Implementation of the proposed action would have limited effects to water quality and no effect to water quantity in Reach 6. Colder water may move into the lowest 0.25 mile of the Little Colorado River as a result of base operations or sediment-related experiments (e.g., HFE), but this would not result in biologically meaningful changes to water quality (i.e., temperature, dissolved oxygen, nutrients), and would not change the quantity of water in critical habitat Reach 6.

Implementation of the proposed action could result in both negative and beneficial effects to the Colorado River from Marble Canyon through Grand Canyon (critical habitat Reach 7). Overall, the beneficial effects will aid in promoting survival and recovery. The main factor resulting in adverse effects to water quality in Reach 7 is the maintenance of reduced water temperatures

(≤12°C) from base operations that can result in decreased growth of chub and increased time young chub are susceptible to predation from nonnative trout. In addition, the cooler water temperatures in the mainstem support habitat for nonnative brown and rainbow trout, which can compete with and prey upon humpback chub. However, the proposed action also includes low summer flow experiments that could, at least temporarily, provide warmer river temperatures to benefit humpback chub growth. As stated above, low summer flow experiments would not occur until the second 10 year period of LTEMP and may only occur one or two times. Therefore, the expected benefit to water temperature (and this PCE) is likely to be extremely limited. The experimental low steady weekend flows for macroinvertebrate production may also result in beneficial effects if the low and steady flows (water quantity change) improve invertebrate production and abundance in critical habitat Reach 7, resulting in an increased prey base for humpback chub, which could help to reduce the effects of reduced growth in cold water by increasing food production.

Physical Area PCE: This PCE includes the physical areas of the Colorado River system that are inhabited by humpback chub or potentially habitable for use in spawning, nursery, feeding, or corridors between these areas. In addition to the main river channel, this includes bottomlands, side channels, secondary channels, oxbows, backwaters, and other areas in the 100-year floodplain, which when inundated provide spawning, nursery, feeding, and rearing habitats, or access to these habitats.

Effect: There would be insignificant effects to spawning, nursery, feeding, or corridor habitat within critical habitat Reach 6 from base operations and experimental flow treatments because these actions would result in little change to the physical environment within the Little Colorado River. Implementation of the proposed action could result in short-term beneficial changes to the confluence area (i.e., increased water temperature from low summer flows, reduction in nonnative fishes from TMF or other actions), but would not likely modify the existing habitat condition for chub at the mouth of the Little Colorado River or within most of the 8-mile reach of critical habitat. The proposed action is designed to maintain (e.g., manage nonnative fishes) or enhance (e.g., warm the temperature) habitat within the Little Colorado River spawning aggregation and effects from the proposed action to this PCE should be beneficial. Aquatic resource-related experimental treatments (e.g., TMF, low summer flows, low steady weekend flows for macroinvertebrate production) and conservation measures (e.g., removal of nonnative fishes, etc.) would aid in maintaining and protecting the area used by spawning and feeding chub in this area.

In critical habitat Reach 7, the physical habitat for spawning, nursery habitat, feeding areas, and movement corridors of humpback chub critical habitat could be affected both negatively and positively by the proposed action. Currently the baseline condition of these habitats in Reach 7 is providing for the physical areas necessary to support humpback chub from the Little Colorado River confluence downstream to the inflow area at Lake Mead (see Environmental Baseline section above). There are spawning, nursery, and feeding locations in Marble Canyon (a group of adult chub likely consisting of between 300-600 individuals has been found near RM 34) and Grand Canyon (there appears to have been a dramatic increase in the absolute abundances of humpback chub in western Grand Canyon - roughly Havasu Creek downriver - with all size classes being represented). It is clear that ongoing management (flow actions that build backwaters and potential nursery habitat) and conservation actions (such as the chub translocations to Shinumo and Havasu) have assisted in improving the functionality of this PCE. The proposed action would build on this momentum with implementation of sediment-related flows that would continue to aid in building and maintaining these habitats over time. However, there may also be adverse effects to spawning and nursery habitats, or feeding areas. Adverse effects, such as degradation of nearshore habitats potentially used by juvenile humpback chub, could occur as a result of hydropeaking during base operations. Sediment-related flow actions could also increase rainbow trout emigration to the Little Colorado River reach. This may increase predation or competition effects, alter the food base, or increase the risk of establishment of warmwater nonnative fish. However, long-term benefits are expected from the implementation of sediment-related flows (e.g., HFEs) designed to rebuild and maintain nearshore and backwater nursery habitats. These backwater habitats may be important to native fish growth in the summer as they tend to have warmer water temperatures, which can provide for increased physical growth of young fish.

In addition, the proposed action includes sustained low flows for benthic invertebrate production that may improve feeding areas for humpback chub and other fish species by providing additional aquatic insect prey. As stated above, Kennedy et al. (2016) demonstrated that hydropeaking flows in rivers below hydroelectric facilities may prevent the maintenance of viable populations of many aquatic invertebrates that constitute important components of the food base for humpback chub. This experiment may allow some shoreline egg-laying invertebrates to avoid desiccation that results in egg mortality (Kennedy et al. 2016), and potentially would allow for increased production and possibly diversity of aquatic invertebrates. Furthermore, low steady flows on weekends may help to temporarily improve the quality of nearshore habitats for juvenile humpback chub.

The entirety of Reach 7 allows for movement of humpback chub (Valdez and Ryel 1995, Paukert et al. 2006) and we would not expect the proposed action to modify this PCE. However, the presence of nonnative predators may influence the chub's ability to move into habitats within the action area. The implementation of TMFs and Triggered Conservation Actions to negatively influence trout recruitment in the action area would benefit this PCE component if trout numbers decline over time as a result of these actions. In addition, conservation measures designed to reduce or remove nonnative fish from tributaries (e.g., Bright Angel Creek trout removal) and remove or modify habitats conducive to warmwater nonnative recruitment in Glen Canyon (i.e., Upper Slough) would also assist in improving the ability of humpback chub to move throughout critical habitat Reach 7.

Biological Environment PCE: This PCE includes important elements of the biological environment, food supply, predation, and competition. Food supply is a function of nutrient supply, productivity, and availability to each life stage of the species. Predation and competition (i.e., for food and/or habitat resources) are considered normal components of this environment; but, are likely not at "natural" levels due to the presence of introduced, nonnative fish (e.g., brown and rainbow trout) within the action area.

Effect: The food supply for humpback chub in critical habitat Reach 6 (Little Colorado River) is unlikely to be affected by the proposed action. Reach 6 is the Little Colorado River, and although actions in the mainstem can affect the confluence and a short distance upstream of the confluence, this critical habitat reach's ability to provide invertebrates for chub to eat is unlikely to be affected by the proposed action, as critical habitat extends eight miles upstream of the confluence and neither base operations nor flow actions affect enough area upstream of the confluence to negatively affect the food supply within the Little Colorado River.

Predation and competition within the lower sections of the Little Colorado River could be influenced by increases in rainbow trout or other nonnative fish at the confluence. If these nonnative fish were to increase in abundance in the mainstem, they could predate upon and compete with humpback chub associated with the aggregation at the confluence. However, the proposed action includes continued monitoring of the Little Colorado River aggregation and the humpback chub within the Little Colorado River. Therefore, any potential increases in trout or other nonnative fish in these areas would trigger the appropriate conservation measures to benefit chub and disadvantage trout (i.e., TMF, mechanical removal, etc.).

Food supply within critical habitat Reach 7 would likely continue to be reduced during base operations due to decreased invertebrate production resulting from desiccation of eggs along the shoreline as the water levels change. However, food supply may be positively impacted by low summer flows (if they occur) and low steady weekend flows that are being implemented specifically to improve habitat and survival of invertebrates and increase the food supply for humpback chub.

The FEIS and BA state that sediment-related experiments in critical habitat Reach 7 (i.e., HFEs) have the potential to negatively affect humpback chub by increasing rainbow trout emigration to the Little Colorado River reach. An increase in rainbow trout, or other predatory nonnative fish, may increase predation or competition effects, alter the food base, or increase the risk of establishment of warmwater nonnative fish. However, the proposed action states that these negative impacts would be offset by Triggered Conservation actions (e.g., TMF) to disadvantage recruitment or mechanical removal of nonnative fish (trout or warmwater nonnative fish) and intended to reduce competition and predation; the development of a rapid response protocol to address nonnative species encroachment or their potential to move into critical habitat; and, warmwater species' habitat modification (e.g., addressing potential of the Upper Slough to provide habitat for green sunfish). Furthermore, as stated above, HFEs are intended to create beaches and backwaters, which may provide warmwater rearing habitat for juvenile humpback chub.

Over the 20-year life of LTEMP, uncontrolled warm water releases may occur as a result of the elevation and subsequent water temperature of withdrawals from Lake Powell. Although increased temperatures may benefit humpback chub spawning and growth, warmer water may also allow for warmwater nonnative species to colonize or expand within critical habitat. Warming water could benefit many nonnative fish species that compete with or prey upon native aquatic species as warmer temperatures may provide suitable conditions for these nonnative fish (e.g., smallmouth bass, green sunfish) to spawn, incubate, and grow in the action area. Conservation actions to remove nonnative fishes from tributaries, and efforts to address nonnative fishes higher in the watershed, are included to address the potential for warmwater nonnatives to establish within critical habitat. In addition, because the establishment of warmwater nonnative fishes could be a factor in humpback chub recovery within critical habitat, as a part of LTEMP Reclamation has committed to exploring new technologies for controlling the temperature of water discharged into the Colorado River and technologies to prevent the passage of fish through the dam in order to attempt to reduce the potential for warmwater nonnative fish species to establish in the action area.

Effects of the action on the role of critical habitat in recovery of the species

Adverse effects and associated incidental take from implementation of the LTEMP are not expected to negatively affect humpback chub recovery or further diminish the conservation contribution of critical habitat to the recovery of the humpback chub because the LTEMP includes actions, conservation measures, and actions designed to adaptively modify the proposed action to conserve the humpback chub and its habitat. These actions and measures were identified by the FWS, project proponents, and partners as being necessary to conserve and recover the humpback chub. The LTEMP would implement these actions in designated critical habitat. These actions include the following:

- The LTEMP is designed to aid in meeting humpback chub recovery goals, including maintaining a self-sustaining population, spawning habitat, and aggregations in the Colorado River and its tributaries below the Glen Canyon Dam. Ongoing population status monitoring for humpback chub would continue, which would provide data for evaluating the effects of LTEMP actions and the status and trend of the humpback chub (e.g., monitoring demographic and vital parameters that are defined in the recovery goals). Full implementation of LTEMP, including the conservation measures, is expected to benefit the species and its critical habitat.

- The proposed action identifies condition-dependent flow and non-flow treatments intended to safeguard against unforeseen adverse changes to humpback chub and their habitat, and to prevent irreversible changes to those resources. Specifically, monitoring conducted in response to all experimental actions in conjunction with ongoing monitoring of humpback chub, will allow for detection of deleterious effects to chub that would result in changes to how the proposed action is implemented (adaptive management). In addition, the aquatic resource related experimental treatments are designed almost entirely to benefit humpback chub.

- The proposed action includes ongoing and new conservation measures that are designed to minimize or reduce the effects of the proposed action or benefit or improve the status of humpback chub as part of the LTEMP.

Over the long-term, these actions should increase the sustainability and resiliency of humpback chub critical habitat (particularly through implementation of the conservation measures). Therefore, implementation of the LTEMP is not expected to further diminish the conservation contribution of critical habitat to the recovery of the humpback chub.

Razorback sucker and critical habitat

There are several aspects of the proposed action that may affect razorback suckers through direct impacts to individuals or habitat or by indirectly influencing the abundance and distribution of nonnative fish (that prey upon or compete with suckers), or by influencing macroinvertebrate production (food base). Dam operations have the potential to influence flow, water temperatures, the quantity and quality of nearshore rearing habitats (e.g., backwaters), aquatic insects (food base), and nonnative species presence and abundance. These operations may also result in direct fatality to juvenile native fish through stranding. Other non-flow actions that may have direct and indirect effects to razorback sucker include conservation measures (including actions in Appendix D of the BA, mechanical removal of nonnative fish, etc.) and continued fisheries research and monitoring under the GCDAMP. However, unlike the humpback chub, which occurs relatively frequently throughout the action area, the razorback sucker is relatively rare within the action area and effects to larval fish would only occur in western Grand Canyon (or approximately the lower 100 river miles of the action area).

Effects of Base Operations and Operational Flexibility

As described above, base dam operations would change with the implementation of the proposed action. The distribution of monthly release volumes under the proposed action results in a more even distribution of flows over the course of a water year relative to existing, or baseline, flows. The daily fluctuation in discharge would be proportional to the reservoir volume (i.e., lower fluctuations during lower flows), with a maximum discharge fluctuation range of 8,000 cubic feet/second, which would be the same as the current maximum fluctuation range that has been in place since 1996 (Reclamation 1996). The daily downramp rate would be increased, compared to the current condition, by 67% (from 1,500 cfs/hr to 2,500 cfs/hr). Therefore, it is anticipated that year-round, fluctuating flows over the 20-year life of LTEMP may have adverse effects on razorback suckers through stranding of larval fish, damaging nearshore rearing habitats, degrading aquatic invertebrate prey production, and maintaining cold water temperatures.

The stranding of larval razorbacks sucker is a potential outcome of daily hydropeaking (Bunn and Arthington 2002, Nagrodski et al. 2012), should larval fish be present in nearshore habitats. Increasing downramp rates under the proposed action may increase the risk of stranding larval razorback sucker, depending upon the level of stage changes that occurs during base operations, how that flow attenuates downstream, and the steepness of shallow nearshore areas. Thus far, juvenile (older than larval) life stages of razorback sucker have not been sampled in two years of study in the Grand Canyon since razorbacks were rediscovered in Grand Canyon (Albrecht et al. 2014, Kegerries et al. 2015). It is unclear whether larval razorback sucker experience near 100% mortality prior to transformation to juveniles from unknown causes (unlikely related to Glen Canyon dam operations), or if sucker larvae drift to Lake Mead and rear in the lake. However, to date, surveys have not detected razorback sucker recruitment in the action area. Thus, potential stranding effects would likely only affect larval age classes of suckers, not juvenile fish.

