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Managing Water in the West

Biological Assessment: Development and Implementation of a Protocol for High-Flow Experimental Releases from Glen Canyon Dam, Arizona, 2011 through 2020

U.S. Department of the Interior
Bureau of Reclamation
Upper Colorado Region
Salt Lake City, Utah

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Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to tribes.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American Public.

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1 Introduction and Background

This document serves as the biological assessment (BA) for the Bureau of Reclamation's (Reclamation) proposed action to develop and implement a protocol for high-flow experimental releases (HFEs) from Glen Canyon Dam during the years 2011–2020. Four species identified as endangered are addressed in this BA: humpback chub (*Gila cypha*), razorback sucker (*Xyrauchen texanus*), Kanab ambersnail (*Oxyloma haydeni kanabensis*), and southwestern willow flycatcher (*Empidonax traillii extimus*). Reclamation has also previously consulted on the bald eagle (*Haliaeetus leucocephalus*), American peregrine falcon (*Falco peregrinus anatum*), and California condor (*Gymnogyps californianus*). The California condor is an endangered species that would not be affected by this action. The peregrine falcon and bald eagle have been removed from the list of threatened and endangered species and were not addressed in this BA.

This BA was prepared by Reclamation as part of its compliance with the Endangered Species Act of 1973, as amended (ESA; 87 Stat. 884; 16 U.S.C. §1531 *et seq.*). A biological assessment evaluates the potential effects of the action on listed and proposed species and designated and proposed critical habitat and determines whether any such species or habitat are likely to be adversely affected by the action (50 CFR 402.12). This BA is provided to the U.S. Fish and Wildlife Service (USFWS) to be used in developing its biological opinion (Opinion) which determines if the proposed action is likely to jeopardize the continued existence of a species or result in the destruction or adverse modification of critical habitat.

Reclamation is the agency within the U.S. Department of the Interior (Interior) that operates Glen Canyon Dam of the Colorado River Storage Project as a multipurpose storage facility in northern Arizona. Construction of the dam was authorized by the 1956 Colorado River Storage Project Act. Operation of the dam is governed by a complex set of compacts, federal statutes and regulations, court decrees, and an international treaty collectively and commonly referred to as the Law of the River and as further described below in Section 1.3.

1.1 Overview of Proposed Federal Action

The proposed action was announced in a Federal Register Notice on December 31, 2009 (74 FR 69361) and is described in detail in Reclamation's Environmental Assessment (EA) on the *Development and Implementation of a Protocol for High-Flow Experimental Releases from Glen Canyon Dam, Arizona, 2011 through 2020* (Reclamation 2011a). The protocol is designed to determine whether and how sand conservation can best be achieved in the Colorado River corridor through Grand Canyon National Park (GCNP), Arizona (Figure 1). This proposed protocol is part of the ongoing implementation of the Glen Canyon Dam Adaptive Management Program (GCDAMP), and is a component of Interior's compliance with the Grand Canyon Protection Act of 1992 (Public Law 102-575, GCPA).

The proposed action is tiered from two final environmental impact statements (FEIS)—Reclamation's 1995 *FEIS on the Operation of Glen Canyon Dam* (Reclamation 1995a) and the associated 1996 Record of Decision (ROD; U.S. Department of the Interior 1996); and Reclamation's 2007 *FEIS on Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lakes Powell and Mead* (Reclamation 2007a) and the associated

2007 ROD (U.S. Department of the Interior 2007). The 1996 ROD implemented the Modified Low Fluctuating Flows (MLFF) to govern releases from Glen Canyon Dam at short time increments, down to monthly, daily, and hourly releases. The 2007 ROD governs annual releases from Lake Powell in coordination with water volumes in Lake Mead. There is also an ongoing program of experimental releases (low steady flows from September 1 through October 31) from Glen Canyon Dam in effect from 2008 through 2012, under an EA and Finding of No Significant Impact (FONSI; Reclamation 2008).

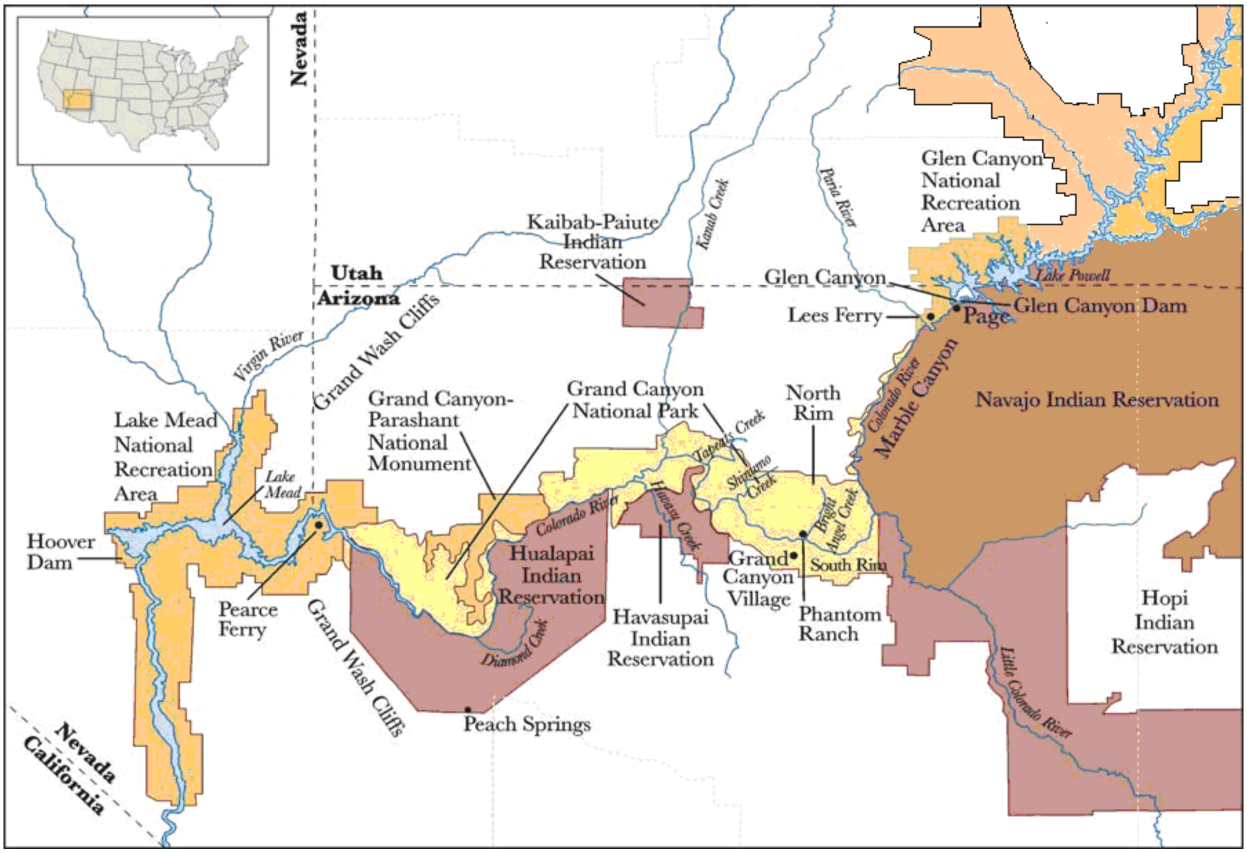

Figure 1. Action area from Glen Canyon Dam to Pearce Ferry, Arizona.

1.2 Concurrent Environmental Assessment

Reclamation is concurrently developing an environmental assessment for *Non-native Fish Control Downstream from Glen Canyon Dam, 2011–2020* (Forthcoming, Reclamation 2011b). The action analyzed in the non-native fish EA: (1) addresses requirements of prior ESA compliance and (2) would also serve to control trout population increases resulting from implementation of the HFE protocol. These EAs are interrelated or interdependent because they are being conducted concurrently in the same geographic area, during overlapping time frames, and because elements of the proposed actions affect each other. The HFE EA proposes a program of high-flow releases that are likely to increase the numbers of rainbow trout (*Oncorhynchus mykiss*) in the Lees Ferry reach, as an unintended consequence of the action. An increased in the trout population could result in greater downstream dispersal of trout into reaches of the Colorado River that are occupied by the humpback chub, where they prey upon and compete with this endangered species. Predation and competition by rainbow trout and brown trout (*Salmo trutta*) have been identified as sources of mortality for juvenile humpback chub (Valdez and Ryel 1995; Marsh and Douglas 1997; Yard et al. 2008). This added mortality reduces recruitment and possibly the overall size of the population of humpback chub (Coggins 2008a). One purpose of the non-native fish control EA will be to assess and mitigate the effects of the increased predation and competition by reducing the numbers of trout in areas from which the trout may disperse and in reaches that they occupy together with humpback chub. In this regard, the NPS, as part of a Reclamation conservation measure, is engaged in removal of non-native fish (principally rainbow trout and brown trout) from Bright Angel Creek. Bright Angel Creek is a known source of brown trout to the LCR reach.

1.3 Progress on Conservation Measures and Other Proposed Offsetting or Mitigating Actions

Section 7(a)(1) of the ESA directs Federal agencies to utilize their authorities to further the purposes of the law by carrying out conservation programs for the benefit of endangered and threatened species. Conservation measures are discretionary agency activities that minimize or avoid adverse effects of a proposed action on listed species or critical habitat, help implement recovery plans or develop additional information. Conservation measures were developed and presented in the 2007 and 2008 biological opinions and the 2009 Supplemental Opinion. These conservation measures have been incorporated into the GCDAMP and have resulted in significant benefits to listed species in the area affected by Glen Canyon Dam operations.

Many of these conservation measures have already been initiated and are ongoing or work on them has been completed. Reclamation remains committed to working with the USFWS and GCDAMP on all the conservation measures in order to offset and mitigate the effects of this proposed action. These conservation measures are described in detail in the 2010 BA (Reclamation 2010), and summarized as follows, as they relate to the proposed action.

Fish Research and Monitoring

Reclamation has been a primary contributor to the development of the GCDAMP's Comprehensive Plan for the Management and Conservation of Humpback Chub in Grand Canyon. Reclamation plans to utilize this plan in cooperation with the USFWS and other GCDAMP members to determine what actions remain to be accomplished, and find additional funding sources that will be provided by other willing partners to help achieve recovery of the humpback chub.

Reclamation continues to support fish research and monitoring efforts in Grand Canyon in 2011 that will help to better determine effects of the proposed action on the endangered species. These efforts include continued population estimates of humpback chub in the LCR and ongoing monitoring of native fish in the mainstem Colorado River, an ongoing nearshore ecology study, non-native fish control, humpback chub translocation and refuge establishment, research on effects of parasites, razorback sucker habitat potential in lower Grand Canyon, sediment research, LCR watershed planning, a monthly flow transition study, continued monitoring of the southwestern willow flycatcher and the Kanab ambersnail. Some of these efforts are contained within conservation measures further described in this section.

Non-native Fish Control

In the past decade, Reclamation has provided financial and/or technical support to control non-native fish species in the Colorado River and its tributaries as a way to minimize effects of predation and competition on native fish species. These activities include ongoing non-native control planning, non-native control methods pilot testing, removal of rainbow trout from the LCR reach of the Colorado River, increased fluctuating flows during the months of January through March to increase mortality of young rainbow trout, and mechanical removal of brown trout through weir operations at Bright Angel Creek.

Reclamation has also funded and helped to conduct a non-native fish workshop and meetings with American Indian Tribe representatives to address concerns about mechanical removal of nonnative fish in the LCR inflow reach. Reclamation recently conducted a structured decision-making workshop to help identify science-based alternatives for non-native fish control downstream of Glen Canyon Dam, and Reclamation's Lower Colorado Regional Office (LCRO) has budgeted $20,000 to support an international symposium on the use and development of genetic biocontrol of non-native invasive aquatic species.

Reclamation will conduct further analysis on the effects from non-native fish removal and analysis of incidental take through its concurrent EA and proposed action on non-native fish control downstream of Glen Canyon Dam (see Section 1.2). The analysis will be directed at further refinement of targets for non-native fish control to determine a level of effort that would effectively reduce non-native numbers to benefit humpback chub, and better understand the link between nonnative control and status and trend of humpback chub. The action on non-native fish control would help to mitigate the unintended consequences of an increased rainbow trout population that is likely to result from the HFE protocol.

As an additional mitigating measure, Reclamation will continue to work with the NPS to implement removal of non-native rainbow trout in Shinumo Creek as part of the humpback chub translocation project and will help support such control measures in Havasu and Bright Angel creeks in advance of future humpback chub translocations in those systems.