If stranding occurs where larval suckers are present, it could include fish being temporarily (i.e., until flows came back up hours later) restricted to isolated habitats away from the main channel, which may or may not become desiccated, as a result of dropping water levels. Desiccation of these isolated habitats would result in fatality of any larval fish (razorback sucker or other species) present. Larval razorback suckers, like other larval fish, have limited swimming ability, and thus are at high risk of stranding. Increasing drawdown rates under the preferred alternative would likely increase the risk of fatality to larval fish in these areas; however, how much of an effect this would be to the razorback sucker population is unknown since there is little information regarding their abundance. Larval sampling in the lower Grand Canyon found razorback sucker larvae to be distributed throughout most shoreline habitats from Lava Falls approximately (RM 179) to Pearce Ferry (RM 280) from May to July. The highest densities of larvae were found in isolated pools, which composed less than 2% of all habitats sampled. These pools have a high likelihood of desiccation with daily flow fluctuations; however, survival rates among different habitats have not been studied. The potential for, and the effect of stranding on, individual razorback sucker survival has not been directly investigated; however, as indicated in the humpback chub effects section, fish stranding as a result of hydroelectric and irrigation projects is well documented (Nagrodski et al. 2012).

Daily fluctuating flows under base operations would also likely continue to degrade nearshore habitats, particularly cobble shoals, riffles, and backwaters in wider sections of the canyon, and where low-angle shorelines susceptible to flow fluctuations are prevalent. For example, cobble riffles and shoals, which are important spawning areas for razorback suckers and invertebrate production areas, would be dewatered daily. Razorback suckers spawn on cobble bars and other gravel substrates near or associated with riffles. Riffles and spawning bars may occur in wider, shallower areas of the channel. Therefore, eggs deposited in these habitats are susceptible to being buried in sediment or washed away due to flow fluctuations. Continued daily flow fluctuations, combined with increased downramp rates, would likely increase the risk of desiccation of spawning areas and incubating razorback sucker eggs, leading to increased mortality rates of eggs. Adult razorbacks can swim off of bars as flows decline, and therefore are not likely to be stranded. Generally, based on catch rates, few larval and small-bodied juvenile native fish have been observed on cobble shoals and riffles below Lava Falls (Albrecht et al. 2014, Kegerries et al. 2015).

Under base operations, river temperatures are expected to continue to be more suitable for coldwater nonnative species than for warmwater nonnative fish, particularly closer to the dam. In general, the estimated average main channel temperatures modeled for the LTEMP EIS indicated that temperature conditions would be most suitable for warmwater nonnative species, as well as native fish such as razorback sucker at locations farther downstream from Glen Canyon Dam (e.g., RM 157 and RM 225) compared to upstream locations (e.g., RM 0 and RM 61), where temperatures would be more suitable to coldwater nonnative fish (e.g., brown and rainbow trout). Razorback sucker are distributed within the project area, from the Colorado River inflow of Lake Mead (~RM 289) and upstream at least as far as an area above Lava Falls (~RM 173) in Grand Canyon. The actual upstream distribution of razorback sucker is unknown. Warm temperatures may be even more critical for larval razorback suckers than other native suckers to transform into juveniles (Bestgen 2008). Therefore, continued cold temperatures under base operations during the LTEMP implementation period should negatively impact razorback suckers and their habitat in the upper 200 miles of the project area. However, razorback suckers have recently been detected in lower Grand Canyon following many years of existing dam operations. Therefore, predicting at this time what the true effects of base operations would be on suckers in the lower 100 river miles of the action area is difficult.

Experimental stable flows (steady flows to increase macroinvertebrate production) may provide some benefit to offset these potential impacts through increased prey abundance.

As stated above, hydropeaking has been demonstrated to have long-term detrimental impacts on aquatic invertebrates (the chub food base) below hydroelectric dams (Kennedy et al. 2016). The continued hydropeaking under LTEMP, along with the existing altered temperature and flow regime, would continue to result in decreased invertebrate production, hence a reduced prey production of insect larvae for razorback suckers, over the life of the LTEMP. Implementation of the low steady weekend flows for the macroinvertebrate production experiment may improve this situation over time in the mainstem river corridor, but until this flow experiment is executed and monitored, the effect of this action, particularly in the lower third of the action area where suckers occur, is unknown.

In summary, under base operations and coldwater conditions, continued hydropeaking flows with increased downramp rates compared to the existing conditions would increase the risk of stranding larval fish, continue to degrade nearshore rearing habitats, and prevent the establishment of aquatic insect larvae (food base). Because we do not know the abundance or distribution of larval razorback sucker, it is difficult to assess how base operations and flow actions would actually affect razorback sucker persistence in lower Grand Canyon, where effects are likely somewhat different than in Glen and upper Grand Canyons. In order to address this issue, LTEMP includes a conservation measure to continue funding larval and small-bodied fish monitoring in lower Grand Canyon in order to determine habitat use and distribution of different life stages of razorback sucker and to determine the extent of hybridization in flannelmouth and razorback sucker larvae through genetic analysis to assist in future management of flows in order to conserve the species. This information would assist Reclamation in identifying sensitive habitats to flow fluctuations to prioritize for monitoring. In addition, Reclamation would also use this survey data to assess the effects of base operations on razorback suckers. Therefore, even though there is potential for daily fluctuating flows to adversely affect razorback sucker spawning habitat, these negative effects would be lessened by conservation measures that would be taken as part of the LTEMP.

Effects of Experimental Actions

Experimental actions are grouped under three categories: (1) Sediment-Related Experimental Treatments; (2) Aquatic Resource-Related Experimental Treatments; and, (3) Native and Non-native Plant Management and Experimental Actions. The anticipated effects of these experimental treatments are described below.

An adaptive management approach is being taken to implement all experimental elements of the LTEMP. Prior to the implementation of any experiment, potential impacts would be considered by the DOI, including the FWS, GCMRC and other DOI subject experts. This would help to identify and minimize the potential for adverse effects to razorback suckers as a result of the implementation of an experimental treatment. The following section summarizes the expected or hypothesized effect of the experimental elements on razorback suckers. However, just as with the humpback chub, we acknowledge that monitoring and research following these experiments would provide more information regarding effects to suckers as the LTEMP is implemented.

This is particularly true of the razorback sucker due to the fact that we have very few adult fish detections and have limited knowledge regarding larval fish persistence within western Grand Canyon.

(1) Effects of Sediment-Related Experimental Treatments

Experimental flows under the proposed action include: sediment-triggered spring and fall HFEs through the entire 20 year LTEMP period; 24-hr proactive spring HFEs in high volume years (≥10 maf release volume); and, extension of the duration of fall HFEs up to 45,000 cfs for as many as 250 hr depending on sediment availability.

Larval fishes in rivers generally rely on low-velocity nearshore environments for rearing. Backwaters potentially created by both HFEs and low summer flows are one such nearshore habitat frequently used by native fishes in the Grand Canyon, and these habitats and their use by native fishes, including razorback suckers, have been a major focus of research (Albrecht et al. 2014). These backwaters, although short lived, may provide ideal rearing conditions for native fishes because water temperatures are often much greater than in the mainstem, particularly when flows are steady.

Due to the fact that HFEs create and maintain backwater habitats important to larval razorback sucker, these HFE experiments would be expected to benefit razorback sucker through creation and maintenance of these habitats. Spring HFEs may be particularly beneficial to razorback suckers if these sediment-related flows create backwater habitat during a time period that coincides with spawning and emergence of larval fish. However, since February-March is the peak of spawning for suckers in western Grand Canyon (Kegerries et al 2015), spring HFEs (March or April) could have adverse impacts on spawning suckers and their habitats. While spring HFEs may mimic the general timing of a natural hydrograph, which historically may have facilitated the transport of larval fish into suitable backwater habitats for rearing (Valdez et al. 2012), in the current altered temperature and sediment regime, the same benefit may not be expected. The degree of adverse impacts to spawning razorback suckers may depend on the timing of a proposed HFE and spawning in a given year.

The magnitude of floods on wide rivers decreases downstream if a substantial amount of the floodwaters temporarily occupies the flood plain. However, the magnitude of a flood can increase downstream if there are large inflows from tributaries. In narrow-bottomed canyons, such as Grand Canyon, flood attenuation caused by overbank flooding is small, and the primary downstream changes in flood magnitude occur when a high flow coincides with tributary inflows. During the 1996 HFE, tributary inflow was minimal, and flow of the Colorado River at Diamond Creek (RM 226) downstream from the dam, exceeded the release at the dam by about 500 cfs, which was only a one percent increase in flood magnitude. In contrast, substantially more tributary inflow was measured in 2004 and in 2008, and discharge at Diamond Creek exceeded the magnitude of the dam release by about five percent (Schmidt and Grams 2011). Therefore, the effects to larval razorback sucker from HFEs since they currently occur at the western edge of the project area is likely dependent upon the amount of water released in the HFE, any tributary flooding that may also be occurring, and width of the canyon where fish are present.

(2) Effects of Aquatic Resource-Related Experimental Treatments

Effects of Triggered Conservation Actions and Mechanical Removal of Nonnative Fish Experiments

As stated above in the humpback chub Effects section, Young et al. (2015, Appendix D of the BA) developed a tiered, triggered approach to address mechanical removal of nonnative fish. The purpose of this document is to minimize the need for mechanical predator removal through early implementation of humpback chub conservation measures. The tiered, triggered approach identifies two tiers of sequential actions, which are described above. The focus of these actions is on the Little Colorado River humpback chub aggregation. Razorback sucker have not been sampled near the Little Colorado River inflow since the 1980s or early 1990s. In general, removal of nonnative fish would benefit razorback sucker because removing nonnative fishes from any portion of the action area means that there are fewer fish to compete with or predate upon razorback suckers in western Grand Canyon. However, this action would likely have limited beneficial effects to the razorback sucker because the emphasis on nonnative removal is not where suckers have been detected and predominately (at this time) deals with rainbow and brown trout that occur much higher in the action area than where suckers are present. Warmer and more turbid waters characterize the lower (western) Grand Canyon. The farthest upstream locations where larval razorback sucker were detected is about RM 179 (Albrecht et al. 2014). These locations are less suitable for trout due to temperature and turbidity, so removal of nonnative trout near the Little Colorado River, which is approximately 117 river miles from this most upstream location of larval suckers, would likely have negligible impacts on razorback sucker. Similarly, Tier 1 conservation actions developed to conserve humpback chub, including actions to enhance rearing and translocations, would likely have no effect to razorback sucker because these actions would occur within the Little Colorado River and its inflow.

Effects of Trout Management Flows

TMFs are a special type of fluctuating flow designed to reduce the recruitment of rainbow trout by disadvantaging YOY trout. The purpose of trout management activities is to enhance the survival of the endangered humpback chub by reducing the numbers of trout in the river.

The potential for TMFs to strand and cause fatality to razorback sucker could increase under the proposed action. However, it is unclear based on what we currently know of razorback sucker distribution, what the magnitude of effect from TMFs on nearshore habitats and potential stranding of larval razorback suckers in western Grand Canyon would be. TMFs could be implemented from May through August, which would overlap with the presence of larval razorback sucker in rearing habitat. Given that razorback sucker spawning was documented for the first time in the action area in 2014 (and continued in 2015) potential impacts from the proposed action on the species are particularly difficult to predict because prior to the last two years, there was no indication razorback suckers were present in the action area. In addition, it is unclear how attenuation of flows would affect backwaters at the lower end of the action area between approximately RM 179 and RM 279 (at the inflow to Lake Mead) where larval razorback sucker are currently known to occur. However, in both 2014 and 2015, catch-per-unit-effort of razorback sucker larvae was higher in isolated pools and/or backwaters (Albrecht et al. 2014, Kegerries et al. 2015), which could mean that larval razorback sucker may be particularly sensitive to the drastic and rapid fluctuations associated with TMFs due to its dependence upon low-velocity backwater habitats.

In addition, although the location or habitat preference for spawning adult razorback suckers has not been identified or defined in the Grand Canyon, the species is known to spawn on clean cobble bars in other systems (USFWS 2002b). Valdez et al. (2012b) identified potential spawning bars in the Grand Canyon at tributary inflows and canyon mouths including Diamond Creek (RM 226), Spencer Canyon (RM 246), and Surprise Canyon (RM 248.3). These and other shallow cobble bars that provide habitat for spawning and egg incubation may be sensitive to flow variation. Large fluctuations during the spawning period (February or March to July; Kegerries et al. 2015) associated with TMFs implemented between May and August may impact spawning and incubation habitat by dewatering.

In summary, TMFs could have negative impacts on larval razorback sucker and rearing habitats that would continue to occur for the duration of the action. The risk to larval razorback sucker would likely vary by location depending upon the level of stage changes experienced and the steepness of shallow nearshore areas. Monitoring of the impacts of TMFs throughout GCNP, particularly in the western Grand Canyon where larval razorback suckers are present, would be implemented to assess the effectiveness of the action, as well as the potential for detrimental effects to razorback sucker and other native fishes.

Effects of Low Summer Flow Experiments

Low summer flow experiments involve holding flows low (approximately 8,000 cfs) and relatively steady, compared to base operations during warm summer months. The goal of this flow experiment is to temporarily achieve warmer river temperatures to benefit humpback chub. A secondary benefit that may occur is increased stability in shoreline habitats (due to the steady flow), which could also improve potential rearing habitat for razorback suckers.

Few studies have investigated the use of backwaters or other shoreline habitats that may be important to razorback sucker rearing in the western Grand Canyon, where water temperatures are more suitable (warmer) for native fish rearing than closer to Glen Canyon Dam. Shoreline habitats have the potential to provide warmer rearing habitat than the mainstem under certain conditions (Grams et al. 2010, Trammell et al. 2002). Given razorback suckers' need for warm, productive floodplain or backwater habitats for rearing larval fishes, and the lack or low abundance of nonnative fish found in recent backwater sampling where razorback suckers were found (Albrecht et al. 2014, Kegerries et al. 2015), reduced fluctuations, lower flows, or low summer flows may be beneficial for razorback sucker by providing warm and persistent backwater habitats. During the 2000 Low Steady Summer Flow experiment, which included steady flows of 8,000 cfs from June through September 2000, mainstem temperatures were 1.4–3°C higher than under previous dam operations, and backwaters were 0.3–5.3°C warmer (Trammell et al. 2002). Similarly, NPS sampling of 47 backwaters located between RM 115 and RM 220 under steady flows in September 2009 showed that at least 21 backwaters were at least 2°C warmer than the adjacent mainstem (Speas and Trammell 2009). The longer residence time of water in nearshore and backwater habitats with steady flows results in warmer temperatures than in the mainstem (Behn et al. 2010), which may provide suitable rearing habitat for larval razorback sucker.

Low summer flows included under the proposed action as an experiment after the first 10 years of the LTEMP period would likely increase warming and overall stability in these nearshore habitats, thereby benefitting razorback sucker in Grand Canyon. Implementation of the experiment may occur only under rare conditions, so the potential for this action to be implemented is unlikely. However, due to the positive effect on habitat low summer flows may have on the creation, maintenance, and warming of backwater habitats important to larval razorback sucker, these experiments would likely benefit razorback sucker.

Effects of Low Steady Weekend Flows for Macroinvertebrate Production Experiments

Experimental low steady flows are steady flows that would be provided every weekend from May through August (34 days total) to test the hypothesis that daily flow fluctuations to meet hydropower demand negatively affect habitat quality along the shorelines to improve the invertebrate assemblage within the action area.

In addition to potential benefits of increased aquatic food base production (Kennedy et al. 2016), steady flows on weekends may help improve the quality of nearshore habitats for larval razorback sucker. We do not know whether two days per week of nearshore habitat stability would result in a measureable impact on larval growth, rearing, and recruitment. However, under current operations it does not appear that razorback sucker are successfully recruiting from the larval to juvenile life stages, possibly due to cooler water temperatures and lack of stable rearing habitats. Because larval razorback sucker need stable, low-velocity, warm, productive habitats for rearing, a beneficial effect to suckers is expected under this experiment (combined with HFEs to build bars and backwaters).

(3) Effects of Native and Nonnative Plant Management and Experimental Treatments

Sediment monitoring and research and efforts to manage riparian vegetation are not expected to have impacts on humpback chub individuals or habitat. Riparian vegetation management would occur in only small, localized areas within the project area and will not result in measurable direct or indirect effects to humpback chub or its habitat.

<u>Effects of Conservation Measures</u>

LTEMP includes ongoing and new conservation measures (see Description of the Proposed Action section above) that are designed to minimize or reduce the effects of the proposed action or benefit or improve the status of listed species, including razorback suckers, as part of the LTEMP. These conservation measures were developed in consultation with the FWS and biologists from Reclamation, NPS, and GCMRC. As stated above, razorback suckers have only recently reoccupied the project area and the most urgent need is for increased knowledge regarding how suckers are using habitats in the project area, spatially and temporally; and, the response of the species to base operations and experimental flow actions under the proposed action.

As a part of LTEMP, Reclamation would continue to fund ongoing studies designed to understand the status of the razorback sucker population in the Grand Canyon and Lake Mead. Specifically, these conservation measures include: (a) studies to determine the extent of hybridization in flannelmouth and razorback sucker larvae collected; (b) studies to determine habitat use and distribution of different life stages of razorback sucker to assist in future management of flows that may help to conserve the species (including identification of habitats sensitive to flow fluctuations); and, (c) studies to assess the effects of TMFs and other dam operations on the species. These studies will aid in our ability to better incorporate sucker needs into the proposed action over time. In addition, razorback sucker will benefit from all conservation measures in the proposed action designed to reduce both cold- and warmwater nonnatives.

Although some fatality of individual razorback sucker may occur as a result of these studies, including fatality of larval fish, as has occurred in 2014 and 2015 related to larval studies (Albrecht et al. 2014, Kegerries et al. 2015), the information gained would be important for understanding population-level impacts on the species due to dam operations and experimental actions under the proposed action. The adaptive management structure of the LTEMP would allow for adjustments in management actions throughout the life of the LTEMP. Thus, negative effects on individuals would likely be offset by population-level benefits that may be expected if adjustments in operations are made as a result of these studies.

Summary

In summary, there is the potential (depending upon timing, flow attenuation, water temperature, and other factors) for the short-term dewatering of spawning areas and stranding of larval and young-of-year razorback sucker in nearshore habitats as a result of base operations (daily fluctuating flows, including increased downramp rates). Spring HFEs should they occur in March, which overlaps with the peak of spawning activities (Kegerries et al. 2015), may also result in the scouring of spawning habitat. However, spring and fall HFEs may also result in the creation of warm, productive nursery backwater habitats for razorback suckers. Although base operations would likely continue to degrade the food base, low summer flows and low steady weekend flows may alleviate these negative effects and improve the quality of nearshore habitats for larval razorback suckers and increase the food base for all fish.

Effects of the action on razorback sucker critical habitat

In our analysis of the effects of the action on critical habitat, we consider whether or not a proposed action would result in the destruction or adverse modification of critical habitat. In doing so, we must determine if the proposed action would result in effects that appreciably diminish the value of critical habitat for the recovery of a listed species. To determine this, we analyze whether the proposed action would adversely modify any of the PCEs that were the basis for determining the habitat to be critical. To determine if an action results in adverse modification of critical habitat, we must also evaluate the current condition of all designated CHUs, and the PCEs of those units, to determine the overall ability of all designated critical habitat to support recovery. Further, the functional role of each of the CHUs in recovery must also be considered because, collectively, they represent the best available scientific information as to the recovery needs of the species.

Below, we describe the PCEs for razorback sucker critical habitat and briefly describe the effects to these PCEs within the critical habitat that includes the Colorado River from where the Paria River joins the Colorado down to Lake Mead from implementation of LTEMP. Many of the potential effects described are more thoroughly summarized above. Razorback suckers have always been rare in the action area, and although we have recent records of adult fish and spawning occurring in the lower portion of the action area (~ lower 100 river miles), the ability of the Glen and Grand Canyon reaches of the Colorado River (~ upper 200 river miles) to fully provide the PCEs is uncertain due to the greater influence of Glen Canyon dam operations in Glen and upper Grand Canyon.

Water Quality/Quantity PCE: This PCE calls for water of sufficient quality (i.e., temperature, dissolved oxygen, lack of contaminants, nutrients, turbidity, etc.) that is delivered in sufficient quantity to a specific location in accordance with a hydrologic regime that is required for the each of the life stages of razorback sucker.

Effect: The water temperature in the upper portion of the this critical habitat unit (from Paria Canyon down to the upper portion of Grand Canyon) would likely remain too cold to provide the water quality needed to support razorback suckers. The main factor resulting in adverse effects to water quality here is reduced water temperatures (≤12°C) from base operations that would likely continue to result in suckers not using the Colorado River from Paria Canyon (RM 0.9) down to approximately Lava Falls (known upstream extent of razorback suckers in the action area, ~RM 173). The proposed action also includes low summer flow experiments that could, at least temporarily, provide somewhat warmer river temperatures at the Little Colorado River and downstream. As stated above, low summer flow experiments would not occur until the second 10 year period of LTEMP and may only occur one or two times. Therefore, the expected benefit to water temperature (and this PCE) is likely to be extremely limited. The experimental low steady weekend flows for macroinvertebrate production may also result in beneficial effects if the low and steady flows (water quantity change) improve invertebrate production and abundance in critical habitat, potentially resulting in an increased invertebrate prey base.

Implementation of the proposed action would result in discountable effects to water quantity (overall), but may temporally and spatially affect the presence of habitat as flows increase and decrease to provide power (i.e., hydropeaking) or improve habitat (e.g., low summer flows, low steady weekend flows for macroinvertebrates). Low summer flow experiments (including low steady weekend flow experiments) would, at least temporarily, provide potentially warmer river temperatures that could benefit habitat for both adult and larval razorback suckers by providing warmer water temperatures for growth of larvae and spawning of adult fish. However, low summer flow experiments would not occur until the second 10 year period of LTEMP and may only occur one or two times. Therefore, the expected benefit to water temperature (and this PCE) is likely to be extremely limited.

Physical Area PCE: This PCE includes the physical areas of the Colorado River system that are inhabited by razorback sucker or potentially habitable for use in spawning, nursery, feeding, or corridors between these areas. In addition to the main river channel, this includes bottomlands, side channels, secondary channels, oxbows, backwaters, and other areas in the 100-year floodplain, which when inundated provide spawning, nursery, feeding, and rearing habitats, or access to these habitats.

Effect: The physical habitat for spawning, nursery habitat, feeding areas, and movement corridors of razorback sucker critical habitat could be affected both negatively and positively by the proposed action. Adverse effects from hydropeaking include continued degradations of nearshore habitats and backwaters used by larval razorback sucker. Potential positive effects could occur from HFEs that create and/or build up backwater habitats.

Razorback sucker spawning areas below Lava Falls could be affected by HFEs, particularly in the spring when razorbacks are spawning (February to late March; Kegerries et al. 2015). The increased amount of water moving from the river to the lake would raise water levels at the Lake Mead inflow and possibly increase turbidity through additional sedimentation once the water slows down in the upper lake. This could potentially encourage spawning if this occurred at the right time of year (i.e., in March). In addition, if suckers have already spawned, sediment deposition that occurred during egg incubation could result in damage or fatality to the eggs if the eggs were buried in sediment. However, because incubation time for razorback sucker eggs occurs over approximately seven days, the effects of a spring HFE conducted later in April could have less of an impact. Larval razorback sucker may also be displaced from nursery areas and moved into unsuitable habitats as the water deepens with passage of the HFE. The actual impacts likely depend upon the timing of spawning, water temperature, and other factors (e.g., weather conditions) in any individual year. Our knowledge of the razorback sucker population is limited, and factors controlling reproduction and the lack of recruitment in the action area is unknown, which makes it difficult to predict what effects would occur from implementation of flow actions, other than the potential stranding of larval suckers in nearshore habitats.

In addition, the proposed action includes sustained low flows for benthic invertebrate production that may improve feeding areas for humpback chub and other fish species by providing additional aquatic insect prey. As stated above, Kennedy et al. (2016) demonstrated that hydropeaking flows in rivers below hydroelectric facilities may prevent the maintenance of viable populations of many aquatic invertebrates that constitute important components of the fish food base. This experiment may allow some shoreline egg-laying invertebrates to avoid desiccation that results in egg mortality (Kennedy et al. 2016), and potentially would allow for increased production and possibly diversity of aquatic invertebrates. Furthermore, low steady flows on weekends may help to temporarily improve the quality of nearshore habitats for larval razorback suckers.

Based upon the locations of adult razorback suckers upstream of Lava Falls, it would appear that movement of fish, at least in western Grand Canyon, is not impeded by existing management of Glen Canyon dam, but is it unclear how sediment-related or aquatic species flow actions would modify or enhance movement of suckers from Lake Mead, upstream to Lava Falls.

Biological Environment PCE: This PCE includes important elements of the biological environment, food supply, predation, and competition. Food supply is a function of nutrient supply, productivity, and availability to each life stage of the species. Predation and competition (i.e., for food and/or habitat resources) are considered normal components of this environment, but are likely not at "natural" levels due to the presence of introduced, nonnative fish (e.g., brown and rainbow trout) within the action area.

Effect: The food supply for razorback sucker could be negatively and positively affected by the proposed action. Although base operations would continue to result in decreased invertebrate production, hence a reduced food base for razorback suckers, food supply may be positively impacted by low summer flows (if they occur) and low steady weekend flows that are attempting to improve habitat and survival of invertebrates. Because our knowledge of razorback suckers in the project area is still developing, it is difficult to determine exactly how these actions would affect the fish. However, if the proposed action is successful, the proposed action will ultimately aid in promoting the survival and recovery of razorback suckers through increased food production.

Over the 20-year life of LTEMP, uncontrolled warm water releases may occur as a result of the elevation and subsequent water temperature of withdrawals from Lake Powell. Although increased temperatures may benefit razorback sucker spawning and growth, warmer water may also allow for warmwater nonnative species to colonize or expand within critical habitat. Warming water could benefit many nonnative fish species that compete with or prey upon suckers as warmer temperatures may provide suitable conditions for these nonnative fish (e.g., smallmouth bass, green sunfish) to spawn, incubate, and grow in the action area. Because the establishment of warmwater nonnative fishes would be detrimental to razorback suckers within the action area, as a part of LTEMP Reclamation has committed to exploring new technologies for controlling the temperature of water discharged into the Colorado River and technologies to prevent the passage of fish through the dam in order to attempt to reduce the potential for warmwater nonnative fish species to establish in the action area.

Effects of the action on the role of critical habitat in recovery of the species

Adverse effects and associated incidental take from implementation of the LTEMP are not expected to negatively affect razorback sucker recovery or further diminish the conservation contribution of critical habitat to the recovery of the species because the LTEMP includes actions, conservation measures, and "off-ramps" designed to adaptively modify the proposed action to conserve the razorback sucker and its habitat. These actions and measures were identified by the FWS, project proponents, and partners as being necessary to conserve and recover the sucker. The LTEMP will implement these actions in designated critical habitat. These actions include the following:

- The proposed action includes funding larval and small-bodied fish monitoring in order to:
  - Determine the extent of hybridization in flannelmouth and razorback sucker collected in the western Grand Canyon.
  - Determine habitat use and distribution of different life stages of razorback sucker to assist in future management of flows that may help conserve the species.