Humpback Chub Translocation and Refuge

Reclamation has supported translocation of humpback chub to the LCR above Chute Falls since 2003 and has been involved with the NPS translocation plan and logistics coordination for Shinumo Creek since late summer 2007. During July 2008 and 2009, humpback chub were translocated to areas above Chute Falls, and additional fish were collected for the purposes of establishing a hatchery refuge population and translocation to Shinumo Creek during both years. Reclamation assisted the USFWS with development and funding of a broodstock management plan and creation and maintenance of the refuge population at the Dexter National Fish Hatchery and Technology Center, New Mexico. These translocations and the refuge population help to offset losses of young humpback chub to predation and displacement of young by HFEs.

Parasite Monitoring

A considerable amount of research has been done on parasites of the humpback chub in Grand Canyon (e.g., Clarkson et al. 1997; Choudhoury et al. 2001; Cole et al. 2002; Hoffnagle et al.

2006). In coordination with the GCDAMP participants and through the GCDAMP, Reclamation will continue to support research on the effects of parasites, such as the Asian tapeworm (*Bothriocephalus acheilognathi*) on humpback chub and potential methods of controlling these parasites.

Razorback Sucker Habitat Assessment and Potential Augmentation

As part of the USFWS concurrence with the determinations made for Reclamation's adoption and implementation of the interim guidelines, the 2007 Opinion (USFWS 2007) states that "Reclamation will, as a conservation measure, undertake an effort to examine the potential of habitat in the lower Grand Canyon for the species (razorback sucker), and institute an augmentation program in collaboration with FWS, if appropriate." Reclamation has initiated a contract for this study with a comprehensive evaluation of razorback sucker habitat and convened a Science Panel in fall of 2010 to evaluate the suitability of habitat in lower Grand Canyon and Lake Mead inflow. Reclamation is undertaking this effort in collaboration with the USFWS, GCDAMP, Lower Colorado River Multi-Species Conservation Program (MSCP), NPS, GCMRC, Nevada Department of Wildlife (NDOW), and the Hualapai Tribe. This measure will help to better understand the status of the razorback sucker in the lower end of the HFE protocol action area and could lead to a better understanding of how to offset effects of the proposed action.

Sediment Research

Reclamation has modified releases from Glen Canyon Dam and supported studies on the effects of sediment transport on humpback chub habitats. Substantial progress has been made toward these efforts. High Flow Experiments (HFE) conducted in 1996, 2004, and 2008 have enhanced our knowledge of sediment transport and its effects on humpback chub habitat. Extensive data collection and documentation has resulted from these tests (Hazel et al. 1999; Schmidt 1999; Topping et al. 2000a, 2000b, 2006; Rubin et al. 2002; Schmidt et al. 2004; Wright et al. 2005; Melis et al. 2010; Melis in press). In coordination with other DOI GCDAMP participants and through the GCDAMP, Reclamation will continue to support monitoring of the effect of sediment transport on humpback chub habitat and will work with the GCMRC to develop and implement a scientific monitoring plan acceptable to the USFWS. This sediment research will also help to quantify the amount of sediment available for an HFE, and could help to determine the proportion of the inorganic sand component and the finer organic component that is important to the aquatic ecosystem in Grand Canyon.

Little Colorado River Watershed Planning

Reclamation will continue its efforts to help other stakeholders in the LCR watershed development planning efforts, with consideration for watershed level effects to the humpback chub in Grand Canyon. Under contract with Reclamation, SWCA, Inc. has developed a draft LCR Management Plan that has, to date, identified some of the primary water development risks to sustainable humpback chub critical habitat, steps toward effective risk management, and key players in the implementation of the management plan (Valdez and Thomas 2009).

Monthly Flow Transition Study

Transitions between monthly flow volumes from August, a large flow volume month, to September, a low flow volume month, can potentially have negative effects on nearshore habitats and endangered fish. Such transitions can result in a river stage level that is below the varial zone of the previous month's flow, and may be detrimental to fishes and food base for fish. In 2009, Reclamation adjusted daily flows between months in an attempt to attenuate these transitions such that they are more gradual. Reclamation has also committed to study the biological effects of these transitions through the Nearshore Ecology Study. Reclamation has also worked to adjust September and October monthly flow volumes to achieve improved conditions for young-of-year, juvenile, and adult humpback chub. This transition study will help inform the HFE protocol by identifying potential effects of flow transitions on fish and their habitats and food base.

1.4 Relevant Statutory Authority

Reclamation is responsible for defining the extent of its discretionary authority with respect to this action in compliance with Section 7(a)(2) of the ESA and its implementing regulations. Reclamation's authority for operation of Glen Canyon Dam stems from a body of documents commonly referred to as the Law of the River, as described below. While there is no universally accepted definition of this term, the Law of the River comprises numerous operating criteria, regulations, and administrative decisions included in federal and state statutes, interstate compacts, court decisions and decrees, an international treaty, and contracts with the Secretary of the Interior (Secretary).

Notable among these documents are:

1. The Colorado River Compact of 1922 (Compact);
2. The 1944 Treaty (and subsequent minutes of the International Boundary and Water Commission);
3. The Upper Colorado River Basin Compact of 1948;
4. The Colorado River Storage Project Act of 1956 (CRSPA);
5. The 1963 U.S. Supreme Court Decision in Arizona v. California;
6. The 1964 U.S. Supreme Court Decree in Arizona v. California (the Decree was supplemented over time after its adoption and the Supreme Court entered a Consolidated Decree in 2006);
7. The Colorado River Basin Project Act of 1968 (CRBPA);
8. The Colorado River Basin Salinity Control Act of 1974; and
9. The Grand Canyon Protection Act of 1992.

1.5 Detailed Description of Proposed Federal Action

1.5.1 Operation of Glen Canyon Dam

Implementation of the HFE protocol will be done in concert with coordinated river operations as described above in Section 1.4. Reclamation prepares an Annual Operating Plan each year that describes the past year's annual releases and projects the current year's releases. Since 1970, the annual volume of water released from Glen Canyon Dam has been made according to the provisions of the Criteria for Coordinated Long-Range Operations of Colorado River Reservoirs (LROC) that includes a minimum objective release of 8.23 million acre-feet (maf). The interim guidelines for lower basin shortages and the coordinated reservoir operations 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 (e.g., during low reservoir conditions). A more thorough description of Reclamation's process for determining and implementing annual release volumes is available in the 2007 FEIS (Reclamation 2007a), the 2007 ROD (U.S. Department of the Interior 2007), and the 2007 Opinion (USFWS 2007).

The proposed action provides for continued operation of Glen Canyon Dam under MLFF and all applicable prior decisions, with the inclusion of a protocol for high-flow experimental releases from Glen Canyon Dam for the 10-year period, 2011 through 2020. The proposed action is intended to meet the need for high-flow experimental releases during limited periods of the year when large amounts of sand from tributary inputs are likely to have accumulated in the channel of the Colorado River. Annual releases would follow prior decisions, including the MLFF, interim guidelines for lower basin shortages and coordinated reservoir operations, and the steady flows as identified in the 2008 Opinion and the 2009 Supplemental Opinion. The timing of HFE releases from Glen Canyon Dam would be March-April (spring) and October-November (fall); the magnitude would be from 31,500 cfs to 45,000 cfs; and the duration would be from less than one hour to 96 hours. The number and sequence of HFEs over the 10-year experimental period cannot be predicted because of the uncertainty of water availability and sediment input, but one or two HFEs in a given year are possible, as are more than two consecutive HFEs (see Section 1.4.2 below).

The timing, magnitude, duration, and frequency of HFEs are not expected to impact water delivery because Reclamation plans to reallocate water within or among months to achieve the necessary yearly volumes, while complying with the MLFF. The HFE protocol may call for high flow events during a fall and spring HFE implementation periods. High flow events under the HFE protocol could potentially require more water than what is scheduled for monthly release through the coordinated operating process. In order to conduct these high flow events as prescribed by the HFE protocol, reallocation of monthly releases from Glen Canyon Dam may be necessary. If Reclamation determines that it is not possible to achieve the high flow event within the monthly release volume projected for October-November or March-April, Reclamation will adjust the projected monthly release volumes as necessary for the following December through March period, or May through August period, respectively. A more complete description of dam operations is provided in the HFE EA.

1.5.2 Proposed HFE Protocol

The HFE protocol is a decision-making process that consists of three components: (1) planning and budgeting, (2) modeling, and (3) decision and implementation. A more complete description of the proposed HFE protocol is provided in the HFE EA. An important aspect of planning and budgeting is the preparation, development, and implementation of research and monitoring activities appropriate to monitor the effects of the HFEs. An annual Interior agency report would assimilate and synthesize the information on the effects of HFEs and the status and trends of key resources. This information would be provided to Interior to assist with the decision and implementation component of this protocol.

The second component of the protocol is modeling, which is based on an evaluation of the hydrology and the sand budget. The sand budget is the net amount of sand in metric tons that has accrued in the river channel during each of two accounting periods—fall and spring (Figure 2). The primary reach of the Colorado River that would be monitored for sand accrual for this protocol is Marble Canyon (Paria River to Little Colorado River [LCR]), which receives sand primarily from the Paria River. Average monthly sand load (i.e., the amount of sand being imported) is greatest for the Paria River during two periods—July through October and January through March. During these two periods, sand is being accumulated at a higher rate than in the remaining months, and the maximum accumulation of sand in the river channel usually occurs in November and April, respectively. It is important to note that sand in sandbars and beaches, as well in the river channel, is being continually eroded and transported downstream by water released from the dam; at a higher rate during high magnitude releases and fluctuating flows, and at a lower rate during low magnitude releases and more stable flows (Grams et al. 2010).

This progressive accumulation of sand is the fundamental basis of the store and release approach being evaluated with this protocol. The store and release approach relies on accumulation of sand during periods of above-average sediment input from tributaries to achieve sediment-enriched conditions called for in the development of the HFE protocol (74 FR 69361). An approach similar to store and release was used for the 2004 and 2008 HFEs and these were effective at redepositing sediment. Sand or sediment is accumulated over a period of several months and at which time a recommendation is made to release or not release a high flow from the dam. HFEs in November and April would likely be the most effective times for HFEs because of the greatest sand accumulation during these months. However, to accommodate the decision process that begins with hydrology and sediment modeling on October 1 and March 1, the HFE windows (times when an HFE could be conducted) are broadened to October-November and March-April. These 2-month windows also accommodate logistical preparation for monitoring, as well as an evaluation of the status of resources. As this decision process is refined and made more efficient with the experience of conducting HFEs, it is likely that the time necessary to make HFE decisions can be decreased, and it may be possible to conduct an HFE on a shorter notice.

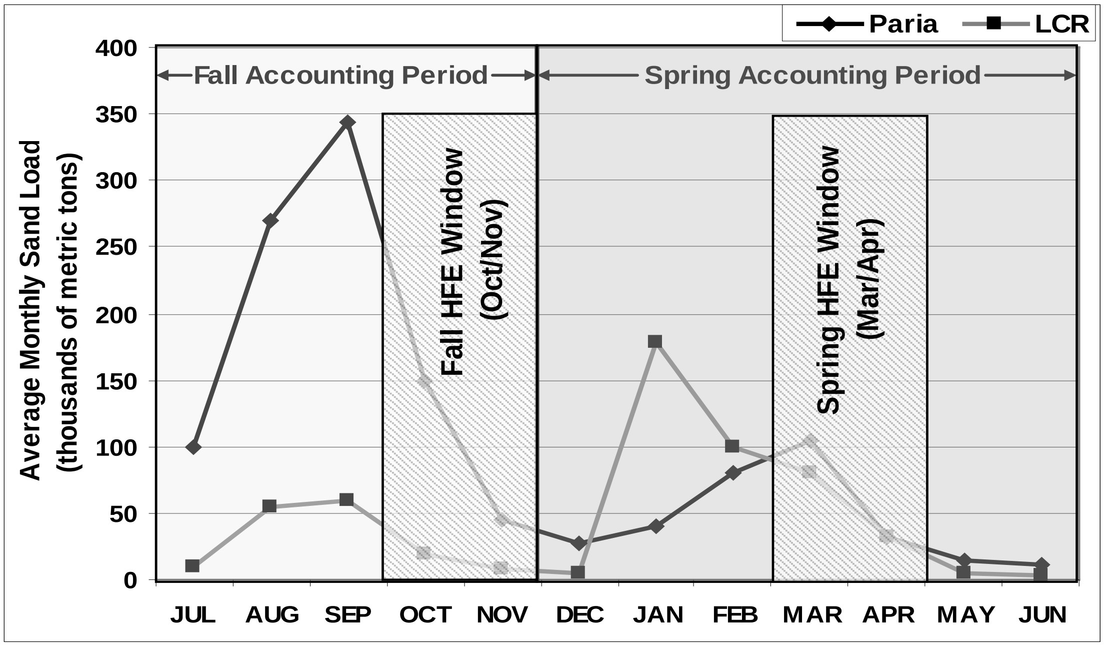

Figure 2. The two sand accounting periods and the two high-release periods with average monthly sand loads for the Paria River and the Little Colorado River. Note that although average monthly sand load from the Paria River for the fall accounting period is August and September, greatest accumulation of sand occurs in October and November.

Sand availability at the onset of each HFE window is determined by the amount of sand received from the Paria River during the accounting period less the amount transported downstream as estimated by the sand routing model (Wright et. al. 2010; see HFE EA for a description of this model). Sand in Grand Canyon received from the LCR is viewed as an added benefit to the amount received from the Paria River. The LCR input cycle largely follows the same accrual periods as the Paria River; however, only sand inputs from the Paria River would be used in HFE modeling recommendations in this protocol.

The third component of the protocol is the decision and implementation process for conducting an HFE. The hydrology model and sediment model (Russell and Huang 2010), as identified above, help to define the magnitude and duration of an HFE that is possible given the conditions for hydrology and sediment during each of the accounting periods. The range of possible HFEs is 31,500 cfs to 45,000 cfs for durations of about 1 hour to 96 hours. It is projected that because of ongoing maintenance of the eight generating units at Glen Canyon Dam, a maximum release of only 42,000 cfs (i.e., 27,000 cfs from the power plant and 15,000 cfs from the bypass valves) may be possible for much of the 10-year period, rather than 45,000 cfs.

1.5.3 Modeled HFE Magnitude, Duration, and Frequency

Because the hydrology and sediment conditions are unpredictable, the magnitude, duration, and frequency of HFEs cannot be prescribed in advance. Although hydrological conditions can be forecast months in advance with the Colorado River Simulation System (CRSS; Reclamation 2007b), sediment condition depends on periodic and unpredictable tributary floods. For the purpose of this effects analysis, model runs were done for nine traces using dry, moderate, and wet hydrology settings for each of three representative years of low (1983, 862,000 metric tons), moderate (1990, 1,334,000 metric tons), and high (1934, 1,649,000 metric tons) sediment input. It is important to note that this modeling procedure was conducted to evaluate the possible HFEs during a 10-year period, and differs from the actual future determination of an HFE in that actual tributary sediment data and forecasted hydrology will be used as model inputs.

Each of the nine traces was evaluated against 13 described HFEs to determine their possible occurrence in spring and fall for a hypothetical 10-year period (Table 1). The type of HFE possible was determined by the volume of available sediment and water, as predicted through the modeling process. Based on these model simulations, an HFE could occur 56 percent of the time. Of these HFE's, 91 percent had a peak magnitude of 45,000 cfs. Typically, HFEs occur in groups (consecutive HFEs); 80 percent of the HFEs had an HFE in the neighboring accounting periods.

The numbers of HFEs for the nine traces of sediment and hydrology indicate that HFEs are most likely to occur during low sediment with dry hydrology conditions, followed by a tie among low sediment with moderate hydrology, high sediment with dry hydrology, and high sediment with moderate hydrology. These conditions of suitability reveal the influence of hydrology and the consequent magnitude of MLFF dam releases. HFEs are most likely to occur in years of dry to moderate hydrology because lower seasonal releases from the dam cause less ongoing export of sediment. Conversely, low year-round dam releases allow for a greater accumulation of sediment than high releases that have higher velocity and a greater scouring effect.

Summary statistics relevant to this BA are included in Table 2 (magnitude, duration) and Table 3 (frequency, timing). Summary statistics are based on modeling simulations for traces of sediment and hydrology based on Table 1, but because the likelihood that sediment and hydrology combinations will be the same from year to year is low, the model does not necessarily reflect what may happen during the 10-year HFE protocol period. Nevertheless, the numbers provide an insight into a possible range of HFE magnitude, duration, and frequency. Table 2 indicates that flows of 45,000 cfs for 96 h could be relatively frequent (occurring in about a third of all model runs), whereas lower frequency flows of this magnitude (1–24 hours) account for another third of all model runs. If one or more of the eight-powerplant units were not available, the HFE magnitude would be adjusted to the maximum release possible. In terms of frequency and timing, Table 3 indicates that 58 percent of HFEs could occur in fall months and 42 percent in spring. Overall, an average of 1.1 HFEs could be conducted per year over the 10-year period, and for a given trace of sediment and hydrology, 3 to 5 consecutive HFEs could occur, with no more than 2 HFEs in one year.

Table 1. Type of HFE by month for each of the nine traces of sediment (Low, Moderate, and High) and hydrology (Dry, Moderate, Wet). Numbers in cells represent HFEs of different magnitudes and durations as shown in Table 2 (e.g., a type 5 HFE is 45,000 cfs for 36 hours).

Months - Year	Low, Dry	Low, Mod.	Low, Wet	Mod, Dry	Mod, Mod.	Mod, Wet	High, Dry	High, Mod.	High, Wet
Mar/Apr Yr 1	5	5					7	7	
Oct/Nov Yr 1	2	2		6	6		6	6	
Mar/Apr Yr 2									
Oct/Nov Yr 2		7							
Mar/Apr Yr 3	6	12		1	2	1	8		
Oct/Nov Yr 3	3	8	4	1	2	1	1	1	1
Mar/Apr Yr 4	10			1	1	1	2	8	3
Oct/Nov Yr 4	1	1	7	8	8		6	8	
Mar/Apr Yr 5							2	7	1
Oct/Nov Yr 5	1		4	8					
Mar/Apr Yr 6	11	8	8	5	1	1		12	9
Oct/Nov Yr 6			8				1	1	1
Mar/Apr Yr 7	8	8			8		9	10	
Oct/Nov Yr 7	7	7					1	1	1
Mar/Apr Yr 8			7	8		4	4	9	1
Oct/Nov Yr 8	4	3	3	1	1	1	6	7	8
Mar/Apr Yr 9									
Oct/Nov Yr 9	9	7		1	1	1			
Mar/Apr Yr 10	1	1	2						
Oct/Nov Yr 10	2	2	1	5	6	2	6	7	1
No. of HFEs	14	13	9	11	10	8	13	13	9

Table 2. Total number and frequency of HFEs for all nine traces of sediment and hydrology, from a possible 100 occurrences (see Table 1).

HFE	Flow Magnitude (cfs)	Duration (hours)	Number and Percent Frequency
1	45,000	96	33
2	45,000	72	10
3	45,000	60	4
4	45,000	48	5
5	45,000	36	4
6	45,000	24	9
7	45,000	12	11
8	45,000	1	15
9	41,500	1	4
10	39,000	1	2
11	36,500	1	1
12	34,000	1	2
13	31,500	1	0

Table 3. Frequency and timing of HFEs possible under the proposed action. Number of HFE series to the number of instances where HFEs occur as two or more consecutive HFEs, and maximum consecutive HFEs refer to the number of HFEs possible in any given series (see Table 1).

Sediment/ Hydrology	No. HFEs	No. Fall HFEs	No. Spring HFEs	Average HFEs/yr	No. of HFE Series	Max.Consecutive HFEs
Low/Dry	14	6	8	1.4	5	4
Low/Mod.	13	5	8	1.3	4	3
Low/Wet	9	3	6	0.9	3	3
Mod./Dry	11	4	7	1.1	3	4
Mod./Mod.	10	4	6	1.0	1	4
Mod./Wet	8	4	4	0.8	2	3
High/Dry	13	6	7	1.3	3	5
High/Mod.	13	6	7	1.3	3	6
High/Wet	9	4	5	0.9	3	3
Total	100	58	42	Ave: 1.1/yr		

1.5.4 Basis and Approach to Proposed Action

The Colorado River downstream from Glen Canyon Dam is depleted of its natural sediment load due to the presence of the dam, and ongoing dam operations that further deplete sediment delivered to the main channel by periodic tributary floods. High dam releases mobilize sand stored in the main river channel and redeposit it as sandbars and beaches that form associated backwater habitats (Topping et al. 2010). Sandbars and beaches provide key wildlife habitat, protect archeological sites and vegetation structure, and provide camping opportunities in Grand Canyon; and backwaters can be important nursery habitat for young fishes and islands of productivity (Stevens 1996). One of the best tools available for rebuilding sandbars and beaches is to use dam operations to release short-duration high flows, preferably after sediment-laden tributary floods deposit new sand into the main channel.

This protocol is intended to be experimental in nature and is designed to provide a better understanding of how to incorporate high releases into future dam operations in a manner that effectively conserves sand in the long-term. The HFE protocol is designed to help determine the timing, magnitude, duration, and frequency of HFEs that may occur during ongoing hydrologic conditions and sand budgets. The HFEs conducted through this protocol would help to build on knowledge acquired from previous adaptive management experiments and would provide information that will lead to a better understanding of how to conserve sand in the Colorado River through Grand Canyon. Sand deposited as sandbars and beaches is a primary component of the historic Colorado River ecosystem, and determining how sand conservation can be achieved in areas within GCNP downstream of Glen Canyon Dam is a high priority of the GCDAMP and Interior.

This protocol is designed as a multi-year, multi-experimental approach, and constitutes the next logical step in adaptive management with respect to high-flow testing at Glen Canyon Dam. High flows mobilize sand stored in the main river channel and rebuild sandbars, beaches, and associated backwater habitats along shorelines. Sandbars are dynamic features, however, that are progressively degraded and reduced by the erosive forces of the same river that forms them during floods. Developing this protocol is important for implementing a strategy of high-flow releases over a period longer than one year or one event. In the past, Reclamation has conducted three single-event HFEs and the benefits to sediment have been temporary. One purpose for this protocol is to assess whether multiple, sequential, predictable HFEs conducted during sediment-rich conditions and under consistent criteria can better conserve sediment resources while not negatively impacting other resources. Previous HFEs from Glen Canyon Dam above the powerplant capacity of 31,500 cfs were conducted in 1996, 2004, and 2008. Other high dam releases of near powerplant capacity were conducted, one in 1997 and two in 2000. All of these experiments provided valuable information and increased the understanding of responses by physical and biological resources to high-flow releases.

This protocol is intended to be experimental in nature, and is designed to learn how to incorporate high releases into future dam operations in a manner that effectively conserves sediment and sediment-dependent resources in the long-term. A number of hypotheses may be tested through this experimental protocol. These hypotheses could be directed at varying the timing, magnitude, duration, and frequency of HFEs to determine the effectiveness on sand conservation. Two approaches have been put forward with respect to timing of a high release in response to the delivery of sediment into the river channel. The "store and release" approach was developed by USGS and was first introduced as the basis for the HFE protocol in a June 2010 modeling workshop. The "rapid response" approach was provided later in September by Western Area Power Administration.

The store and release approach relies on accumulation of sand during periods of above-average sediment input from tributaries to achieve sediment-enriched conditions called for in the development of the HFE protocol (74 FR 69361). An approach similar to store and release was used for the 2004 and 2008 HFEs and these were effective at redepositing sediment. Sand or sediment is accumulated over a period of several months and at which time a recommendation is made to release or not release a high flow from the dam. In contrast, the rapid response approach relies on real-time measurements of flood events by stream gages in the tributary supplying the sediment (i.e., Paria River). This information must be transmitted to dam operators in sufficient time so they can release water from the dam to coincide with the flood input from the tributary. The success of the rapid response approach requires coupling of tributary floods and dam releases to transport sediment-enriched water downstream. The decision process for rapid response must occur within a matter of hours, with the assumption that a report of resource condition shows no potential adverse effect to other resources in the canyon. It is anticipated that the possible impacts of a rapid response HFE will need to be addressed in a supplemental environmental assessment after initiation of the HFE EA. Prior to the implementation of the rapid response approach, a science plan will also need to be developed.

1.5.5 Geographic Scope and Extent of Action Area

The area directly and indirectly affected by this proposed action is the Colorado River corridor from Glen Canyon Dam in Coconino County, Arizona downstream to the inflow of Lake Mead near Pearce Ferry, Mohave County, Arizona (Figure 1). This action area includes Glen Canyon National Recreation Area (GCRA) in a 20.3-mile reach from Glen Canyon Dam to Navajo Bridge; and Grand Canyon National Park (GCNP), a 274-mile reach from Navajo Bridge to a point about 1.7 miles upstream of Pearce Ferry. Three distinct canyons lie within the proposed action area and are referenced in this document: Glen Canyon encompasses the 16-mile reach from the dam to the Paria River; Marble Canyon is the 61-mile reach from the Paria River to the LCR; and Grand Canyon is the 217-mile reach from the LCR to near Pearce Ferry.

2 Environmental Baseline

The environmental baseline includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early Section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process (50 CFR 402.02).