Sensitive habitats to flow fluctuations could be identified and prioritized for monitoring.
  - Assess the effects of TMFs and other dam operations on razorback sucker.

  This research would allow us learn how razorback suckers are using the action area and how the proposed action might be modified to benefit and/or minimize effects to razorback suckers from the proposed action.

- The conservation measures that address removal and/or control of nonnative fish would all lead to beneficial impacts on razorback sucker habitat by reducing competition and predation and perhaps aid in improving recruitment of suckers to the limited population in Grand Canyon.

Over the long-term, these actions should increase the sustainability and resiliency of razorback sucker critical habitat (particularly through implementation of the HFEs designed to build backwater habitat and steady flow experiments that may benefit the food base and larval rearing habitats). Therefore, implementation of the LTEMP is not expected to further diminish the conservation contribution of critical habitat to the recovery of the razorback sucker.

Kanab ambersnail

Components of the proposed action that have the potential to affect Kanab ambersnails and their habitat include sediment-related experiments (such as HFEs) and nonnative vegetation management. Other experiments or changes in dam operations included in the proposed action (i.e., changes in base operations, TMFs, nonnative fish control, low summer flows, and sustained low flows for invertebrates) would have no impact on the Kanab ambersnail, because these activities would not occur in occupied areas or in suitable habitat. The effects of changes in base operations, low summer flows, and sustained low flows for invertebrates would be limited to areas within the river channel, where no Kanab ambersnails or habitat occur. Nonnative fish control would occur in the river, in the vicinity of the Little Colorado River inflow, which does not contain habitat for Kanab ambersnail; however, no fish control would occur in off-channel springs.

<u>Effects of Experimental Elements</u>

Effects of Sediment-Related Experimental Treatments

Within the Grand Canyon, populations of the Kanab ambersnail occur at Vasey's Paradise and Elves Chasm. Because the Elves Chasm population is located above the 100,000 cfs stage (USFWS 2008), this population would not be affected by any of the proposed actions. At Vasey's Paradise, the proposed action will have no effect on the water flow from the side canyon spring that maintains wetland and aquatic habitat at Vasey's Paradise. However, some Kanab ambersnail habitat would likely be adversely affected by scouring if river flows exceed 17,000 cfs (Kennedy and Ralston 2011). The HFE's proposed under LTEMP may reach flows of up to 45,000 cfs which at that stage would inundate approximately 16.4% of the Kanab ambersnail habitat at Vasey's Paradise and likely scour the vegetation and wash some snails downstream.

Most Kanab ambersnail habitat at Vasey's Paradise is located above the 33,000 cfs stage (Reclamation 2011b) and very little habitat and few individuals occur below the 25,000 cfs stage (Meretsky and Wegner 2000, Sorensen 2009). Surveys conducted following HFEs to date did not detect substantial declines in the Kanab ambersnail population (Kennedy and Ralston 2011). This may be due in part to the fact that Kanab ambersnails can survive up to 32 hours underwater in cold, well-oxygenated water (USFWS 2011a); so as long as they are not washed away, Kanab ambersnails could survive inundation from short-term HFEs.

Recovery of Kanab ambersnail habitat scoured by HFEs can take up to 2.5 years (Sorensen 2009). Therefore, frequent HFEs may result in long-term loss of Kanab ambersnail habitat (USFWS 2011a). Under LTEMP, HFEs could occur much more frequently than they have under baseline conditions (19.3 HFEs, or one almost every year, could occur over the life of LTEMP). This means that the loss of habitat due to scouring could extend several years beyond the LTEMP period at Vasey's Paradise. In addition, depending on the elevation of maximum dam discharge during TMFs, temporary scouring of habitat could occur during those flows as well; however, these flows would be unlikely to reach Kanab ambersnail habitat that is above the 30,000 cfs elevation. Therefore, due to the fact that most snails and their habitat are above the level that would be affected by HFEs, implementation of LTEMP should not diminish the long-term sustainability of the population at Vasey's Paradise.

Effects of Native and Nonnative Plant Management and Experimental Treatments

Vegetation management may occur, on rare occasions, near or within habitat at Vasey's Paradise, which could result in disturbance to Kanab ambersnails within small areas. If nonnative vegetation encroaches on the spring during the life of LTEMP, careful manual removal of the vegetation would occur. If removal of vegetation at Vasey's Paradise occurs, biologists would conduct surveys and relocate any ambersnails found to habitat away from the treatment area. Because ambersnails can be difficult to locate, it is possible that some individual snails could be killed during the vegetation treatment; however, pre-treatment surveys and relocation of snails would minimize the loss of snails. In addition, vegetation management should aid in maintaining ambersnail habitat.

Effects of Conservation Measures

Kanab ambersnail monitoring would continue under the LTEMP. Monitoring would allow for detection of any declines in the population and/or changes to habitat.

Summary

In summary, the LTEMP flow actions most likely to result in adverse effects (i.e., inundation and scouring of habitat) to Kanab ambersnails are HFEs. Other experiments or changes in dam operations included in the proposed action (i.e., changes in base operations, TMFs, nonnative fish control, low summer flows, and sustained low flows for invertebrates) would have no impact on the Kanab ambersnail, because these activities would not occur in occupied areas or in suitable habitat.

CUMULATIVE EFFECTS

Cumulative effects include the effects of future State, tribal, local or private actions that are reasonably certain to occur in the action area considered in this biological opinion. Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the Act. The Colorado River Watershed within the action area is predominately managed by the NPS. Since the land within the action area is almost exclusively managed by the NPS, most activities that could potentially affect listed species are Federal activities and subject to additional section 7 consultations.

Humpback chub and critical habitat

Cumulative effects to the humpback chub and its critical habitat outside of NPS lands stem from Native American actions, and State, local, or private actions in tributary watersheds upstream of the action area. Native American use of the Colorado River in Grand Canyon includes cultural, religious, and recreational purposes, as well as land management of tribal lands (e.g. recreational use including rafting, hunting, and fishing). These uses are projected to have minimal effects to humpback chub and its critical habitat due to the small scale at which they occur.

The Navajo Nation has proposed a 420-ac development project, known as the Grand Canyon Escalade, on the Grand Canyon's eastern rim on the western edge of the Navajo reservation at the confluence of the Little Colorado and Colorado rivers. The development would include a gondola to transport visitors 3,200 ft from the rim to the canyon floor. On the rim, the development would include retail shops, restaurants, a museum, a cultural/visitor center, a hotel, multiple motels and shops, a lodge with patio, roads, and parking for cars and recreational vehicles. Analysis for this project has not been conducted, so impacts have not been fully determined; however, the construction and operation of the Escalade project could result in adverse impacts on natural and cultural resources in the areas of the Little Colorado River confluence, wilderness, visual resources, and resources of importance to multiple Tribes.

There is the potential for non-native fishes, including those hosting parasites, to invade the lower Little Colorado River from upriver sources 155 miles (250 km) away during certain flood events travelling through the intermittent river segments (Stone et al. 2007). Non-native fishes stocked into the area in Arizona utilizing federal funds have been evaluated under section 7 and are not anticipated to significantly affect humpback chub or its critical habitat (USFWS 2011c).

Non-Federal actions on the Paria River and Kanab Creek are limited to small developments, private water diversions, and recreation, and are expected to continue to have little effect on humpback chub and its critical habitat because these effects are diffuse over a wide area, and are distant from humpback chub and its critical habitat.

Increased uranium mining on state and private lands could increase the amount of uranium, arsenic, and other trace elements in local surface water and groundwater flowing into the Colorado River (Alpine 2010). Uranium, other radionuclides, and metals associated with uranium mines can affect the survival, growth, and reproduction of aquatic biota. However, aquatic biota and habitats most likely to be affected during mine development and operation are those associated with small, ephemeral, or intermittent drainages, which are not areas used by humpback chub or razorback sucker in the action area and do not connect to habitats used by these fish within the action area.

In addition, although the Little Colorado River stretches almost 550 km (340 mi), only the headwaters and the lowermost reaches flow year-round. The lower 21 km (13 mi) of the Little Colorado River is fed by groundwater springs. As stated earlier in the document, this reach of the Little Colorado River is occupied by the largest self-sustaining population of humpback chub, and the lower 13 km (8 mi) is designated critical habitat. These water sources may also be vulnerable to basin-wide drought and climate change impacting overall habitat availability and the humpback chub. As the population in the Basin States grows and expands, municipal, industrial, and agricultural water demand continues to increase. A study in 2012 showed that the demand for Colorado River Basin water may exceed supply before 2060 (Reclamation 2012a), which may result in lower Lake Powell levels and changes in flow, sediment, and water temperature regimes in the Grand Canyon.

Razorback sucker and critical habitat

Razorback sucker and its critical habitat would be affected through the same activities as humpback chub and its critical habitat.

Kanab ambersnail

Kanab ambersnail occurrence in the action area is entirely on Federal lands managed by Grand Canyon National Park. However, their habitat is created by springs, and it is conceivable that a non-Federal action could affect the ground water that supplies these springs. We are currently unaware of any possible future non-Federal actions that affect the aquifers that create Kanab ambersnail habitat. Extended drought is currently affecting the flow of water Vasey's Paradise and we expect continued drought as a result of climate change will continue to reduce habitat at this site. Fortunately, the Elves Chasm site has not suffered the same drying effects from drought.

Climate change

Climate change is predicted to affect climate and hydrology in the region, which could affect humpback chub, razorback sucker, and Kanab ambersnails within the action area. In the arid/semiarid western states, climate change is having serious consequences on the region's scarce water supplies; this particularly applies to the snow that makes up most of the region's precipitation and that, when melted, provides 70% of its water. To date, decreases in snowpack, less snowfall, earlier snowmelt, more winter rain events, increased peak winter flows, and reduced summer flows in rives have been documented (Saunders et al. 2008).

A key Reclamation document that provides information regarding climate change is the 2011 SECURE Water Act Report (Reclamation 2011c). In this report, Reclamation identified challenges likely to occur within the Colorado River Basin:

- On average, Colorado River Basin temperature is projected to increase by 5 to 6°F during the 21st century, with slightly larger increases projected in the upper Colorado Basin.
- Precipitation is projected to increase by 2.1% in the upper basin while declining by 1.6% in the lower basin by 2050.
- Mean annual runoff is projected to decrease by 3.5 to 8.5% by 2050.
- Warmer conditions will likely transition snowfall to rainfall, producing more December to March runoff and less April to July runoff.

Warmer climatic and weather conditions may also cause changes to fisheries habitat, shifts in species geographic ranges, increased water demands for instream ecosystems and thermoelectric power production, increased power demands for municipal uses (including cooling), and increased likelihood of invasive species infestations. These effects could substantially change the environmental baseline of the humpback chub, razorback sucker, and Kanab ambersnail.

Although no studies specifically evaluate the potential effects of climate change on Lake Powell or the Colorado River between Lake Powell and Lake Mead, decreases in Lake Powell elevation and corresponding increases in temperatures of water releases from Glen Canyon Dam and in water temperature of the Colorado River downstream (as well as to tributaries of the Colorado River) are important potential effects of climate change on the project area. Projections of future supply and demand in the basin indicate that inflows into Lake Powell may decrease, and the effect of climate change is likely to exacerbate this effect (Reclamation 2012b). Climate-induced changes in inflow, evaporation, and evapotranspiration all have the potential to influence water quality. For example, increased temperatures would increase metabolic rates of aquatic biota, increasing the demand for nutrients and oxygen, and potentially changing the quality of habitat for various organisms (Wrona et al. 2006, Heino et al. 2009, Woodward et al. 2010).

Increases in the water temperature of the Colorado River mainstem and its tributaries in the Grand Canyon due to climate change could expand the distribution of warmwater-adapted nonnative fishes (Eaton and Scheller 1996, Rahel and Olden 2008), which can prey on and compete with native fishes such as endangered humpback chub and razorback sucker. Climate-change-driven warmer water temperatures across the United States are predicted to expand the distribution of existing aquatic nonnative species by providing 31% more suitable habitat for aquatic nonnative species, based upon studies that compared the thermal tolerances of 57 fish species with predictions made from climate change temperature models (Mohseni et al. 2003). Climate change also may facilitate expansion of nonnative parasites such as Asian tapeworm (Rahel et al. 2008), another threat to native fishes. Cold water temperatures in the mainstem Colorado River in Marble and Grand Canyons have so far prevented these warmwater fishes and parasites from expanding their distribution in the project area. Warmer climate trends could result in warmer overall water temperatures, increasing the prevalence of these species and threating native fish populations.

In addition to water temperature, other aspects of water quality are also affected by Lake Powell's elevation. Dissolved oxygen concentrations in the tailwater are usually slightly below saturation but have not dropped to concentrations low enough to affect the aquatic ecosystem in the Grand Canyon. However, climate-change driven decreases in the elevation of Lake Powell could increase the chances of water that is low in dissolved oxygen being released from Glen

Canyon Dam (Vernieu et al. 2005). Similarly, an increase in water temperatures of the Colorado River driven by climate change could cause low levels of dissolved oxygen in Lake Mead that could adversely affect native and nonnative fish (Tietjen 2014).

CONCLUSION

After reviewing the current status of the humpback chub and its critical habitat, the razorback sucker and its critical habitat, and the Kanab ambersnail, the environmental baseline for the action area, the effects of the proposed action, and the cumulative effects, it is our biological opinion that the LTEMP, as proposed, is not likely to jeopardize the continued existence of these species, and is not likely to destroy or adversely modify designated critical habitat for the humpback chub and razorback sucker. No critical habitat has been designated for the Kanab ambersnail; therefore, none will be affected. We base these conclusions on the following:

<u>Humpback chub and critical habitat</u>

- LTEMP includes implementation of ongoing and new conservation measures that are designed to reduce the effects of the proposed action and improve the status of humpback chub. Conservation measures identified in the 2011 BO on operations of Glen Canyon Dam (USFWS 2011a) included the establishment of a humpback chub refuge, which has been created and will continue to be funded as a part of this action. Other conservation measures include humpback chub translocation; Bright Angel Creek brown trout control; determination of the feasibility of flow options to control trout, including increasing daily down-ramp rates to strand or displace age-0 trout, and high flow followed by low flow to strand or displace age-0 trout; assessments of the effects of actions on humpback chub populations; sediment research to determine effects of equalization flows; and Asian tapeworm monitoring. Conservation measures that were not completed are ongoing and are elements of existing management practices (e.g., brown trout control, humpback chub translocation, and sediment research to determine the effects of equalization flows), while new conservation measures or adjustments to the existing ones have been developed for the proposed action. Many of these conservation measures meet management objectives identified in the Humpback Chub Recovery Goals (USFWS 2002a), including investigating the anticipated effects of and options for providing warmer water temperatures in the mainstem Colorado River through Grand Canyon, ensuring adequate protection from diseases and parasites, and the regulation and control of nonnative fish.

- Population modeling indicates an overall upward trend in the number of adult humpback chub over the last decade in the action area, which continues to be the largest population range wide. This is in part due to humpback chub populations in the Little Colorado River which is largely unaffected by dam operations. The upward trend is also likely due to implementation of the ongoing conservation measures (translocations, nonnative control, triggered mechanical removal, triggered proactive conservation actions, and other conservation measures) associated with LTEMP that have resulted in beneficial effects to humpback chub in the action area.

- New conservation actions for humpback chub include expanding the Havasu Creek translocation area; identifying new translocation areas; exploring the efficacy of a temperature control device at the dam to respond to potential extremes in hydrological conditions due to climate change that could result in nonnative fish establishment; pursuing means of preventing the passage of deleterious invasive nonnative fish through Glen Canyon Dam; completion of planning and compliance to alter the backwater slough at RM12, making it unsuitable or inaccessible to warmwater nonnative species; and, completing planning and compliance of a plan for implementing rapid response control efforts for deleterious invasive nonnative species within and contiguous to the action area. These conservation measures are designed to minimize or reduce the effects of the proposed action or benefit or improve the status of listed species as part of the LTEMP.

- The proposed action includes funding and support of projects to monitor and evaluate the effect of the proposed action including various monitoring and research projects of the GCDAMP annual work plans, which will provide timely information if the trend in the humpback chub population were to change. In addition, the proposed action requires the action agencies to respond where necessary, in consultation with the FWS, to respond to unanticipated or adverse effects that would be taken to reverse significant declines in the humpback chub population.

- Although LTEMP would result in adverse effects to some PCEs, the proposed action overall would maintain, and likely enhance, the function and conservation role of critical habitat for the humpback chub.

<u>Razorback sucker and critical habitat</u>

- Although razorback sucker appear to be increasing within the action area, they are still relatively rare and it is unclear if much of the action area would ever provide suitable habitat for all life stages. However, implementation of LTEMP is likely to improve habitat through experimental steady flows and the required adaptive management. The research and monitoring included as part of the proposed action will allow FWS and the action agencies to adjust management as necessary to aid razorback survival and recovery.

- LTEMP includes experimental components that would likely improve habitat for razorback suckers within the action area. There is the potential for creation of warm, productive nursery habitats for razorback suckers from increased reshaping of nearshore deposits and backwater development resulting from HFEs.

- Although LTEMP would result in adverse effects to some PCEs, overall, the proposed action would maintain, and likely enhance, the function and conservation role of critical habitat for the razorback sucker within the action area. Conservation measures identified in the 2011 BO on operations of Glen Canyon Dam (USFWS 2011a) included the evaluation of the suitability of habitat in the lower Grand Canyon for the razorback sucker, which was initiated under the 2011 BO and will continue under the proposed action. In addition, the proposed efforts to control nonnative fish in the project area, is an identified management action in the Razorback Sucker Recovery Goals (USFWS 2002b) and will aid in creation of more suitable habitat for suckers in the project area.

Kanab ambersnail

- Most snails and their habitat are above the level that would be affected by HFEs; therefore, implementation of LTEMP should not affect the sustainability of the population at Vasey's Paradise.

- The Elves Chasm population would not be affected by any of the proposed actions.

- Monitoring status of Kanab ambersnails would continue under the proposed action an ongoing conservation measure.

The conclusions of this biological opinion are based on full implementation of the project as described in the Description of the Proposed Action section of this document, including any Conservation Measures that were incorporated into the project design**.**

INCIDENTAL TAKE STATEMENT

Section 9 of the Act and Federal regulations pursuant to section 4(d) of the Act prohibit the take of endangered and threatened species, respectively, without special exemption. "Take" is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. "Harm" is further defined (50 CFR § 17.3) to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. "Harass" is defined (50 CFR § 17.3) as intentional or negligent actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding or sheltering. "Incidental take" is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the Act provided that such taking is in compliance with the terms and conditions of this Incidental Take Statement.

The measures described below are non-discretionary, and must be undertaken by Reclamation so that they become binding conditions of any grant or permit issued, as appropriate, for the exemption in section 7(o)(2) to apply. Reclamation has a continuing duty to regulate the activity covered by this incidental take statement. If Reclamation (1) fails to assume and implement the terms and conditions or (2) fails to require the (applicant) to adhere to the terms and conditions of the incidental take statement through enforceable terms that are added to the permit or grant document, the protective coverage of section 7(o)(2) may lapse. In order to monitor the impact of incidental take, Reclamation must report the progress of the action and its impact on the species to the FWS as specified in the incidental take statement. [50 CFR § 402.14(i)(3)].

AMOUNT OR EXTENT OF TAKE

Humpback chub

Incidental take of humpback chub is reasonably certain to occur as a result of implementation of the LTEMP. This incidental take is expected to be in the form of harm (including direct fatality) and harassment resulting from the effects of the proposed action on chub. Incidental take could potentially occur from the stranding of young chub (larval and small juvenile fish only as medium and large juvenile fish are unlikely to be stranded due to their increased swimming ability) during base operations, sediment-related flow actions (HFEs), and TMFs. In addition, there is likely to be ongoing harassment to an unknown number of chub from the degraded food base which could affect all size classes of chub through non-lethal harassment. The FWS anticipates incidental take of humpback chub would be difficult to detect for the following reason(s): 1) dead or impaired individuals are almost impossible to find (and are readily consumed by other fish or predators) and losses of fish may be masked by seasonal fluctuations in environmental conditions; 2) the humpback chub estimated population is changing over time through immigration, emigration, and natural loss; 3) the species occurs within almost 300 miles of river within the action area in extremely remote locations, so individual fish are difficult to locate; and, 4) the larvae and small juvenile life stages of chub that are most at risk to the changing water levels associated with flow actions are already the most vulnerable life stages to natural mortality factors (i.e., predation) and are extremely difficult to monitor. However, even though it is difficult to find, assess, and monitor small-bodied life stages of chub, we are not using a surrogate to estimate the amount of incidental take for the species, but are estimating the number based on modeling conducted for humpback chub in the Little Colorado River (Pine et al. 2013). This is currently the best available information regarding how many chub may be incidentally taken from the population without affecting the species persistence within the action area, which is why we are using this information in this BO to calculate the incidental take.

The Little Colorado River is responsible for much of the recruitment and persistence of humpback chub in the Lower Basin and project area. Most of the larval humpback chub produced in the Little Colorado River are protected from flow actions because the Little Colorado River itself is really not affected by flow actions associated with LTEMP (see Effects section). As stated in the Environmental Baseline, recent survey data indicates that the relative abundance of adult humpback chub in Colorado River mainstem aggregations has increased (Persons et al., *In review*). Additionally, an aggregation consisting of between 300-600 individuals has been found near 34-Mile in Marble Canyon and there appears to have been a dramatic increase in the absolute abundances of humpback chub in western Grand Canyon (roughly Havasu Creek downriver), with all size classes being represented. Because of this, we expect that incidental take of larval and small juvenile fish as a result of the proposed action would occur only in the mainstem Colorado River, where fish could be stranded and/or habitat is desiccated as a result of flow actions associated with LTEMP.

Under existing management of Glen Canyon Dam, numbers of humpback chub in the mainstem and the Little Colorado River have been stable (Van Haverbeke et al, 2013, Yackulic et al. 2015). Pine et al. (2013) assessed extinction risk and resiliency of humpback chub in Grand Canyon using a population viability assessment (PVA) model to evaluate incidental or permitted take. This assessment was conducted to model the effects to the chub population in the Little Colorado River of culling of larval and small juvenile humpback chub to translocate to new areas; but, the model results are also applicable to determining a number of chub that could be incidentally taken as a result the proposed LTEMP action (Pine et al. 2013). The model assessed the change in the number of age-1 and older humpback chub from cropping either 10% or 50% of the available female fish from different size classes in the Little Colorado River. The calculated yield is the average number of fish available for cropping in the last year of a five year removal period (Pine et al. 2013). Based upon the PVA model and results, at the 50% cropped level, 127,000 to 128,000 larval fish <30 mm TL and 7,500 to 8,000 small juvenile 30-60 mm TL fish could be cropped from the Little Colorado River, before a decline in the adult population would occur. Both of these modeled scenario runs resulted in a "0" extinction probability (Pine et al. 2013).

Therefore, we think it is appropriate to use the PVA model data from the Little Colorado River to estimate the number of larval and/or small juvenile chub that could be incidentally taken as a result of flow actions associated with LTEMP. We know that spawning and recruitment is occurring within the Colorado River based on recent survey data of mainstem aggregations. Hence, we are using the PVA model estimates to provide estimated numbers of larval and small juvenile chub in the mainstem that could be harmed as a result of LTEMP flow actions and not affect humpback chub survival and recovery. We would consider incidental take to be exceeded if more than 128,000 larvae (chub less than 30 mm total length [TL] and 8,000 small juveniles (chub 30-60 mm TL) are stranded as a result of base operations and flow actions (sediment-related flow actions or TMFs) in a five year period. This incidental take also accounts for reduced reproduction in individual chub that may be negatively impacted through reduced fitness, but not killed, as a result of a degraded food base due to the proposed action.

Pine et al. (2013) found that the Little Colorado River population of humpback chub is robust to removals of up to 50% of the larvae or small juveniles over a five year period. There is also evidence to suggest there are other mainstem aggregations of humpback chub contributing to recruitment of chub to the lower basin (below Glen Canyon dam) chub population; therefore, basing the number of fish that could be incidentally taken as a result of the action on the Little Colorado River population would further ensure that this expected take would not jeopardize the chub by significantly reducing either survival or recovery potential.

Incidental take within these limits would still allow for recruitment to the adult population. Recruitment is important to survival and recovery of the species because species only persist when they successfully reproduce and enough of those young fish survive to reproductive age, and produce more fish. In addition, ongoing population monitoring would continue under the proposed action. Incidental take from fatality would be predominantly to larvae (<30 mm TL) and small juvenile (30-60 mm TL) humpback chub, size classes that have high mortality rates, and thus losses of this amount would not result in an appreciable loss of recruitment to the adult population (Pine et al 2013). Further, ongoing population monitoring, as well as additional conservation actions (i.e., tiered, triggered conservation actions which include predator removal either through flow actions or mechanical means) and other aspects of Reclamation's proposed action are designed to be implemented to ensure that the humpback chub status does not decline and continues the improvement in population numbers seen over the last decade.

While we have estimated the number of humpback chub that could be incidentally taken as a result of the proposed action, as described above, we acknowledge that assessing and monitoring the incidental take of larval and small juvenile humpback chub associated with this action is extremely difficult. We have no feasible means of locating these fish when nearshore habitat or backwater habitats become separated from the mainstem Colorado River and potentially desiccate due to dropping water levels. Therefore, we are quantifying the incidental take of larval and small juvenile fish based upon the information in Pine et al. (2013) as described above; however, we are basing the measure of our exceedance criteria on the action triggers identified in the "Proposed Action Triggers for the Management of Humpback Chub" (Young et al. 2015, Appendix D in BA). If the Tier 1 (point abundance estimate for adult chub in the Colorado River mainstem aggregation and Little Colorado River fall below 9,000 as estimated by the currently accepted population model OR if recruitment of sub-adult chub [150-199 mm] does not equal or exceed estimated adult mortality as described in document) and Tier 2 triggers (point abundance estimate of adult chub decline to <7,000 fish, as estimated by the currently accepted humpback chub population model) are met and the prescribed conservation measures and remedial actions under each trigger do not mitigate a decline in the humpback chub population, then incidental take will have been exceeded. Additionally, as described in Young et al. (2015), if monitoring detects declines in the humpback chub, the FWS, in coordination with action agencies and traditionally associated Tribes, will identify appropriate actions to reverse the decline.

<u>Razorback sucker</u>

Incidental take of razorback sucker is reasonably certain to occur as a result of implementation of the LTEMP. This incidental take is expected to be in the form of harm (including direct fatality) and harassment resulting from the effects of the proposed action on razorback suckers. The FWS anticipates incidental take of razorback suckers would be difficult to detect for the following reason(s): 1) dead or impaired individuals are almost impossible to find (and are readily consumed by predators) and losses may be masked by seasonal fluctuations in environmental conditions; 2) the status of the species within the action area is still relatively unknown; 3) at some stages of development razorback and flannelmouth suckers are too small for species identification in the field; 4) the species is very rare in the action area; and, the species occurs within almost 100 miles of river within the action area in extremely remote locations, so individual fish are difficult to locate. Because razorback suckers are extremely rare within the project area and it is impossible in the field to identify larval razorback suckers from larval flannelmouth suckers, we are using flannelmouth suckers as a surrogate for incidental take of razorback suckers. Larval flannelmouth sucker occupy the same habitats within the project area as larval razorback suckers that may be affected by the proposed action, but flannelmouth sucker are more abundant and changes in recruitment of young fish can be estimated as described below. Therefore, we think that it appropriate to measure flannelmouth sucker recruitment responses over time to base operations and flow actions (e.g., HFEs, TMFs) that could result in take of larval fish, as a surrogate measure for incidental take of razorback suckers.