2.1 Regulatory Context

Several Federal and states agencies and tribes have authority over land and various resources within the action area. Past consultations have evaluated the impact of proposed actions on the threatened and endangered species that live in the Colorado River and its floodplain between Glen Canyon Dam and the inflow area of Lake Mead. This anticipated area of effect lies within Glen Canyon National Recreation Area and Grand Canyon National Park, and the Colorado River inflow of Lake Mead in the Lake Mead National Recreation Area, all of which are administered by the National Park Service. The action area is bordered by, or is in proximity to, tribal lands of the Navajo Nation, Hopi Tribe, Pueblo of Zuni, Paiute Tribe, Havasupai Tribe, and Hualapai Tribe. These lands are administered by the respective tribal governments, and the Bureau of Indian Affairs has fiduciary responsibility to assist these tribes. The Arizona Game and Fish Department (AGFD), through its Commission, manage the fish populations in the action area, including the sport fish, native fish, and non-native fish populations, in cooperation with the NPS. The Commission sets fishing regulations that are enforced by the AGFD.

2.2 Related Consultation History

Reclamation has consulted with the U.S. Fish and Wildlife Service under Section 7 of the ESA on the effects of various projects on federally listed species and designated critical habitat. Since 1995, Reclamation has consulted with the USFWS on a total of five important experimental actions, and has undertaken a sixth experimental action that did not require separate ESA consultation. This history is listed and described below. The USFWS issued a "jeopardy" determination in the 1995 Opinion, but non-jeopardy opinions on all other actions.

2.2.1 1996 Record of Decision on the Operation of Glen Canyon Dam

Reclamation received a final biological opinion from the USFWS on the preferred alternative for the *Final Environmental Impact Statement on the Operation of Glen Canyon Dam* in January 1995. The USFWS concluded that without the included reasonable and prudent alternative, implementation of the MLFF alternative was likely to jeopardize the continued existence of the humpback chub and razorback sucker and was likely to destroy or adversely modify their critical habitat, but was not likely to jeopardize the bald eagle, Kanab ambersnail, and peregrine falcon. The 1995 Opinion identified one reasonable and prudent alternative (RPA) containing four elements that were necessary to avoid jeopardizing the continued existence of the humpback chub and razorback sucker. Reclamation implemented these elements through the principles of adaptive management starting in 1996 within the GCDAMP, and the USFWS has agreed with

Reclamation that sufficient progress has been made on these elements. The 1995 Opinion was replaced by the 2008 Opinion and the 2009 Supplemental Opinion, as described below.

2.2.2 Spring 1996 High Flow Test from Glen Canyon Dam

Consultation was initiated in November of 1995 for a proposed high flow test from Glen Canyon Dam in the spring of 1996 in the Colorado River. Consultation with the USFWS was reinitiated on the preferred alternative from the 1995 FEIS because a new species was listed since the original consultation (southwestern willow flycatcher with proposed critical habitat), and new information[1] revealed that incidental take for the Kanab ambersnail determined in the 1995 Opinion would be exceeded. Reclamation concluded in its BA that the test would have no effect on the endangered peregrine falcon, threatened bald eagle, or the endangered razorback sucker. The USFWS concurred and concluded in its biological opinion that the proposed test was not likely to jeopardize the continued existence of the humpback chub, Kanab ambersnail, or southwestern willow flycatcher, and was not likely to destroy or adversely modify humpback chub critical habitat. The USFWS also provided a conference opinion that the test was not likely to destroy or adversely modify proposed critical habitat for the southwestern willow flycatcher.

2.2.3 November 1997 Fall Test Flow from Glen Canyon Dam

The 1997 action was proposed as a test of a near powerplant capacity release of 31,000 cfs for 48 hours. While powerplant capacity releases were described in the 1995 draft EIS as habitat maintenance flows, such a test in the fall was not addressed in the 1995 FEIS, which necessitated additional consultation. The USFWS in its biological opinion concluded that the test flow was not likely to jeopardize the continued existence of the humpback chub or Kanab ambersnail and was not likely to destroy or adversely modify designated critical habitat for the humpback chub. The USFWS concluded the action was not likely to jeopardize the bald eagle or the American peregrine falcon.

2.2.4 2000 Steady Flow Test from Glen Canyon Dam

During the period March 25 through September 30, 2000, Reclamation conducted a 6-month flow test that included steady flows of about 8,000 cfs from June 1 to September 4, and short-term (48 hours) high flow releases of near powerplant capacity (31,000 cfs) during early May and early September. The steady flows were intended to determine if stable flows would provide more reliable, warm habitat for young humpback chub. The high spring release was designed to

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[1] In its December 21, 1994, Final Biological Opinion, the Service evaluated impacts to Kanab ambersnail from the operation of Glen Canyon Dam according to operating and other criteria of the preferred alternative contained in the FEIS. The Service determined implementation of the preferred alternative would not jeopardize the continued existence of the Vasey's Paradise Kanab ambersnail population. This opinion also supported the concept of a beach/habitat building flow of 40,000 to 45,000 cfs, which is part of the preferred alternative. At the time of the 1994 Biological Opinion, the Service thought that 10 percent of habitat would be lost in a 45,000 cfs flow and set this amount, as vegetation rather than number of snails, to be the expected incidental takes. Information obtained in ensuing investigations showed that the incidental take in a 45,000 cfs release could be as much as 17 percent of snail habitat (Service 1996), and, pursuant to that finding, the Service adjusted the incidental take to be 17 percent (Service 2000).

determine if ponding would occur at tributary mouths to provide a warm transition zone for young native fish escaping from the warm tributary into the cold mainstem. The fall release was designed to determine if high flows could be used to displace and reduce numbers of small-bodied non-native fish. This test was performed in accordance with an element of the reasonable and prudent alternative of the 1995 Opinion, so no additional consultation with USFWS was conducted.

2.2.5 2002–2004 Experimental Releases and Removal of Non-Native Fish

In 2002, Reclamation, the National Park Service, and the U.S. Geological Survey (USGS) consulted with the USFWS on: (1) experimental releases from Glen Canyon Dam, (2) mechanical removal of non-native fish from the Colorado River in an approximately 9-mile reach in the vicinity of the mouth of the LCR to potentially benefit native fish, and (3) release of non-native fish suppression flows having daily fluctuations of 5,000–20,000 cfs from Glen Canyon Dam during the period January 1–March 31. Implicit in the experimental flows and mechanical removal proposed action was the recognition that modification of dam operations alone likely would be insufficient to achieve objectives of the GCDAMP, which include removal of jeopardy for the humpback chub and razorback sucker.

In their biological opinion, the USFWS concluded that the proposed action was not likely to jeopardize the continued existence of the humpback chub, Kanab ambersnail, bald eagle, razorback sucker, California condor, or southwestern willow flycatcher. The December 2002 Opinion included incidental take of up to 20 humpback chub during the non-native fish removal efforts and the loss of up to 117 m^2 of Kanab ambersnail habitat.

Two conservation measures were included in the 2002 Opinion. The first measure included relocation of 300 humpback chub above Chute Falls in the LCR where predation was low to increase the likelihood of humpback chub surviving throughout the LCR during inclement environmental conditions. The second conservation measure consisted of temporary removal and safeguard of approximately 29–47 m^2 (25–40 percent) of Kanab ambersnail habitat that would be inundated by the experimental release. The relocated habitat and ambersnails would be replaced once the high flow was complete to facilitate re-establishment of vegetation.

The USFWS translocated young humpback chub above Chute Falls in the LCR (ca. 16 km from the confluence). Under contract with the GCMRC, USFWS translocated nearly 300 young humpback chub above a natural barrier in the LCR located 16 km above the confluence in August 2003. This translocation was followed by another 300 fish in July 2004 and by another 567 fish in July 2005 (Sponholtz et al. 2005; Stone 2006). Results indicate that this experiment has been a success: translocated fish survival and growth rates are high; limited reproduction and downstream movement below Chute Falls has been documented; and recent increases in the humpback chub population are likely partially attributable to this effort (Coggins and Walters 2009).

The sediment input triggered high experimental flow was analyzed for an indefinite period of time because of the uncertainty of knowing when the sediment trigger would be reached. The other two actions were analyzed for water years 2003 and 2004. Consultation was reinitiated in 2004 to make several changes to the timing and duration of the proposed experiments described in the 2002 consultation. The 2004 high flow experiment was intended to occur immediately following significant tributary sediment inputs, while the 2002 high flow experiment was proposed to occur in winter or spring. In the November 2004 Opinion, the USFWS concurred with Reclamation that the action was not likely to adversely affect razorback sucker or its critical habitat, California condor, or southwestern willow flycatcher. The USFWS concluded that the action was not likely to jeopardize the continued existence of the humpback chub, Kanab ambersnail, or bald eagle. The USFWS also concluded that the action was not likely to destroy or adversely modify designated critical habitat for humpback chub.

The 2004 Opinion included the 2002 conservation measures related to humpback chub including the continuation of translocating humpback chub in the LCR, and further study and monitoring of the results, as well as a study of effects on chub from various flow conditions. The Kanab ambersnail conservation measures included removal and safeguard of Kanab ambersnail habitat that would be inundated by the experimental release. Reclamation implemented conservation measures for Kanab ambersnail and humpback chub in conjunction with the proposed activities (Peterson 2002).

2.2.6 2007 Colorado River Interim Guidelines and Coordinated Operations

In October 2007, Reclamation issued a FEIS on *Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead* (Reclamation 2007a). A Record of Decision (Shortage ROD) was issued on December 13, 2007, which adopted these interim guidelines and coordinated reservoir operations (U.S. Department of the Interior 2007). This Shortage ROD specified reduction of consumptive uses below Lake Powell during times of low reservoir conditions and modification of the annual release volumes from Lake Powell. The Shortage ROD established annual release volumes from Glen Canyon Dam, but did not, in any manner, alter the constraints imposed by the 1996 ROD or as adopted in the 1997 Glen Canyon Dam Operating Criteria (discussed in Section 1.3). Since many of the potential resource impacts identified in that FEIS were being investigated in the GCDAMP, the biological opinion made use of this institutional arrangement as a key mechanism for addressing impacts.

The USFWS issued a final biological opinion on this Federal action on December 12, 2007 (USFWS 2007). In that 2007 Opinion, the USFWS determined that implementation of the guidelines was not likely to jeopardize the continued existence of the humpback chub, the southwestern willow flycatcher, or the Kanab ambersnail, and was not likely to destroy or adversely modify designated critical habitat for the humpback chub or the southwestern willow flycatcher. The 2007 Opinion did not render a determination for the razorback sucker because of the perceived absence of the species from the action area. However, in its concurrence for adoption and implementation of these guidelines, USFWS determined that Reclamation would, as a conservation measure, undertake an effort to examine the potential of habitat in the lower Grand Canyon for the species, and institute an augmentation program in collaboration with USFWS, if appropriate. Reclamation has implemented a project to address this measure starting in 2010.

As part of the 2007 Opinion, Reclamation, through the GCDAMP, will continue to monitor Kanab ambersnail and its habitat in Grand Canyon and the effect of dam releases on the species.

Reclamation will also continue to assist USFWS in funding morphometric and genetic research to better determine the taxonomic status of the subspecies. Reclamation will also continue to monitor southwestern willow flycatcher and its habitat and the effect of dam releases on the species throughout Grand Canyon and report findings to USFWS, and will work with the NPS and other GCDAMP participants to identify actions to conserve the flycatcher. Five conservation measures were identified in the 2007 Opinion to help reduce the threat to the humpback chub. The status of these conservation measures is described in Section 1.3.

2.2.7 2008 Biological Opinion

On February 27, 2008, the USFWS issued a biological opinion on the operation of Glen Canyon Dam for the period 2008–2012. That 2008 Opinion concluded that implementation of a March 2008 high flow test and a five-year implementation of MLFF with steady releases in September and October, as proposed, was not likely to jeopardize the continued existence of the humpback chub or the Kanab ambersnail, and was not likely to destroy or adversely modify designated critical habitat for the humpback chub. The Incidental Take Statement in the 2008 Opinion states that incidental take would be exceeded if the proposed action resulted in detection of more than 20 humpback chub mortalities during the high-flow test of March 2008 that were attributable to the high flow. The 2008 Opinion identified eight conservation measures for the humpback chub that expanded on the measures identified in the 2007 Opinion, including a Humpback Chub Consultation Trigger, a Comprehensive Plan for the Management and Conservation of Humpback Chub in Grand Canyon, Humpback Chub Translocation, Non-native Fish Control, Humpback Chub Nearshore Ecology Study, Monthly Flow Transition Study, Humpback Chub Refuge, and LCR Watershed Planning. These are further described in the *Reissuance Of the 2009 Supplemental Biological Opinion on The Operation of Glen Canyon Dam 2008-2012* (USFWS 2010).