Incidental take is expected to occur due to stranding of larval razorback sucker in nearshore habitats as a result of base operations (daily fluctuating flows, including increased downramp rates) and HFEs. Based on the analysis presented in the Effects of the Action section of this BO, an unknown number of larval razorback suckers have the potential to be killed or harmed with implementation of the LTEMP, as these fish would be unable to swim out of backwaters or nearshore habitats that become disconnected or even desiccate as a result of flow actions. As stated above, we cannot measure the number of razorback suckers taken as a result of this action because razorback suckers are rare and we have very little data on actual numbers of adult, larval, or other age/size classes of suckers that may be present in western Grand Canyon.

Flannelmouth sucker are known to hybridize with razorback suckers and the two species habitat needs overlap in western (lower) Grand Canyon. While there are differences between the two species, the similarities in spawning requirements have resulted in these two sucker species hybridizing throughout their ranges, particularly where flannelmouth are abundant. In addition, both larval flannelmouth and razorback suckers are occurring in the same or similar habitats in western Grand Canyon. Although juvenile razorback suckers were not captured during small-bodied fish community sampling in 2013–2014 (juvenile fish are a later stage of development than larval fish), Albrecht et al. (2014) used flannelmouth sucker capture information to show that should small-bodied razorback suckers occur within the lower Grand Canyon, the monitoring methods used would allow for razorback sucker captures in the future. Therefore, there is some precedent in this system for using flannelmouth suckers as a surrogate species for razorback suckers.

Currently, flannelmouth suckers are reproducing and recruiting in the areas of western Grand Canyon where razorback suckers are thought to have spawned and larval fish have been detected. Therefore, we are using adult flannelmouth sucker as a surrogate for recruitment of larval razorback sucker into the population. This would be measured using CPUE data collected by AGFD on their yearly Colorado River System-Wide Electrofishing surveys. The primary goal of the System Wide Electrofishing project is to provide baseline status and trend information on native and nonnative fish in the Colorado River from Lees Ferry to Lake Mead (Rogowski et al. 2015).

We will consider incidental take of razorback suckers to be exceeded if actions associated with LTEMP base operations and experimental flow actions result in a statistically significant decline (95% confidence intervals) in mean catch per unit effort (CPUE) of adult flannelmouth suckers for a consecutive 3-year period following the occurrence of experimental flow(s) actions. This would be measured using CPUE data collected by AGFD in lower Grand Canyon where flannelmouth sucker overlap with known locations of larval razorback suckers (approximately from RM 179.1 to RM 225 [AGFD sampling Reach 5] and >RM 225 [AGFD sampling Reach 6]). We are providing for a relatively large change in the adult flannelmouth sucker mean CPUE to account for natural variability and for possible shifts in the CPUE following large flannelmouth sucker recruitment events that could result in mature fish moving upstream, out of the identified river reaches. Although using the relatively abundant flannelmouth sucker as a surrogate for the relatively rare razorback sucker is not ideal, our reasoning is that a reduction in the flannelmouth sucker population in the identified sampling reaches would provide for reasonable inference of a concomitant reduction in the confamilial razorback sucker.

Kanab ambersnail

Incidental take of Kanab ambersnails is reasonably certain to occur as a result of implementation of the LTEMP. This incidental take is expected to be in the form of harm (including direct fatality) and harassment resulting from the effects of the proposed action on snails. The FWS anticipates incidental take of Kanab ambersnails would be difficult to detect for the following reason(s): 1) ambersnails are difficult to detect when alive due to their small size, finding dead or impaired individuals would be almost impossible; and, 2) losses of ambersnails may be masked by seasonal fluctuations in environmental conditions.

The level of take that could occur from the proposed action would be in the form of harm or fatality resulting from scouring of habitat during the highest flows of the proposed action. The number of individual snails cannot be estimated because of seasonal and annual fluctuations in the population; therefore, as a surrogate measure of take, we will consider incidental take to be exceeded if photo monitoring of the habitat following an HFE shows that more than 17% of Kanab ambersnail habitat is removed at Vasey's Paradise in any one year and this loss is attributable to LTEMP flow actions. The anticipated take is not expected to substantially diminish the size or vigor of the Vasey's Paradise population because these areas are not currently providing habitat for most of the population. Approximately 16.4% of the population occurs below the elevation of 45,000 cfs flow. Since experimental HFE flows could be as much as 45,000 cfs, if more than 17% of the habitat is inundated in a year, then incidental take would be exceeded.

The Elves Chasm population is located above the elevation of 45,000-cfs flow; therefore we do not expect any incidental take resulting from flow operations at this site.

EFFECT OF THE TAKE

In this biological opinion, the FWS determines that this level of anticipated take is not likely to result in jeopardy to the humpback chub, razorback sucker, or Kanab ambersnail, or destruction or adverse modification of critical habitat for the reasons stated in the Conclusions section.

REASONABLE AND PRUDENT MEASURES

Humpback chub

We determine that the proposed action incorporates sufficient conservation measures that reasonably and prudently minimize the effects of incidental take of humpback chub as well as aim to maintain and improve the status of the species. The proposed conservation measures are at least as strong, and likely stronger, than any reasonable and prudent measures we would require. The FWS worked with Reclamation, NPS, and GCMRC to review ongoing conservation actions and reasonable and prudent measures from past biological opinions and identify new conservation measures for the action area, and all measures were incorporated into the proposed action. Thus, no reasonable and prudent measures are included in this incidental take statement.

Razorback suckers

We determine that the proposed action incorporates sufficient conservation measures that reasonably and prudently minimize the effects of incidental take of razorback suckers. All reasonable measures to minimize take have been incorporated into the project description. Thus, no reasonable and prudent measures are included in this incidental take statement. The FWS worked collaboratively with Reclamation and NPS to ensure that all conservation measures needed to minimize the effect of incidental take were included in the proposed action.

Kanab ambersnail

We determine that the proposed action incorporates sufficient conservation measures (Kanab ambersnail monitoring and reporting) that reasonably and prudently minimize the effects of incidental take of Kanab ambersnails. All reasonable measures to minimize take have been incorporated into the project description. Thus, no reasonable and prudent measures are included in this incidental take statement.

Disposition of Dead or Injured Listed Species

Upon locating a dead, injured, or sick listed species initial notification must be made to the FWS's Law Enforcement Office, 4901 Paseo del Norte NE, Suite D, Albuquerque, NM 87113; 505-248-7889) within three working days of its finding. Written notification must be made within five calendar days and include the date, time, and location of the animal, a photograph if possible, and any other pertinent information. The notification shall be sent to the Law Enforcement Office with a copy to this office. Care must be taken in handling sick or injured animals to ensure effective treatment and care, and in handling dead specimens to preserve the biological material in the best possible state.

CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the Act directs Federal agencies to utilize their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help implement recovery plans, or to develop information.

1. We recommend that Reclamation and NPS work with FWS, Tribes, GCMRC, AGFD, and other partners to continue discussions regarding the taking of life related to nonnative fish control and to further discussions regarding the beneficial use of fish killed as a result of implementation of the conservation measures associated with LTEMP (e.g., nonnative removal). We support selecting for actions that do not result in the taking of life and ensuring beneficial use of life taken occurs, but we would like to pursue further discussions with the Tribes regarding how we practicably and efficiently implement ways to disadvantage nonnative species, achieve beneficial use, and expand upon the potential uses that could be considered beneficial.

2. We recommend that Reclamation, NPS, FWS, AGFD, GCMRC, and other partners review and consider modifying the timeframe for implementing TMFs specifically to control brown trout, and consider modifying the HFE protocol if implementation of HFEs is found to be associated with brown trout recruitment. Additional planning and compliance may be needed in order to make modifications to flow actions.

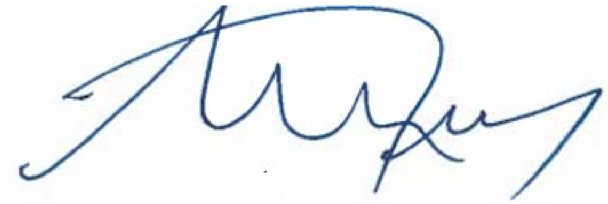
In order for the FWS to be kept informed of actions minimizing or avoiding adverse effects or benefiting listed species or their habitats, the FWS requests notification of the implementation of any conservation recommendations.

REINITIATION NOTICE

This concludes formal consultation on the action(s) outlined in the (request/reinitiation request). As provided in 50 CFR 402.16, reinitiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained (or is authorized by law) and if: (1) the amount or extent of incidental take is exceeded; (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion; (3) the agency action is subsequently modified in a manner that causes an effect to the listed species or critical habitat not considered in this opinion; or (4) a new species is listed or critical habitat designated that may be affected by the action. In instances where the amount or extent of incidental take is exceeded, any operations causing such take must cease pending reinitiation.

In keeping with our trust responsibilities to American Indian Tribes, we encourage you to continue to coordinate with the Bureau of Indian Affairs in the implementation of this consultation and, by copy of this biological opinion, are notifying the Havasupai Tribe, Hopi Tribe, Hualapai Tribe, Kaibab Band of Paiute Indians, Las Vegas Paiute Tribe, Moapa Band of Paiute Indians, Navajo Nation, Pueblo of Zuni, Shivwits Band of Paiute Indians, Southern Paiute Consortium, Ute Mountain Ute Tribe, Yavapai-Apache Nation, and Bureau of Indian Affairs of its completion. We also encourage you to coordinate the review of this project with the Arizona Game and Fish Department.

We appreciate the Reclamation’s efforts to identify and minimize effects to listed species from this project. Please refer to the consultation number, 02EAAZ00-2012-F-0059 in future correspondence concerning this project. Should you require further assistance or if you have any questions, please contact Shaula Hedwall at (928) 556-2118 or Brenda Smith at (928) 556-2157.



/s/ Steven L. Spangle

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APPPENDIX A – CONCURRENCES

This appendix contains our concurrences with your "may affect, not likely to adversely affect" determinations for the endangered southwestern willow flycatcher (*Empidonax traillii extimus*) and the endangered Yuma Ridgway's rail (*Rallus obsoletus yumanensis*).

Southwestern willow flycatcher

We concur with your determination that the proposed action may affect, but is not likely to adversely affect the endangered southwestern willow flycatcher. We base this concurrence on the following:

- Southwestern willow flycatchers are not expected to be in the action area when spring HFEs could occur (March – April). In addition, high flows of 45,000 cfs or less are not expected to have measurable effects on potential foraging or nesting habitat.

- Designated critical habitat for the southwestern willow flycatcher does not occur in the area of the proposed action; therefore, there will be no effects to critical habitat.

Yuma Ridgway's rail

We concur with your determination that the proposed action may affect, but is not likely to adversely affect the endangered Yuma Ridgway's rail. We base this concurrence on the following:

- The project area has very little cattail/marsh habitat that would provide suitable habitat for rails. In addition, due to the dropping water levels in Lake Mead, this potential habitat in the lowest portion of Grand Canyon is now ten or more feet above the flowing river level, and therefore is out of reach of fluctuating flows, including HFEs. Therefore, if rails used the habitat, it is not close enough to the river to be impacted by HFEs because HFEs have minimal stage change in this broad floodplain habitat.

- Designated critical habitat for the Yuma Ridgway's rail does not occur in the area of the proposed action; therefore, there will be no effects to critical habitat.

ATTACHMENT F:

STATEMENT OF NON-IMPAIRMENT DETERMINATION FOR THE SELECTED ALTERNATIVE

The National Park Service (NPS) is required by the *Management Policies 2006* (Section 1.4) to make a written determination regarding whether or not an NPS action would impair a park's resources and values. This non-impairment determination has been prepared for the selected alternative for the Long-Term Experimental and Management Plan (LTEMP), Alternative D, as described in the Record of Decision.

By enacting the NPS Organic Act of 1916 (Organic Act), Congress directed the U.S. Department of the Interior and the NPS to manage units "to conserve the scenery, natural and historic objects, and wild life in the System units and to provide for the enjoyment of the scenery, natural and historic objects, and wild life in such manner and by such means as will leave them unimpaired for the enjoyment of future generations" (54 U.S.C. 100101).

NPS *Management Policies 2006* (NPS 2006), Section 1.4.4, explains the prohibition on impairment of park resources and values:

> "While Congress has given the Service the management discretion to allow impacts within parks, that discretion is limited by the statutory requirement (generally enforceable by the federal courts) that the Park Service must leave park resources and values unimpaired unless a particular law directly and specifically provides otherwise. This, the cornerstone of the Organic Act, establishes the primary responsibility of the National Park Service. It ensures that park resources and values will continue to exist in a condition that will allow the American people to have present and future opportunities for enjoyment of them."

The NPS has discretion to allow impacts on park resources and values when necessary and appropriate to fulfill the purposes of a park (NPS 2006, Section 1.4.3). However, the NPS cannot allow an adverse impact that will constitute impairment of the affected resources and values (NPS 2006, Section 1.4.3). An action constitutes impairment when its impacts "harm the integrity of park resources or values, including the opportunities that otherwise will be present for the enjoyment of those resources or values" (NPS 2006, Section 1.4.5). To determine impairment, the NPS must evaluate the "particular resources and values that will be affected; the severity, duration, and timing of the impact; the direct and indirect effects of the impact; and the cumulative effects of the impact in question and other impacts: (NPS 2006, Section 1.4.5).