On May 26, 2009, the District Court of Arizona, in response to a lawsuit brought by the Grand Canyon Trust, ordered the USFWS to reevaluate the conclusion in the 2008 Opinion that the MLFF does not violate the ESA (Case number CV-07-8164-PHX-DGC). The Court ordered the USFWS to provide an analysis and a reasoned basis for its conclusions in the 2008 Opinion, and to include an analysis of how MLFF affects critical habitat and the functionality of critical habitat for recovery purposes by October 30, 2009.

2.2.8 2009 Supplement to the 2008 Biological Opinion

On October 29, 2009, the USFWS issued a supplement to the 2008 Opinion for the operation of Glen Canyon Dam, as a result of the Court Order of May 26, 2009, and affirmed the 2008 Opinion that the action was not likely to jeopardize the continued existence of the humpback chub or the Kanab ambersnail, and was not likely to destroy or adversely modify designated critical habitat for the humpback chub. The Incidental Take Statement in the 2009 Supplemental Opinion states that incidental take would be exceeded if the proposed action caused the conditions of the consultation trigger to be met. The consultation trigger was identified in the 2008 Opinion as a conservation measure, and states in the 2009 Supplemental Opinion that "Reclamation and USFWS agree to specifically define this reinitiation trigger relative to humpback chub, in part, as being exceeded if the population of adult humpback chub (≥200 mm [7.87 in] TL) in Grand Canyon declines significantly, or, if in any single year, based on the age-structured mark recapture model (ASMR; Coggins 2008a), the population drops below 3,500 adult fish within the 95 percent confidence interval." Based on the recommendation of the GCDAMP Protocol Evaluation Panel (PEP), the decision was made to employ the ASMR model once every three years. Hence, the ASMR would not be utilized annually, but only employed to test the humpback chub consultation trigger if other data, such as annual mark-recapture, closed population estimates of humpback chub abundance in the LCR, indicated that the population was declining to the abundance level defined in the trigger.

On June 29, 2010, the District Court of Arizona ruled that the 2009 Supplemental Opinion adequately explained the USFWS conclusion that the proposed action was not likely to neither jeopardize the humpback chub nor adversely modify its critical habitat. However, the incidental take portion of the 2009 Supplemental Opinion was remanded back to the USFWS, and addressed in separate documentation. On September 1, 2010, in response to the June 29 District Court of Arizona order, a revised incidental take statement and biological opinion were issued (Reissuance of the 2009 Supplemental Opinion, USFWS 2010).

2.2.9 Cancellation of Non-native Fish Removal in 2010

On March 5, 2010, Reclamation requested reinitiation of formal consultation (2009 Supplemental Opinion) to accommodate a modification of the 5-year experimental nonnative fish removal efforts planned for May and June 2010. Concerns were expressed by American Indian Tribes over the killing of fish as loss of life in sacred areas, and a draft biological opinion was submitted by USFWS to Reclamation on October 14, 2010, evaluating the cancellation of nonnative mechanical removal in 2010.

The focus of this consultation was the cancellation of two nonnative removal trips scheduled for May and June 2010. All other aspects of the proposed action remained the same as described in the 2009 Supplemental Opinion described above. Conservation measures such as parasite monitoring, potential razorback sucker augmentation, and the monthly flow transition study, as described in the 2008 and 2009 Opinions, would likely not occur during the 13-month period but were planned for the future. Other conservation measures, such as the Nearshore Ecology Study and the Fall Steady Flow Plan are proceeding. Because the high flow test conservation measure had already occurred in March of 2008, it was not addressed in this consultation. The flows for this consultation, which have been addressed in earlier biological opinions, were to occur as follows: flows in March–August 2010 will occur under the MLFF strategy, September-October 2010 will consist of steady flows, and November 2010 through April 30, 2011 will return to MLFF which is the preferred alternative as described in the 1996 ROD on Glen Canyon Dam Operations.

This reinitiated consultation resulted after meetings with American Indian Tribes and with the GCDAMP members. Due to cultural and religious concerns regarding the taking of life associated with mechanical removal of nonnative fishes as a conservation measure, it was decided that the two nonnative removal trips scheduled for May and June 2010 would be cancelled. This resulted in a modification of the action proposed as addressed in the 2008 and 2009 Opinions.

The USFWS determined that proposed action was not likely to jeopardize the continued existence of the humpback chub or destroy or adversely modify its critical habitat. The USFWS also concluded that the proposed action was not likely to destroy or adversely modify critical habitat for the razorback sucker. Although razorback sucker critical habitat was not addressed in the formal consultation portion of the 2008 Opinion, it was addressed in the 2010 Opinion, at Reclamation's request. All other effects determinations remained the same as for the 2008 and 2009 Opinions for the razorback sucker, Kanab ambersnail, and southwestern willow flycatcher.

For the 2010 Biological Opinion, the USFWS anticipated that between 1,000 and 24,000 y-o-y or juvenile humpback chub would be lost to predation by trout as a result of the modified proposed action during the 13-month period. The USFWS adopted the incidental take estimate provided in the April 2010 BA, of 10,817 young-of-year and juvenile humpback chub for the 13-month period. Even with the occurrence of other lethal and nonlethal stressors from suboptimal water temperatures and unstable shoreline habitat associated with fluctuating flows, except for September and October, USFWS did not anticipate that incidental take would exceed the 24,000 estimate. Reclamation has committed in the 2007 Opinion to the monitoring and control of non-native fish in coordination with other Interior agencies and working through the GCDAMP (USFWS 2007).

2.3 Description of Species Identified for Analysis

Four endangered species are identified within or near the area affected by the proposed action: the humpback chub, razorback sucker, Kanab ambersnail, and the southwestern willow flycatcher. Descriptions of these species and their legal status, life history, current range, and abundance are provided below. More detailed information on the four species analyzed in this BA can be found in Reclamation's 2007 BA (Reclamation 2007a).

2.3.1 Humpback Chub

The humpback chub was included in the List of Endangered Species on March 11, 1967 (32 FR 4001) and was listed as endangered with passage of the ESA in 1973. The humpback chub recovery plan was approved on September 19, 1990 (USFWS 1990) and Recovery Goals were developed in 2002 (USFWS 2002a). The final rule for determination of critical habitat was published on March 21, 1994 (59 FR 13374), and the final designation became effective on April 20, 1994. Designated critical habitat occurs in two reaches within or near the action area: the lower 8 miles of the LCR and 173 miles of the Colorado River and its 100-year floodplain in Marble and Grand Canyons from Nautiloid Canyon (RM 34) to Granite Park (RM 208). The LCR is a seasonally-warmed tributary with a spring-fed base flow of about 230 cfs and highly turbid floods of over 10,000 cfs; light gravel deposits are principal spawning sites for humpback chub, and young inhabit rocky shorelines while adults use deep pools. The mainstem habitat remains too cold most years (<15°C) for spawning by humpback chub, but young escape from the LCR and inhabit rocky nearshore areas while adults use large deep eddy complexes.

The humpback chub is a moderately large cyprinid fish endemic to the Colorado River system (Miller 1946). It is surmised from various reports and collections that the species occupies about 68 percent of its historic habitat of about 470 miles of river (USFWS 2002a). Range and population reductions are thought to have been caused primarily by streamflow regulation and habitat modification (including cold-water dam releases and habitat loss), competition with and predation by non-native fish species, parasitism, hybridization with other native *Gila*, and pesticides and pollutants. Six humpback chub populations are currently known—all from canyon-bound reaches. Five are in the upper Colorado River Basin and the sixth, known as the Grand Canyon population, is located in Marble and Grand Canyon's of the lower basin. Upper basin populations range in size from a few hundred individuals to about 5,000 adults.

The most recent estimate of the Grand Canyon population is between 6,000 and 10,000 adults (most likely estimate at 7,650 adults; Coggins and Walters 2009). The majority of individuals in this population are located in the LCR and in a 10-mile reach of the Colorado River above and below the confluence of the two rivers. There are eight other small aggregations of humpback chub in Grand Canyon: seven are located at distances up to 150 miles below the confluence and one is located 30 miles above the confluence (Valdez and Ryel 1995).

Young-of-year and juvenile humpback chub are found primarily in the LCR and the Colorado River near the LCR inflow, although many have been found upstream of the LCR (Figure 3), presumably from spawning at warm springs near RM 30 (river miles downstream from Lees Ferry) (Valdez and Masslich 1999). Reproduction by humpback chub occurs annually in spring in the LCR, and the young fish either remain in the LCR or disperse into the Colorado River. Dispersal of these young fish has been documented as nighttime larval drift during May through July (Childs et al. 1998; Robinson et al. 1998), as density dependent movement during strong year classes (Gorman 1994), but primarily as movement with summer floods caused by monsoonal rainstorms during July through September (Valdez and Ryel 1995). Survival of these young fish in the mainstem is thought to be low because of cold mainstem temperatures (Clarkson and Childs 2000; Robinson and Childs 2001), but an unknown number of fish survive and return to the LCR and contribute to recruitment. The cold mainstem temperatures appear to suppress growth of young humpback chub when compared to growth in the LCR, but growth of adults in the mainstem may be greater or comparable to that of adults in the LCR (Valdez and Ryel 1995; Coggins 2008b). These different growth rates may also be influenced by available food supplies in the two systems (Rosi-Marshall et al. 2010).

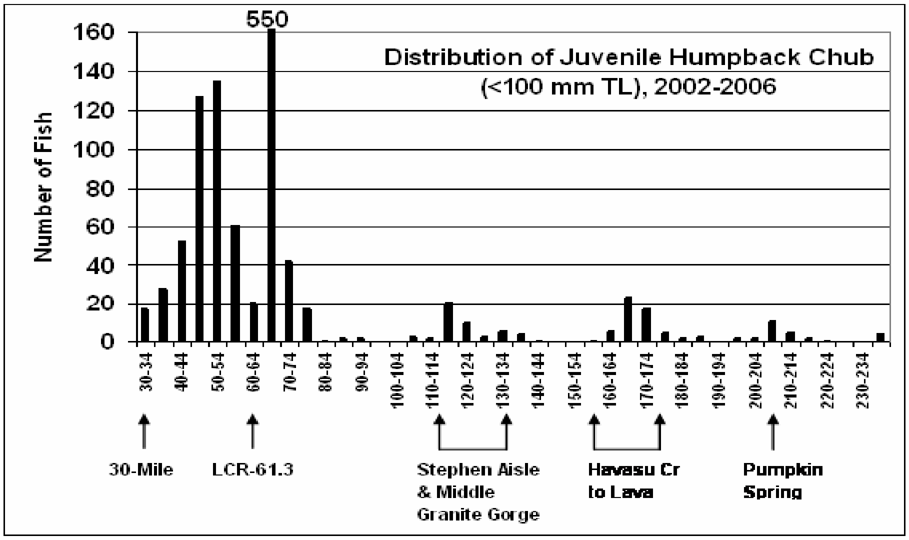

Figure 3. Distribution of juvenile humpback chub < 100 mm TL during 2002-2006 by 5-miles increments from RM 30 to RM 230. Principal humpback chub aggregations are indicated (data from Ackerman and Valdez 2008)

Survival of humpback chub is also affected by diseases and parasites (e.g., Asian tapeworm, *Bothriocephalus acheilognathi*, and parasitic copepod, *Lernaea cyprinacea*; Hoffnagle et al. 2000), available food supply, and downstream displacement of young (Valdez and Ryel 1995). The extent and disposition of downstream displacement is not known, but was not significant for the late-March, early-1996 HFE (Hoffnagle et al. 1999). Evidently, some fish that disperse downstream survive. Aggregations located downstream from the LCR include fish that were marked and released near the LCR, as well as fish that likely were produced locally. Predation by rainbow trout and brown trout in the LCR confluence area has been identified as an additional source of mortality affecting survival and recruitment of humpback chub (Valdez and Ryel 1995; Marsh and Douglas 1997; Coggins 2008a; Yard et al. 2008).

2.3.2 Razorback Sucker

The razorback sucker was listed as endangered under the ESA on October 23, 1991 (56 FR 54957). The final rule for determination of critical habitat was published on March 21, 1994 (59 FR 13374), and the final designation became effective on April 20, 1994. Designated critical habitat includes the Colorado River and its 100-year floodplain from the confluence with the Paria River (RM 1) downstream to Hoover Dam, a distance of nearly 500 miles, including Lake Mead to full pool elevation. A recovery plan was approved on December 23, 1998 (USFWS 1998a) and Recovery Goals were approved on August 1, 2002 (USFWS 2002b). Primary threats to razorback sucker populations are streamflow regulation and habitat modification and fragmentation (including cold-water dam releases, habitat loss, and blockage of migration corridors); competition with and predation by non-native fish species; and pesticides and pollutants (Bestgen 1990; Minckley 1991; USFWS 2002b).

The razorback sucker is endemic to the Colorado River System. Historically, it occupied most of the middle and lower elevations of the mainstem Colorado River and many of its tributaries. Distribution and abundance of razorback sucker declined throughout the 20th century over all of its historic range, and the species now exists naturally only in a few small, discontiguous populations or as dispersed individuals. In the last 40–50 years, numbers of razorback suckers have declined sharply because of little natural reproduction and recruitment, and the few remaining wild populations are comprised primarily of old adults.

The razorback sucker has not been reported upstream of about Pearce Ferry since 1990 and only 10 adults were reported between 1944 and 1995 (Valdez 1996; Gloss et al. 2005). Carothers and Minckley (1981) reported four adults from the Paria River in 1978–1979. Maddux et al. (1987) reported one blind female razorback sucker at Upper Bass Camp (RM 107.5) in 1984, and Minckley (1991) reported five adults in the lower LCR from 1989–1990. A full complement of habitat types (large nursery floodplains, broad alluvial reaches for feeding and resting, and rocky canyons for spawning), as used by razorback suckers in the Upper Colorado River Basin (USFWS 2002b), does not appear to be available between Glen Canyon Dam and Pearce Ferry; however, alluvial gravel bars off tributary mouths and side canyons are available for spawning, a few backwaters are available for nursing by young, and alluvial reaches are present for resting and feeding. If razorback suckers use lower Grand Canyon, it most likely involves fish that spend at least part of their life cycle in the more complex habitat offered by the Lake Mead inflow downstream from Pearce Ferry.

The largest reservoir population, estimated at 75,000 in the 1980s, occurred in Lake Mohave, Arizona and Nevada, but it had declined to about 60,000 in 1989 (Marsh and Minckley 1989), to 25,000 in 1993 (Marsh 1993; Holden 1994), to about 9,000 in 2000 (Burke 1994), and to less than 3,000 by 2001 (Marsh et al. 2003). Mueller (2005, 2006) reported that the wild Lake Mohave razorback sucker population was approaching 500 individuals, while the most recent 2009 estimate is approximately 30 wild fish remaining (Pacey 2009). Today, the Lake Mohave population is largely supported by periodic stocking of captive-reared fish (Marsh et al. 2003, 2005). Adult razorback sucker are most evident in Lake Mohave from January through April when they congregate in shallow shoreline areas to spawn, and larvae can be numerous soon after hatching.

A second razorback sucker population of approximately 500 adults exists in Lake Mead. The Lake Mead population is the only known recruiting population of razorback sucker in the Lower Colorado River Basin (Holden et al. 2000; Abate et al. 2002; Albrecht and Holden 2005; Albrecht et al. 2008a, 2008b). From 1990 through 1996, 61 razorback sucker were collected, 34 from the Blackbird Point area of Las Vegas Bay and 27 from Echo Bay in the Overton Arm (Holden et al. 1997). Two razorback sucker larvae were collected by in 1995 near Blackbird Point, confirming suspected spawning in this area. In addition to the captures of these wild fish, Nevada Department of Wildlife also stocked subadult (sexually immature) razorback sucker into Lake Mead; a total of 26 were stocked into Las Vegas Bay in 1994 and 14 were stocked into Echo Bay in 1995.

From 1996 to 2008, netting efforts have yielded more than 750 total razorback suckers captured or stocked, represented by nearly 500 unique individuals (Kegerries et al. 2009). In 1997, four subadult razorback suckers were captured in Echo Bay, indicating that recent, natural reproduction and recruitment had occurred within the Lake Mead population. Seventeen additional wild subadults were captured in the Blackbird Point area of Las Vegas Bay through 2005. During 2005–2008, an additional 39 subadults were captured in Lake Mead, indicating continued, natural reproduction and recruitment. Of 186 razorback sucker aged from fin-ray cross sections, adults were 7–36 years old and subadults were 2–6 years of age.

Kegerries et al. (2009) hypothesized that lake-level fluctuation, which promotes growth and inundation of shoreline vegetation, is largely responsible for the recruitment observed in the Lake Mead razorback sucker population. The inundated vegetation likely serves as protective cover that, along with turbidity, allows young razorback sucker to avoid predation by nonnative fishes. Recent nonnative introductions, such as quagga mussels (*Dreissena rostriformis bugensis*) and gizzard shad (*Dorosoma cepedianum*), could also affect the razorback sucker population in Lake Mead, but the nature and severity of these new potential stressors remains unknown.

During the last several years, declining Lake Mead elevations have affected the use of several spawning sites by razorback sucker in Lake Mead (Figure 4). From 1997 to 2001, aggregations of sonic-tagged adults, nest locations, and larval concentrations indicate that spawning was occurring at the back of Echo Bay along the south shore. Specifically, it appeared that adults were spawning at the base of a 50-foot cliff, but by the end of the spawning season in May 2001, this site was dry. As lake levels declined during 2002–2009, this population continued to find new spawning sites in Echo Bay at lower elevations, as sites from previous years dried.
At Las Vegas Bay during 1996–2004, most razorback sucker larvae were captured along the western shore and tip of Blackbird Point, suggesting that the same portion of Blackbird Point was used for spawning every year. However, the depth in this area changed dramatically as lake levels dropped and possible siltation occurred from Las Vegas Wash. In the late 1990s, at a high lake elevation, the spawning site was thought to be at a depth of about 80 feet, but by 2003, the spawning depth was closer to 20 feet and by the end of 2004, the area was dry. Spawning was not observed at Blackbird Point during 2003–2004, and only four larval razorback suckers were captured during the entire season at Las Vegas Bay, a site that once harbored the largest razorback sucker population in Lake Mead. However, during the 2005 spawning period (January through April), Lake Mead elevations rose more than 20 feet, allowing access to the Blackbird Point spawning site. However, in 2006 and in 2007, lake elevation lowered and the spawning aggregate shifted locations from Blackbird Point to the southwestern shore of Las Vegas Bay.

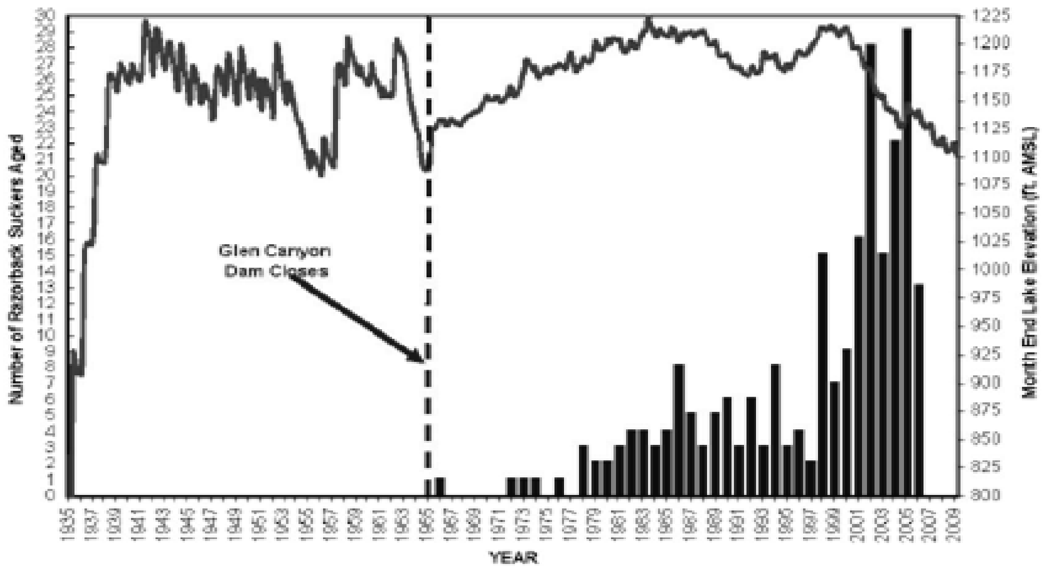

Figure 4. Lake Mead elevation from January 1935 to June 2009 with the number of razorback sucker that were born each year lake-wide, based on ages of fish captured during 2005-2008 (figure from Kegerries et al. 2009). Note that the historic decline in numbers of fish is not necessarily a measure of spawning success for given years, but reflects the numbers of fish surviving over time from those spawning periods.

In 2000 and 2001 larval razorback sucker were captured in the Colorado River inflow region of Lake Mead (Kegerries et al. 2009). During the 2002 and 2003 spawning periods, no larval razorback suckers were captured in this area. This spawning site was either not used in 2002–2003, or spawning took place outside of the sampling area. Alteration of spawning sites resulting from lake elevation changes may be responsible for the apparent inconsistent use of spawning sites in the Colorado River inflow region, as in other sites on Lake Mead described above.

In spring of 2010, larval sampling in the Colorado River inflow area (presently in the Gregg Basin region of Lake Mead) resulted in the capture of seven larval razorback sucker, one larval flannelmouth sucker (*Catostomus latipinnis*), and four larval fish thought to be either flannelmouth sucker or hybrid flannelmouth x razorback sucker (Albrecht et al. 2010). Although catch per unit effort was low, the identification of larval razorback sucker in the Colorado River inflow helped confirm the presence of spawning adult razorback sucker and documented successful spawning in 2010. Spawning is believed to have occurred on rock and gravel points between North Bay and Devil's Cove, in the lake interface about 10 miles downstream from Pearce Ferry. Moreover, Albrecht et al. (2010) reported that trammel netting in the inflow area yielded three wild razorback suckers, four razorback x flannelmouth sucker hybrids, and 52 flannelmouth suckers. All three razorback sucker were males expressing milt, which helped confirm spawning activities. Two of these individuals were 6 years old and one was 11 years old. Sonic-tagged razorback sucker released near the Colorado River inflow in 2010 used the riverine habitat and inflow region as far upstream as the mouth of Devil's Cove, about 8 miles downstream from Pearce Ferry.

2.3.3 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. Fully mature snail shells are translucent amber with an elongated first whorl, and measure about 23 mm in shell size (Sorensen 2007). Two populations of Kanab ambersnail currently exist 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, 1998; Meretsky and Wegner 1999; Meretsky 2000; Webb and Fridell 2000).

The Kanab ambersnail lives approximately 12–15 months and is hermaphroditic and capable of self-fertilization (Clarke 1991; Pilsbry 1948). Mature Kanab ambersnail mate and reproduce in May–August (Stevens et al. 1997a; Nelson and Sorensen 2001). 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 (Interagency Kanab Ambersnail Monitoring Team [IKAMT] 1997; Stevens et al. 1997a). Populations fluctuate widely throughout the year due to variation in reproduction, survival, and recruitment (Stevens et al. 1997a).

The number of ambersnails at Vasey's Paradise has remained stable since 1998 (Ralston 2005), although flows greater than 45,026 cfs are thought to decrease the population by up to 17 percent in the short-term (Stevens et al. 1997a, 1998b). Microclimatic conditions such as higher humidity and lower air temperatures relative to the surrounding environments and high vegetative cover may be important habitat features related to Kanab ambersnail survival (Sorenson and Nelson 2002). Kanab ambersnail are pulmonate or air-breathing mollusks, but are able to survive underwater for up to 32 hours in cold, highly oxygenated water (Pilsbry 1948).

Stevens et al. (1997a) 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. Surveys in 1995 revealed rapid changes in vegetative cover over the growing season, with 5.9–9.3 percent of the primary habitat occurring below the 33,000 cfs stage, and 11.2–16.1 percent occurring below the 45,000 cfs stage. Area of primary habitat varied from 850–905 m^2 in March–September 1995. The same vegetation occupied from 7.0–12.5 percent of the area below 45,000 cfs from 1996–1999 following a 45,000 cfs beach/habitat building flow (BHBF) test (GCMRC 1999).

The total estimated population of Kanab ambersnail at Vasey's Paradise increased from approximately 18,500 snails in March 1995 to 104,000 snails in September 1995 as reproduction took place in mid-summer (Stevens et al. 1997a). The proportion of the total estimated population occurring below the 33,000 cfs stage rose from 1.0 percent in March to 7.3 percent in September, and that occurring below the 45,000 cfs stage was 3.3 percent in March, 11.4 percent in June, and 16.4 percent in September 1995. Subsequent surveys have reported population estimates of between approximately 5,000 and 52,000 individuals (Interagency Kanab Ambersnail Monitoring Team [IKAMT] 1998; GCMRC 1999; Meretsky and Wegner 1999). Nelson and Sorensen (2001) analyzed sampling and analytical techniques used for these estimates and concluded that overestimation of actual population size has occurred in monitoring reports, and pointed out that these errors make more difficult the assessment of risk to the population.