As stated in NPS *Management Policies 2006* (NPS 2006, Section 1.4.5), an impact on any park resource or value may constitute an impairment, but an impact would be more likely to constitute an impairment to the extent that it affects a resource or value whose conservation is:

- Necessary to fulfill specific purposes identified in the establishing legislation or proclamation of the park; or

- Key to the natural or cultural integrity of the park or to opportunities for enjoyment of the park; or

- Identified in the park's general management plan or other relevant NPS planning documents as being of significance.

The purpose and significance of both Glen Canyon National Recreation Area (GCNRA) and Grand Canyon National Park (GCNP) were considered during this impairment determination process for the selected action. GCNRA was established:

> "to provide for public outdoor recreation use and enjoyment of Lake Powell and lands adjacent thereto in the States of Arizona and Utah and to preserve scenic, scientific, and historic features contributing to public enjoyment of the area."

GCNP was established to:

> "provide for the recognition by Congress that the entire Grand Canyon, from the mouth of the Paria River to the Grand Wash Cliffs, including tributary side canyons and surrounding plateaus, is a natural feature of national and international significance."

Statements of a park's significance describe why a park is important within a global, national, regional, and ecosystem-wide context and are directly linked to the purpose of the park. For GCNP, additional significance is found in the 1979 World Heritage designation, which states "The Grand Canyon is among the earth's greatest ongoing geological spectacles. Its vastness is stunning; the evidence it reveals about the earth's history invaluable. The 1.5-kilometer (0.9 mile)-deep gorge ranges in width from 500 m to 30 km (0.3 mile to 18.6 miles). The Canyon twists and turns 445 km (276.5 miles), and was formed during six million years of geologic activity and erosion by the Colorado River on the earth's upraised crust. The Canyon's buttes, spires, mesas, and temples appear as mountains when viewed from the rims. Horizontal strata exposed in the canyon retrace geological history over two billion years and represent the four major geologic eras."

GCNP is significant for the following reasons:

- It one of the planet's most iconic geologic landscapes.

- During the last six million years, the Colorado River carved Grand Canyon; these same erosional and tectonic processes continually shape the canyon today. The Grand Canyon's exposed layers span more than one-third of the Earth's history and record tectonic and depositional environments ranging from mountain-building to quiet seas. Taken as a whole, the Grand Canyon, with its immense size, dramatic and colorful geologic record exposures, and complex geologic history, is one of our most scenic and scientifically valued landscapes.

- The force and flow of the Colorado River, along with its numerous and remarkably unaltered tributaries, springs, and seeps, provide plants and animals opportunity to flourish in this otherwise arid environment. These vital resources represent transmission of local aquatic recharge from high-elevation rims to the arid inner canyon. There are hundreds of known seeps and springs throughout the park, and probably more to be discovered.

- Wilderness landscapes are an important current resource and future preserve. Park boundaries extend beyond canyon walls to include 1,904 square miles (1,218,376 acres) of which 94% are managed as wilderness. When combined with additional contiguous public and tribal lands, this area makes up one of the largest U.S. undeveloped areas. The Grand Canyon offers outstanding opportunities for visitor experiences, including extended solitude, natural quiet, clean air, dark skies, and a sense of freedom from the mechanized world's rigors.

- GCNP contains a superlative array of natural resources. Much of this diversity can be attributed to the park's dramatic topographic spectrum. This elevational variety provides microhabitats for natural processes supporting rare and endemic plant and wildlife species. These diverse habitats serve as a living laboratory for scientific research in numerous fields that contribute greatly to our understanding of the relationship between biotic communities and abiotic environments.

- The human-Grand Canyon relationship has existed for at least 12,000 years. The Canyon is an important homeland for native people and a place of historic Euro-American exploration and discovery. Today that relationship continues; both for ongoing Native American associations and millions of visitors who visit the canyon and its surrounding landscapes.

- The Grand Canyon's immense and richly colored scenic vistas, enhanced by a natural setting, inspire a variety of emotional, intellectual, artistic, and spiritual impressions. Its unsurpassed natural beauty is a source of profound inspiration for people worldwide.

The purpose statement of GCNP further articulates the preservation mandate by stating that the mission is to preserve and protect the Grand Canyon's unique geologic, paleontologic, and other natural and cultural features for the benefit and enjoyment of the visiting public; provide the public opportunity to experience the Grand Canyon's outstanding natural and cultural features, including natural quiet and exceptional scenic vistas; and protect and interpret the Grand Canyon's extraordinary scientific and natural values.

Similarly, GCNRA, located at the center of the Colorado Plateau, provides for public enjoyment through diverse land- and water-based recreational opportunities, and protects scenic, scientific, natural, and cultural resources on Lake Powell, the Colorado River and its tributaries, and surrounding lands.

GCNRA is significant for the following reasons:

- The Colorado River and its many tributaries, including the Dirty Devil, Paria, Escalante, and San Juan Rivers, carve through the Colorado Plateau to form a landscape of dynamic and complex desert and water environments.

- The vast, rugged landscapes of GCNRA provide an unparalleled spectrum of diverse land- and water-based recreational opportunities for visitors of wide-ranging interests and abilities.

- GCNRA preserves a record of more than 10,000 years of human presence, adaptation, and exploration. This place remains significant for many descendant communities, providing opportunities for people to connect with cultural values and associations that are both ancient and contemporary.

- The deep, 15-mile-long, narrow gorge below the dam provides a glimpse of the high canyon walls, ancient rock art, and a vestige of the riparian and beach terrace environments that were seen by John Wesley Powell's Colorado River expedition in 1869, providing a stark contrast to the impounded canyons of Lake Powell.

For the selected alternative, a determination of non-impairment is made for each of the resources carried forward for detailed analysis in the Final Environmental Impact Statement (FEIS). Pursuant to the Guidance for Non-Impairment Determinations and the NPS NEPA Process (2011), impairment findings are not necessary for visitor experience, socioeconomics, public health and safety, environmental justice, land use, or park operations, because these impact topics are not generally considered to be park resources or values in this context (though some of these are considered "downstream resources" or values for the purposes of GCPA in the LTEMP FEIS), and are therefore not subject to the written impairment determination requirement found in NPS *Management Policies 2006*. A description of the current state of each of the resource topics evaluated for impairment can be found in Chapter 3 of the FEIS, "Affected Environment". Those carried forward for which a non-impairment determination has been completed include water resources, sediment, aquatic resources (including threatened and endangered species), vegetation, wildlife, cultural resources, and air quality.

Water Resources

The selected LTEMP alternative will change the operations of the Glen Canyon Dam. The Glen Canyon Dam controls the flow of the Colorado River through both park units and affects the reservoir levels in Lake Powell and Lake Mead. The Colorado River and its tributaries, the reservoirs of Lake Powell and Lake Mead, and the seeps and springs on NPS-managed lands are significant water resources within GCNP, GCNRA and Lake Mead National Recreation Area (LMNRA). Water quantity and quality affect a number of other resources, such as sediment, aquatic resources, and wildlife, but since those issues are considered separately below, this section focuses mainly on effects to recreation and fishing which are not considered separately below.

The water flow into the tributaries and the water supplying the seeps and springs are not affected by the Glen Canyon Dam releases. The only effects on these resources would be from temporary inundation close to the Colorado River at higher stage levels or temporary flushing from high-flow experiments (HFEs). The selected alternative does not increase the stage levels that are already reached under current conditions from dam releases and inflows. These temporary and minor inundation effects would not negatively impact the typical uses for current and future generations of these resources.

The selected alternative will not affect overall water inflow to Lake Powell and will not change the annual operating tier for water releases and flow through the canyons. The selected alternative in the LTEMP will only change monthly, daily, and hourly releases out of the dam. There will be negligible changes from current conditions related to reservoir elevations. The elevations of Lake Powell and Lake Mead are more affected by annual and seasonal variation in inflow than by the selected alternative. Because the selected alternative changes reservoirs elevations temporarily and much less than the annual and seasonal variations normally experienced, the selected alternative is not expected to impair the uses in Lake Powell and Lake Mead, and they would remain in a similar state to current conditions.

The Glen Canyon Dam releases affect the flow of the Colorado River below the dam that runs through 15 miles of GCNRA and 277 miles of GCNP. The overall range of normal operational releases from the dam will not change from current conditions, remaining between 5,000 cfs and 25,000 cfs. Experimental releases will not change from current conditions and will still be between 25,000 cfs and 45,000 cfs. There would still be a cap of 8,000 cfs for daily fluctuations levels under normal operations, as is the case under current conditions. The selected alternative would, however, change the monthly release volumes. October through December monthly volumes would remain the same, but the rest of the monthly release volumes would have less variation in magnitude (be more even) than is the case under current conditions. The selected alternative also changes the mean daily fluctuations for hydropower, which would be slightly less in some months, slightly more in others, and overall would still have a slightly higher average daily fluctuation level than under current conditions. These minor changes to monthly, daily flows are not expected to negatively impact navigability or safety concerns or other aspects of rafting, fishing, or other typical uses for current and future generations.

The selected alternative includes several types of experimental flows, including HFEs, Trout Management Flows (TMFs), Macroinvertebrate Production Flows (MPFs), and Low Summer Flows (LSFs). HFEs are flows between 31,500 and 45,000 cfs that would last for a period of 1 hr to several days. HFEs are expected to be more frequent (up to 21.1 HFEs vs. 5.5 under the No-Action Alternative) and could have an extended duration (250 hr vs. 96 hr for the No-Action Alternative) in comparison to current conditions. These HFEs may temporarily (up to 11 days for extended-duration fall HFEs, including ramp-down) impact some uses such as rafting and fishing or access to some sites along the river. Extended-duration fall HFEs can only occur up to 4 times in a 20-year period, and HFEs primarily impact recreation in Lees Ferry only during the time of the HFE. Also, the fall HFE time window is not the peak recreation season.

TMFs, MPFs, and LSFs involve increases and decreases in flow levels within the normal operational range of 5,000 cfs to 25,000 cfs and are not expected to negatively impact rafting, fishing, or other typical uses. While as shown in the FEIS, these temporary and limited experimental flow effects will negatively affect uses in Lees Ferry, they will have beneficial effects for many downstream resources and uses (see sections below on sediment, aquatic resources and wildlife for the beneficial effects) and are not expected to impair typical uses for current and future generations.

The selected alternative would have some water quality effects on the Colorado River through GCNRA and GCNP, including a slight increase in summer warming of the temperature of the Colorado River (about 0.4°C between Lees Ferry and Diamond Creek under normal operations with an additional 2.0°C with LSFs) and a slightly higher probability of the temporary occurrence of bacteria or pathogen contamination along shorelines compared to the No-Action Alternative. This change in temperature would not have a negative impact on river rafting, fishing, or other typical uses. The higher probability of temporary increases in bacteria or pathogens would result from occasional LSFs and the expected increase in the frequency of HFEs. These flows could increase the occurrence of bacteria and pathogens along shorelines temporarily. HFEs would be expected to flush the bacteria and pathogens out of backwaters and move them downstream, resulting in temporary increases followed by lower levels after the HFEs. The expected probability of this increase in pathogens is very low, and any increase would be very localized and temporary and would not be expected to have negative effects on rafting, fishing, or other typical uses.

In summary, because the selected alternative will only have direct and indirect effects that are of limited severity, duration, and timing, and will have no long-term or cumulative negative impacts on water availability or water quality, the effects of the selected alternative would not constitute impairment to the significant water resources in these park units. The integrity of these water resources would not be harmed, and these resources will continue to exist in a manner that can be enjoyed by current and future generations.

Sediment

The sediment resources that could be affected by the selected alternative would include the sandbars and beaches along the Colorado River corridor between Glen Canyon Dam and Lake Mead, and inflow deltas in Lake Mead. Sediment is defined as unconsolidated material derived from the weathering of rock that is transported and deposited by water or wind. Sediment is one of the fundamental components of the ecosystem along the river corridor in Glen and Grand Canyons. Sandbar deposits (and sandbar-dependent resources such as camping beaches and some archaeological sites) are affected by the amount of riverbed sand transported under a given alternative. A long-term net loss of riverbed sand would result in long-term loss in the number and size of sandbars, with corresponding changes in aquatic and riparian habitat (Reclamation 1995).

Changes in sandbar and riverbed sand depend primarily on tributary sand supply; the magnitude, frequency, and duration of HFEs; and the magnitude of annual release volumes and daily flow fluctuations. The annual release volume will not be affected by the selected alternative. The dynamics affected are the building and erosion of sandbars and beaches as well as the sediment remaining in the river channel, in the river corridor below the dam. Sandbars are built by high flows designed for sediment conservation purposes and based on sediment triggers. According to Schmidt and Grams (2011), "the HFE research program demonstrated that eddy sandbars are quickly constructed by high flows if those flows have high suspended-sand concentrations." Sandbars erode between HFEs and in years or months with very high release volumes. Erosion rates tend to be highest immediately after an HFE (when bars have the most sediment available for erosion), then decrease with time (Grams et al. 2010).

As is explained in Section 3.3 of the FEIS, the amount and frequency of sediment supply from tributaries is not affected by the dam operations; only the distribution of the sediment that is supplied is affected. Sediment is contributed to the system below the dam from the Paria River reach, the Little Colorado River, and various other small tributaries. Sand contribution from the Paria and Little Colorado Rivers varies greatly from year to year and may be affected by changes to watershed characteristics and land management practices, the presence of local dams or impoundments, or climate change and local weather patterns.

The selected alternative will have minimal impact on the size and position of the Colorado River deltas in Lake Mead. The deltas in Lake Mead are directly affected by Lake Mead reservoir elevation rather than by the selected alternative.