Current threats to Kanab ambersnail include loss and adverse modification of wetland habitats, which are scarce in this semi-arid region (USFWS 1995). Historically, the Grand Canyon often experienced annual floods of 90,000 cfs or greater and Kanab ambersnail were periodically swept downstream and drowned (Stevens et a. 1997a). Today, Glen Canyon Dam limits such floods, although numerous high flows (>45,000 cfs) have occurred in the last 30 years. For example, during the late-March, early-April 1996 HFE, up to 16 percent of Kanab ambersnail habitat at Vasey's Paradise was lost or degraded and hundreds of snails were lost. Recovery of this habitat to pre-flood conditions required over two years (IKAMT 1998; Stevens et al. 1997b).

2.3.4 Southwestern Willow Flycatcher

The southwestern willow flycatcher was designated as endangered on February 27, 1995 (USFWS 1995a). A final recovery plan was completed in August 2002 (USFWS 2002c). Critical habitat was initially designated in 1997 (62 FR 39129), but was rescinded by court order in 2001. Designation of critical habitat was finalized in October 2005, and includes portions of the lower Colorado River below Grand Canyon National Park (USFWS 2005b). The affected environment for this action does not include any critical habitat for this species.

The southwestern willow flycatcher is about 15 cm long, and weighs approximately 11 g. It has a grayish-green back and wings, whitish throat, light grey-olive breast, and pale yellow belly. Recognition of the different subspecies in the field is nearly impossible and is mainly based on differences in color and morphology using museum specimens (Unitt 1987; Paxton 2000). Southwestern willow flycatchers have been documented along the Colorado River between RM 47 and RM 54, at RM 71, and at RM 259 (Unitt 1987; Sogge et. al. 1995; Tibbets and Johnson 1999, 2000). Presence-absence surveys and life history studies of the species have been conducted along the Colorado River since 1996 (McKernan and Braden 1997, 1998, 1999, 2001, 2006a, 2006b; Koronkiewicz et al. 2004, 2006; McLeod 2005). These studies show that the bird has consistently nested along the river in Grand Canyon from Separation Canyon to the delta of Lake Mead, as new riparian habitat, primarily tamarisk, has developed in response to regulated river flows (Gloss et al. 2005). The expansion of riparian vegetation in Grand Canyon may have provided additional habitat for the southwestern willow flycatcher, but birds in the upper river corridor persist at a very low level at only one or two sites.

The southwestern willow flycatcher breeds across the Southwest from May through August. The birds typically arrive on breeding grounds between early May and early June. Along the lower Colorado River, main nest substrates include Goodding's willow (20–30 percent), coyote willow (5–15 percent), Fremont cottonwood (5 percent) and tamarisk (50–70 percent). Egg lying can start as early as late May, but is usually in early to mid-June (Sogge et al. 1997a, 1997b). The female usually incubates the eggs for approximately 12 days, and all eggs usually hatch within

24–48 hours of one another. Nestlings fledge usually within 12–15 days (Paxton and Owen 2002). Chicks are usually present from mid-June through early August.

At most sites along the Colorado River and tributaries, occupied habitats usually have high canopy closure with no distinct understory, overstory, or structural layers (Koronkiewicz et al. 2006). Nest sites are usually located within 200 m of open or standing water and usually contain soils that are higher in water content than non-use sites (McKernan and Braden 2001; Stoleson and Finch 2003; Paradzick 2005; Koronkiewicz et al. 2006). Water or moist soils help regulate temperature and relative humidity within the stand, produce the right conditions for insect development and survival, and are associated with creating a greater foliage density (USFWS 2002c; Paradzick 2005; Koronkiewicz et al. 2006).

Population numbers have fluctuated between five breeding pairs and three territorial, but non-breeding pairs in 1995, to a single breeding pair more recently. The year 2004 marked the sixth consecutive year in which surveys located a single breeding pair at the upper sites, the lowest population level since surveys began in 1982. Between 2005 and 2009, three individuals were detected between Lees Ferry and Phantom Ranch, all in 2009 (Northrip et al. 2008; Slayton et al. 2009). Nesting flycatchers have not been confirmed at Grand Canyon National Park since 2003; however, nest searching has not taken place since 2004. As there are several habitat patches between Lees Ferry and Pearce Ferry that meet the habitat criteria for breeding southwestern willow flycatchers, Grand Canyon National Park conducted surveys in 2010 from RM 0 to RM 275 (Palarino et al. 2010). In May 2010, the NPS surveys found one individual at RM 28.5 and one individual at RM 196. In June, they located two individuals at RM 217 and two individuals at RM 274.5. Breeding pairs were not detected (NPS 2010 draft report). Given these low numbers, the continued presence of the SWWF in Grand Canyon appears tenuous.

The southwestern willow flycatcher has been detected within lower Grand Canyon–upper Lake Mead since surveys began in 1997 with breeding flycatchers detected in 1999–2001, but not in 2002 or 2003. A single breeding pair was detected in 2004, an unpaired male occupied this same area in 2005, and two nests were detected during the 2006 breeding season (Koronkiewicz et al. 2006). Due to extreme drops in water levels that started in 2000, much of the occupied habitat of the 1990s is now dead or dying. More recently, new stands of vegetation have been developing in areas exposed by receding water and this vegetation is now developing into suitable flycatcher habitat.

3 Effects Analysis

3.1 Attributes of HFEs Analyzed

Analysis of effects is based on 50 CFR 402.02, in which "[e]ffects of the action refers 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 or interdependent with that action, that will be added to the environmental baseline." The environmental baseline is described in Section 2 of this BA.

The proposed action is a decision strategy based primarily on water availability and sand storage (see Section 1.4). Because of the uncertainty of these two principle components in the decision-making process, it is not possible to prescribe in advance when an HFE will occur, or its magnitude or duration. Hence, it is difficult to predict effects on threatened and endangered species found in the action area. Furthermore, it is not possible to predict the frequency or sequence of HFEs within or among years over the 10-year period of this protocol. It is possible, however, to determine the most likely timing, magnitude, and duration of an HFE, based on model simulations using historical records for water availability and sand storage (see Section 1.4.3). Additionally, information on effects of previous experiments on natural resources helps to identify likely effects of the proposed action on listed species in the action area.

In order to better define the proposed action for this BA, four principal attributes of an HFE are considered during the course of this analysis—timing, magnitude, duration, and frequency. Timing refers to time of year, magnitude is the peak flow, duration is the length of the peak flow, and frequency is the interval of time between HFEs or how often HFEs are conducted. The first three attributes (timing, magnitude, and duration) are related to a single HFE, and the fourth (frequency) is related multiple HFEs.

Based on the previous descriptions of possible HFEs, the following assumptions are made for the purpose of effects analysis:

- The timing of HFEs would be either spring (March and April) or fall (October and November).
- The magnitude of HFEs would range from 31,500 cfs to 45,000 cfs.
- The duration of HFEs would range from an instantaneous release to 96 hours.
- The frequency of HFEs within a year and among years cannot be predicted, but one or two HFEs per year and more than two consecutive HFEs are possible.

Based on these assumptions, the effects analysis of this BA is based on three phases: (1) an evaluation of attributes for a single HFE, (2) an evaluation of likely effects of two consecutive HFEs, and (3) an evaluation of likely effects of more than two consecutive HFEs.

Thirteen types of possible HFEs were evaluated through modeling (see Table 2). These 13 types provide a range of magnitude and duration for HFEs that may occur in March-April and

October-November. The range of 41,000–45,000 cfs represents the range of high releases for the HFEs conducted in 1996 (45,000 cfs), 2004 (41,000 cfs), and 2008 (41,500 cfs). The impacts of these HFEs were evaluated and documented, and provide baseline information for the effects analysis of this BA. The duration range of 60–96 hours is within the range of time for high releases associated with the HFEs of 1996 (7 days), 2004 (60 hrs), and 2008 (60 hrs), but HFEs of less than 60 hours have not been conducted. An HFE with a magnitude greater than 31,000 cfs and less than 41,000 cfs has also not been conducted.

For the purposes of this BA, it is assumed that effects of timing, magnitude, and duration for a single HFE will be similar to effects observed during previous experiments. Effects of the proposed action on endangered species are expected to vary in intensity along a continuum from short duration powerplant releases (31,500 cfs for one hour) to longer duration flows (ca. 96 h) of 45,000 cfs. Together with results from the protocol simulations, results from investigations conducted during powerplant releases of 1997 and 2000 will be used to evaluate future HFEs consisting of 31,500 cfs. Results from HFEs conducted in 1996, 2004, and 2008 will be used to evaluate future HFE's consisting of 41,000 to 45,000 cfs. Effects to endangered species due to untested flows (between 31,500 and 41,000 cfs) are expected to fall between the extremes documented for previous experiments.

A number of uncertainties exist with respect to the effects of timing, magnitude, duration, and frequency of HFEs on various resources, including the endangered species. Some of these questions are listed as research questions in the EA and will be addressed in a Science Plan being developed by GCMRC.

3.2 Summary of Effects from Previous HFEs

Effects of previous high flow experiments on listed species are summarized in Table 4. The 1996 HFE had no discernible effects on humpback chub. Local shifts in habitat use were recorded with changing flows, but there was little evidence of downstream displacement (Valdez and Hoffnagle 1999). No population-level effects were detected. Sandbars were rebuilt and new backwater habitats were created, although many eroded quickly due to fluctuating flows (Andrews et al. 1999; Brouder et al. 1999). The value of backwater habitats to humpback chub and other native fishes is not clear, although these fish are commonly found in this habitat type. Effects of the powerplant capacity releases of 1997 and 2000 were either not studies, or no effects were detected. For the fall 2004 HFE, there was a possible short-term displacement of young humpback chub, but there was no evidence for lasting effects to the population. Similar findings were reported for the spring 2008 HFE, except there was no evidence of displacement of humpback chub.

For Kanab ambersnail, the 1996 HFE inundated and scoured about 17 percent of 851 m^2 of habitat at Vasey's Paradise, and recovery of this habitat delayed 2.5 years (KAIMT 1997). In contrast, for the 2004 HFE, all snails and 1-m^2 plots of habitat in the inundation zone at Vasey's Paradise were moved to higher elevation and returned after the HFE (Sorenson 2005). This immediate relocation of habitat and the cooler temperatures in fall enabled the habitat to recover in 6 months. For the spring 2008 HFE, all snails and all habitats in the inundation zone were moved and relocated, and the habitat recovered in about 6 months (Sorensen 2009).

For the southwestern willow flycatcher, no biologically significant impacts were detected with the 1996 HFE, and there were little long-term negative impact to nesting or foraging habitats (Palarino et al. 2010). Effects of the fall 1997 and spring and fall 2000 high releases were not studied for the listed species, but there were no discernible population-level effects on any of the four listed species.

Table 4. Summary of existing information on all HFEs and powerplant releases from Glen Canyon Dam to conserve sediment resources and their effects on threatened and endangered species. Conclusion is based on a weight-of-evidence evaluation of likely impacts to aquatic resources. HFE = high flow experiment, HMF = habitat maintenance flow.

Parameter	1996 HFE	1997 HMF	2000 HMF	2000 HMF	2004 HFE	2008 HFE
Timing	**Mar-Apr**	**Nov**	**May**	**Sept**	**Nov**	**Mar**
Magnitude	**45,000 cfs**	**31,000 cfs**	**31,000 cfs**	**31,000 cfs**	**41,000 cfs**	**41,500 cfs**
Duration	**7 days**	**48 hours**	**48 hours**	**48 hours**	**60 hours**	**60 hours**
Humpback chub	Local shift in habitat use with changing flows, little evidence of downstream displacement, no population effects detected[1]; Creation of backwater habitat [2,3]	Not studied.	No pre/post sampling.	No effects detected[4].	Possible short-term displacement[5]. No evidence for lasting impacts (population size stable or increasing since 2004[6,7,8]).	Creation of backwater habitat[9]; Population size increasing[10]
Razorback sucker	Not studied.	Not studied.	Not studied.	Not studied.	Not studied.	Not studied.
Kanab ambersnail	Snails in inundation zone at Vasey's Paradise were removed; 17 percent of 851 m^2 of habitat inundated and scoured[11]; habitat delayed 2.5 years to recover.[12]	Not studied	Not studied	Not studied	All snails and 1-m^2 plots of habitat in inundation zone at Vasey's Paradise were moved to higher elevation and returned after HFE; habitat recovered in 6 months.[13]	All habitat with snails in inundation zone at Vasey's Paradise were moved to higher elevation and returned after HFE; habitat recovered in 6 months.[14]
Southwestern willow flycatcher	No biologically significant impacts; little long-term negative impact to nesting or foraging habitats.[15]	Not studied.	Not studied.	Not studied.	Not studied.	Nesting flycatchers not confirmed since 2003; none seen between 2003 and 2008.[16]

[1]Valdez and Hoffnagle 1999
[2]Andrews et al. 1999
[3]Brouder et al. 1999
[4]Trammell et al. 2002
[5]GCMRC, unpublished data (Power Point presentation)
[6] Lauretta and Serrato 2006
[7]Ackerman and Valdez 2008
[8] Makinster et al. 2010a
[9]Grams et al. 2010
[10] Coggins and Walters 2009
[11]1996 Biological Opinion (February 16, 1996)
[12]IKAMT 1998
[13]Sorenson 2005
[14]Sorenson 2009
[15]Stevens et al. 1996
[16] Palarino et al. 2010

3.3 Humpback Chub Effects Analysis

The proposed action is likely to adversely affect the humpback chub and is likely to adversely affect its designated critical habitat. These effects are not expected to be of sufficient magnitude to negatively impact the overall population of humpback chub. This conclusion was reached based on the following effects that are described in detail in the following sections:

- Take could occur from downstream displacement of young into unsuitable habitat, especially during fall HFEs. Effects of displacement, if it occurs, are largely unknown.
- Direct short-term reductions in near-shore habitat could occur in the vicinity of the LCR with changes in flow stage, but long-term benefit is expected from sand redeposition that rebuilds and maintains near-shore and backwater nursery habitats.
- Direct short-term reductions in food supply could occur with scouring and changes in flow stage, but long-term benefit is expected from stimulated food production.
- Increased predation from expanded population of rainbow trout is expected, especially with spring or multiple HFEs.