For sandbar and beach resources along the Colorado River below the dam, the selected alternative is expected to result in higher sandbar-building potential (152% increase over the No-Action Alternative) related to the frequent HFEs and less erosion of sandbars related to the more even monthly volumes. Under the adaptive management implementation process for the selected alternative, HFEs will only be conducted if they are beneficial to sediment resources in the canyon, thus ensuring that HFEs do not negatively affect sediment resources for current and future generations.

In summary, because the selected alternative is expected to have no effects on the amount of sediment supply or the Lake Mead delta and is expected to have positive direct and indirect effects on sandbars and beaches with no long-term or cumulative negative impacts on sandbars and beaches, the effects of the selected alternative would not constitute impairment to the significant sediment resources in these park units. The integrity of these sediment resources would not be harmed, and these resources will continue to exist in a manner that can be enjoyed by current and future generations.

Aquatics Resources

The selected alternative could impact important aquatic ecological resources of the Colorado River between Glen Canyon Dam and the inflow of Lake Mead. These resources include the aquatic food base (i.e., invertebrates, algae, rooted plants, and organic matter that serve as the base of the food web for fish; Section 3.5.1 of the FEIS), and native fish (including endangered and other special status species; Section 3.5.2 of the FEIS). The selected alternative could impact these resources directly through flows or non-flow actions or indirectly through nonnative fish (including coldwater and warmwater species; Section 3.5.3 of the FEIS) or aquatic parasites.

As stated in Section 4.5.3 of the FEIS, the selected alternative would be expected to noticeably alter temperature suitability for aquatic parasites, and the relative distributions of aquatic parasites and the effects of aquatic parasites on survival and growth of native fish or trout would not be expected to change relative to current conditions. Therefore, impacts from the selected alternative on native fish or the food base related to parasites will not harm or impair these aquatic resources in the park units; they will continue to exist in a manner that can be enjoyed by current and future generations.

The selected alternative impacts on nonnative fish that could indirectly impact native fish or the food base are summarized in Section 4.5.3.4 of the LTEMP FEIS. Under the selected alternative, it is expected that a healthy rainbow trout population would continue in the upper reaches of the river below Glen Canyon Dam, while warmwater nonnative species would continue to be largely restricted to the lower portions of the river and to tributaries. There are a number of factors, including temperature, fluctuation levels, ramp rates, the frequency and season of HFEs, TMFs, LSFs, and MPFs, that could influence the nonnative fish populations, particularly rainbow trout in Lees Ferry. However, based on the analysis and modeling, the overall effects are predicted to be very minor. The LTEMP FEIS includes safeguards that would prevent unacceptable adverse impacts on key resources, as stated in Section 2.2.4.3 of the FEIS. Temperature is one of the major factors that could affect nonnative fish, and temperature effects from the selected alternative were shown to very minor (about 0.4°C warmer in summer between Lees Ferry and Diamond Creek under normal operations compared to the No-Action Alternative with an additional 2.0°C with LSFs).

Impacts of the selected alternative on the food base and native fish are summarized in Section 4.5.3.4 of the LTEMP FEIS. The selected alternative is expected to have slightly higher productivity of benthic aquatic food base and drift; experimental MPVs (only featured in this alternative) may further increase productivity and diversity. The habitat quality and stability for native fish are expected to be slightly higher than current conditions; and there is expected to be slightly higher humpback chub abundance than current conditions. As stated in Section 4.1 of Appendix O of the FEIS, the effects of the selected alternative on razorback sucker are expected to include positive effects, such as the potential for the creation of warm, productive nursery habitats from increased reshaping of nearshore deposits and backwater development. However, TMFs could cause negative effects, including potential short-term dewatering of spawning areas during TMFs and stranding of larval, and young-of-year razorback sucker in nearshore habitats may occur as a result of TMFs and base operations (daily fluctuating flows, including increased down-ramp rates). As stated in Section 4.5.3.4 of the FEIS, while indirect benefits of TMFs for native fish as a result of reduced competition and predation by rainbow trout are expected under this alternative, an unknown number of native fish (including razorback sucker) could also suffer mortality as a result of TMFs, downstream in GCNP. In their Biological Opinion on the LTEMP, the U.S. Fish and Wildlife Service (FWS) stated "it is our biological opinion that the LTEMP, as proposed, is not likely to jeopardize the continued existence of these species [humpback chub, razorback sucker, and Kanab ambersnail], and is not likely to destroy or adversely modify designated critical habitat for the humpback chub and razorback sucker [no critical habitat has been designated for the Kanab ambersnail].” The FWS did not include reasonable and prudent measures to minimize take of these species because “all reasonable measures to minimize take have been incorporated into the project description.”

In summary, the selected alternative is expected to have no effects on aquatic parasites and minor effects on nonnative fish, and is not expected to impair the endangered fish populations of humpback chub and razorback sucker or the Kanab ambersnail. The integrity of these aquatic resources would not be harmed. Overall, the native fish population and food base are expected to improve or remain in a condition similar to current conditions and will remain in a state that can be enjoyed by current and future generations. Therefore, impacts from the selected alternative to native fish or the food base related to nonnatives will not impair these aquatic ecological resources.

Vegetation

The response of riparian vegetation to the operation of Glen Canyon Dam has been well studied, as summarized by Ralston (2012) and Sankey, Ralston, et al. (2015). Most evidence indicates that riparian vegetation composition, structure, distribution, and function are closely tied to ongoing dam operations. “Riparian vegetation” includes all plants found within the Fluctuating, New High Water, Old High Water, and Pre-Dam Flood Terrace hydrologic zones of the mainstem Colorado River downstream from Glen Canyon Dam, as described below.

The overall vegetation trend since completion of the dam has been the encroachment of New High Water Zone vegetation onto sandy beaches (Kearsley et al. 1994; Webb et al. 2002). At the same time, water availability decreased or was eliminated at higher elevations above the average annual daily maximum flows. The overall trend in the Old High Water Zone has been increased mortality of species such as mesquite and hackberry (Kearsley et al. 2006; Anderson and Ruffner 1987; Webb et al. 2011).

The Old High Water Zone, above 60,000 cfs to approximately 200,000 cfs, is not affected by the LTEMP selected alternative, which has a maximum dam release level of 45,000 cfs under normal and experimental flows. The dynamics in this zone are due to dam existence rather than dam operations, and therefore the vegetation in this zone cannot be impaired by the LTEMP alternative.

The two vegetation zones along the river that are influenced by the selected alternative through the frequency of inundation and disturbance are the Fluctuating Zone and the New High Water Zone (Ralston 2010, 2012; Kennedy and Ralston 2011). The Fluctuating Zone supports flood-tolerant marsh species such as sedges, rushes, cattail, horsetail, and common reed. These species occupy return current channels and successional backwaters that are inundated daily for at least part of the year (i.e., up to the elevation of the average annual daily maximum discharge of about 20,000 cfs). Under the selected alternative, the New High Water Zone lies within the influence of dam operations but above daily fluctuation levels (Carothers and Brown 1991). Vegetation in the Fluctuating and New High Water Zones are greatly influenced by river flow and dam operations (Stevens et al. 1995; Porter 2002; Kearsley and Ayers 1999; Kearsley et al. 2006; Ralston 2005, 2012).

The selected alternative is expected, based on flows, to have the lowest impact of any alternative on vegetation. The selected alternative is expected to result in an improvement in vegetation conditions compared to current conditions, including more native plant community cover, higher native plant diversity, a lower ratio of native to nonnative plants, less arrowweed, and more wetland. It also includes a non-flow vegetation treatment experiment that is expected to improve vegetation through the removal of nonnative plants and the replanting of native plants in select areas along the river.

In summary, because the selected alternative is expected to have no effects on vegetation in the Old High Water Zone and is expected to have positive direct and indirect effects on vegetation in the New High Water Zone and Fluctuating Zone, then the effects of the selected alternative would not constitute impairment of the riparian vegetation resources in these park units. The integrity of these vegetation resources would not be harmed, and these resources will continue to exist in a manner that can be enjoyed by current and future generations.

Wildlife

Dam operations can influence wildlife in Glen and Grand Canyons. Along the river corridor, 90 mammals, 373 birds, 9 amphibians, 47 reptiles, and several thousand invertebrate species have been identified (NPS 2014; Reclamation 1995; Stevens and Waring 1986). Many wildlife species are habitat generalists, using ecosystems from both the riparian zone and upland communities to meet basic requirements. Some species are habitat specialists, requiring specific vegetation composition and structural components to meet their needs, and therefore may only occur within specific habitats within the river corridor. There is an ecological relationship between river flow and habitat for riparian and terrestrial wildlife. Any changes to shoreline vegetation can affect wildlife habitat. In general, many wildlife species, including invertebrates, have benefited from increased riparian vegetation along the Colorado River corridor (King 2005).

The selected alternative will have negligible impacts on most terrestrial wildlife species in comparison to current conditions. It is expected to have beneficial effects in terms of greater nearshore habitat stability that would result in increased production of aquatic insects and would benefit species that eat insects or use nearshore areas. The selected alternative would also have the least decline of wetland habitat of any alternative, which is also beneficial given that wetland habitat is limited within the canyon and supports a specific group of species as is discussed in the Section 3.7 of the FEIS. The selected alternative will have temporary negative impacts to wildlife individuals from inundation during higher flows, but as documented in Sections 3.7 and 4.7 of the FEIS, the effects to wildlife populations that evolved with even greater natural flooding are expected to be negligible or beneficial.

In summary, because the selected alternative is expected to have negligible effects on most terrestrial wildlife species and beneficial effects to wildlife using nearshore and wetlands habitats, the effects of the selected alternative would not constitute impairment of the wildlife resources in these park units. The integrity of these resources would not be harmed, and these resources will continue to exist in a manner that can be enjoyed by current and future generations.

Cultural Resources

There are a number of ways in which dam operations may affect cultural resources, including the periodicity of inundation and exposure, changing vegetation cover, streambank erosion, slumping, and influencing the availability of sediment. Surveys have documented approximately 300 to 500 archaeological sites in the river corridor of Glen, Marble, and Grand Canyons. For the purposes of this analysis, a review of sites inventoried and monitored as of 2016, and additional analysis performed by Reclamation and NPS working with the U.S. Geological Survey (USGS) and Grand Canyon Monitoring and Research Center (GCMRC) researchers using their classification system cited above, it was determined that up to 220 archaeological and historic site properties could be affected by dam operations or non-flow actions.

The archaeological sites in the 277 miles of GCNP may be affected by dam operations under the selected alternative either directly or indirectly through aggradation of degradation of sediment resources affected by wind transport of sand, because sites may be buried by sand and their stability protected or exposed to the elements as sand erodes and is not replenished. The selected alternative is expected to result in increased sediment conservation and increased sandbar and beach building in Marble and Grand Canyons in comparison to current conditions. This will lead to an increase in the availability of sand for wind transport to protect the stability of archaeological sites in the Grand Canyon. While these impacts are expected to be beneficial in the Grand Canyon, as stated in Section 6.2 of the ROD, DOI has committed to a monitoring and mitigation program to address the effects of any sites that may be adversely affected. In GCNP, the selected alternative will not result in impairment of cultural resources because the effects of the alternative are expected to increase the stability of archeological sites, and these resources will continue to exist in a manner that can be enjoyed by current and future generations.

In the 15-mile stretch of GCNRA below the dam, there is the Spencer Steamboat historic property, which is in the river channel, and may be affected by direct inundation and flows as well as being influenced by sediment in the river over the 20-year period of the LTEMP. There is ongoing monitoring of this resource, and at this time, there have been negligible effects documented from HFE. There are also sites in the terraces in Glen Canyon that have the potential to be affected by experimental flows, particularly HFEs. The selected alternative has an increased potential for slumping of terraces in Glen Canyon compared to the No-Action Alternative. Monitoring will allow for an adaptive response, if needed. The LTEMP FEIS includes safeguards that would prevent unacceptable adverse impacts on key resources as stated in Section 2.2.4.3 of the FEIS. In GCNRA, the selected alternative is not expected to result in impairment because the risk to archaeological sites from inundation, flows, or slumping is slight, and monitoring would allow for modification or suspension of experiments if effects were greater than predicted; thus these resources will continue to exist in a manner that can be enjoyed by current and future generations.

Air Quality

Changes in operations at Glen Canyon Dam can create either more or less hydroelectricity at certain times of the day to meet regional electricity demand. If less electricity is available at Glen Canyon Dam, demand must be met by other means, which may include power plants fueled by fossil fuels (including coal, oil, and gas turbine plants) and nuclear, other hydroelectric, wind, and solar energy sources, or by demand-side management. Changes in the operation of Glen Canyon Dam, therefore, may indirectly affect air quality by potentially changing the degree to which electricity demand is met within the region, with either non-emission hydropower, wind, or solar power plants, or emission-producing power plants, such as fossil fuel–fired power plants that can directly affect air quality and related resources.

The selected alternative would produce no change in SO_2 emissions, a negligible increase in NO_X emissions, and no change in visibility. The selected alternative would result in a 0.042% increase in greenhouse gas (GHG) emissions. Overall, air quality would remain similar to current conditions. Current and future generations will still be able to enjoy the parks' resources with regard to effects related to air quality. As discussed in the FEIS, increases of air emissions will be negligible and increases of GHG emissions will be very slight. Therefore, the selected alternative will not impair air quality or other air resources and these resources will continue to exist in a manner that can be enjoyed by current and future generations.

Other Resources

As was documented in the LTEMP FEIS, the selected alternative was found to have negligible or no impacts on other resources such as visual resources, sound, and others. See Sections 1.5.3 and 4.12 of the FEIS for more information.

Conclusion

In the best professional judgment of the NPS decision-maker, based upon the selected alternative, including its experimental elements and non-flow actions and mitigations, and based upon how that alternative performed in the modeling and impact analysis in the FEIS, relevant scientific and scholarly studies, advice or insights offered by subject matter experts and others who have relevant knowledge or experience, and the results of civic engagement and public involvement activities, no impairment of park resources or values is expected to result from implementation of the selected alternative.

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