3.3.1 Downstream Displacement

Adult humpback chub are expected to be little affected by high flows (Hoffnagle et al. 1999; Valdez and Hoffnagle 1999), although high flows may occur at a time of the year different from the pre-dam hydrograph. Little is known about the extent to which humpback chub rely on changes in flow as a reproductive cue. Valdez and Ryel (1995) held that neither water quantity or quality serve as cues for gonadal development or staging behavior in humpback chub; rather they hypothesized that climatic factors, such as photoperiod, were important. Humpback chub typically begin to spawn on the receding hydrograph as water temperatures start to rise (Tyus and Karp 1989; Kaeding and Zimmerman 1983; Valdez and Ryel 1995; Kaeding et al. 1990), but the LCR population also spawns in years with little appreciable runoff.

3.3.1.1 Potential for Downstream Displacement of Young

High releases from Glen Canyon Dam have the potential to displace young humpback chub from nearshore nursery habitats. The area of greatest potential effect is an approximately 8.4-mile reach of the Colorado River (RM 57 to 65.4) that spans the confluence of the LCR at RM 61.3 (about 76 miles downstream of Glen Canyon Dam). This area is the principal nursery area for young humpback chub that originate from spawning primarily in the LCR, but may also come from a small amount of mainstem spawning as far upstream as warm springs near RM 30 (Valdez and Masslich 1999; Ackerman 2007); where there is evidence of overwinter survival of young humpback chub in some years (Andersen et al. 2010).

Most young humpback chub in this LCR reach originate from spawning that takes place in the LCR during March–May. A few drift into the mainstem as larvae and post-larvae (Robinson et al. 1998), but most escape into the mainstem with late summer monsoonal rainstorm floods as early as mid-July (fish length: 30 mm TL), usually in mid-August (52 mm TL), and most escape by September. By late October, these fish are about 6 months of age and range in size from about

52 mm to 74 mm TL (Valdez and Ryel 1995). Depending on habitat use and growth rate assumptions, humpback chub should be from 5 to 20 mm larger in March and April than in November at 8–12 °C (Lupher and Clarkson 1994; Valdez and Ryel 1995; Gorman and VanHoosen 2000; Petersen and Paukert 2005). In addition to these young-of-year (age 0), humpback chub of ages 1–3 are also found along nearshore habitats, but in greatly diminished numbers. Nearshore and offshore catches in the mainstem (Valdez and Ryel 1995) and in the LCR (Gorman and Stone 1995) show that these fish move to offshore habitats starting at age 1 and complete the transition by age 3—the approximate time of maturity for the species. Thus, the size range of humpback chub in nearshore nursery habitats is about 30–180 mm TL, and includes fish of age 0 (young-of-year) to age 3 (Valdez and Ryel 1995). Valdez and Ryel (1995) also hypothesized, based on aging of juveniles from scales, that humpback chub smaller than 52 mm TL did not survive thermal shock in the cold mainstem following escapement from the warmer LCR.

Young humpback chub in this principal nursery area use well-defined nearshore habitats characterized by low water velocity and complex lateral and overhead cover, primarily rock talus and vegetated shorelines (Converse et al. 1998), as well as backwaters (AGFD 1996a). Because of the cold mainstem temperatures in this nursery reach (8.5–11 °C; Valdez and Ryel 1995) from dam releases upstream, swimming ability of these young fish is likely impeded, such that they may be displaced downstream by high water velocity, or their ability to escape predators is limited, or both. Bulkley et al. (1982) reported that swimming ability of juvenile humpback chub (73–134 mm TL) in a laboratory swimming tunnel was positively and significantly related to temperature. Humpback chub forced to swim at a velocity of 0.51 m/sec (1.67 ft/sec) fatigued after an average of 85 minutes at 20 °C, but fatigued after only 2 minutes at 14 °C, a reduction of 98 percent in time to fatigue. Time to fatigue is presumably further reduced below 14 °C, especially for the smallest individuals. These laboratory results has raised concern over the possible displacement of young humpback chub from nursery areas by high-flow events such as HFEs, especially near the LCR confluence, and has been identified as a potential adverse effect on the species since the 1995 Opinion.

Studies of drifting young within and from five Upper Colorado River Basin population centers of humpback chub support the hypothesis that there is little larval drift or long-distance displacement of any size or age (Valdez and Clemmer 1982; Valdez and Williams 1993; USFWS 2002a). Extensive larval drift-netting in many reaches of the Upper Basin (e.g., Osmundson and Seal 2009; Muth et al. 2000) has yielded large numbers of drifting larval Colorado pikeminnow, razorback sucker, flannelmouth sucker, bluehead sucker, and speckled dace, but larval humpback chub are rarely caught. Furthermore, observations of recently hatched humpback chub in a hatchery reveal a greater association by their larvae for cover, compared to other species more prone to drift, including Colorado pikeminnow and razorback sucker (Hamman 1982; Personal communication, Roger Hamman, Dexter National Fish Hatchery). Furthermore, studies in and around populations in Black Rocks and Westwater Canyon (Valdez et al. 1982), as well as Cataract Canyon (Valdez and Williams 1993) revealed few juvenile humpback chub outside of these population centers, indicating little movement or displacement from these centers despite high seasonal flows (e.g., spring flows often exceed 30,000 cfs in Westwater Canyon and 50,000 cfs in Cataract Canyon).

3.3.1.2 Effects of 1996, 2004, and 2008 HFEs on Displacement

In the 1995 Opinion, the USFWS anticipated that incidental take would occur when some young humpback chub would be transported downstream from the reach of the mainstem below the LCR into unfavorable habitats due to habitat maintenance or habitat building flows. The USFWS acknowledged that this incidental take would be difficult to detect and identified the need for studies to determine how this take might occur and the impact on the year classes of humpback chub. Hoffnagle et al. (1999) sampled shorelines from RM 68 to RM 65.5 with electrofishing and minnow traps, and backwaters with seines before, during, and after the 7-day late-March, early-April 1995 HFE of 45,000 cfs. They reported shifts in habitat use by juvenile humpback chub (born in March–May of 1994) with changes in flow stage, but no significant decreases in catch rates and no discernible effect to the population. Valdez and Hoffnagle (1999) also reported shifts in use of offshore habitats by radiotagged adult humpback chub, but no downstream displacement of any of the 10 fish monitored, or differences in offshore catch rates of adults with trammel nets.

For the 3-day November 2004 HFE of 41,000 cfs, sampling was conducted with hoop nets in approximately 1-km sections in each of three locations (LCR inflow reach near RM 63, near Tanner Rapid near RM 68, and Unkar Rapid near RM 73) three days before and after the HFE. Catch rates of juvenile humpback chub declined by about 66 percent at the upper two sites following the November HFE, suggesting downstream displacement of fish by the high flow (GCMRC unpublished data).. Length frequencies of fish in post-flood samples were shifted to fish roughly 10–20 mm larger than pre-flood fish, indicating a reduction of smaller fish during the flood.

It is unclear if the decline in juveniles was caused by local shifts in habitat use (as was seen with the 1996 HFE) that was not detectable with the limited extent of sampling—or if the displacement was real and reveals a different effect between spring and fall HFEs on juvenile humpback chub. Juvenile humpback chub in the mainstem were about 1 year of age (74–96 mm TL, Valdez and Ryel 1995) during the late-March, early-April 1995 HFE and may have been less susceptible to displacement than the younger fish (probably 6–8 months of age and 52–74 mm TL; Valdez and Ryel 1995) found in the mainstem during the November 2004 HFE. The results of the 2004 HFE may have been further confounded by an LCR flood that dramatically increased turbidity during the post-HFE sampling and could have reduced catch rates; Stone (2010) reported reduced hoop net catch efficiency with increased turbidity.

The need for studies to determine how high flows can impact young humpback chub in nearshore nursery habitats has been identified since the 1995 Opinion. The studies on habitat-specific catches rates and movement of humpback chub for the 1996 HFE and the limited sampling done for the 2004 HFE comprise the only empirical information on the subject. These studies do not provide conclusive evidence of displacement of young humpback chub by high flows, but suggest seasonal differences with greater potential for displacement in November than in March-April. Nevertheless, whether high flows transport young humpback chub from nursery habitats remains unanswered, and should be investigated with future HFEs. The ongoing Nearshore Ecology Study has not been conducted during an HFE and results are not available at this time, but this study could provide a valuable baseline of information for evaluating displacement with ensuring HFEs.

3.3.1.3 Displacement Estimated with the Use of Models

Lacking definitive evidence that supports or refutes long-distance displacement of humpback chub by high flows, models of nearshore depth and velocity are used to approximate possible displacement. It is hypothesized that humpback chub would be negatively impacted in their young-of-year or juvenile stages through physical displacement due to entrainment by high flows (31,500–45,000 cfs), primarily during the months of October and November. Under the proposed action, fall HFEs could occur with a slighter greater frequency than spring HFEs (58 percent vs. 42 percent of the time), and many of these HFEs would consist of flows approaching 45,000 for at least one and as many as 96 hours.

Effects of high flows were evaluated by comparing retention rates (i.e., the opposite of displacement, or percentage of fish able to maintain their position in a given reach) expected during a high flow test to those predicted for the median monthly flow in March under MLFF. Retention rates over a range of flows was modeled using a particle tracking algorithm in conjunction with velocity predictions from a 2-D hydrodynamic model developed by Korman et al. (2004). This model was developed using mainstem channel bathymetry from seven transects located between the LCR confluence (RM 61.5) and Lava Chuar Rapid (RM 65.5). The model contains four assumptions of fish swimming behavior: 1) passive, no swimming behavior; 2) rheotactic, in which particles (or "fish") swim toward lower velocity currents at 0.1 to 0.2 m/s; 3) geotactic, in which particles swim toward the closest bank at 0.2 m/s; and 4) upstream, in which the particle attempts to move upstream at 0.2 m/s. Passively drifting fish were the most susceptible to displacement but also the least sensitive to the effects of variable discharge magnitude. We assumed that passively drifting fish could be used to represent larval fish or the poor swimming ability of young-of-year humpback chub at low temperatures; this analysis applies mainly to the latter group, however, since very few or no larval fish are expected to be present during March-April or October-November (AGFD 1996a; Hoffnagle and Valdez 1999).

Temperature of the Colorado River in the LCR inflow reach during the proposed time period for high flow tests (October-November and March-April) is expected to range from about 10 °C to 15 °C (AGFD 1996b). At these levels, subadults and young-of-year may fatigue rapidly and may be unable to withstand swift currents, forage efficiently, or escape predators (see discussion of Bulkley et al. 1982). For these reasons, and to identify the "worst case scenario" of fish displacement, we focused primarily on results for passive behavior in this analysis.

Using the entrainment model of Korman et al. (2004), we expect that 21–23 percent of age-0 fish will be able to maintain their position within a given river reach during high flow tests of approximately 31,500 and 45,000 cfs, respectively (Korman et al. 2004; Figure 5). The retention rate at mean monthly flows for October, November, March, and April under MLFF (ca. modeled values of 8,000–15,000 cfs), by contrast, is predicted to be about 31 percent. Therefore, we would expect retention to decrease by 10 percentage points during the proposed action. Assumptions of active swimming can be used to simulate displacement rates of more mature fish, as may be present during the proposed HFE windows (Korman et al. 2004). Under these sets of assumptions, 57 percent of fish would be retained under the mean MLLF monthly flow and 39 percent retained at the level of HFE, a decline of 18 percentage points. Since Korman et al.'s (2004) study simulated high flows lasting 1.7 hours, we assumed that retention rates would decline further for HFEs lasting longer than this duration.

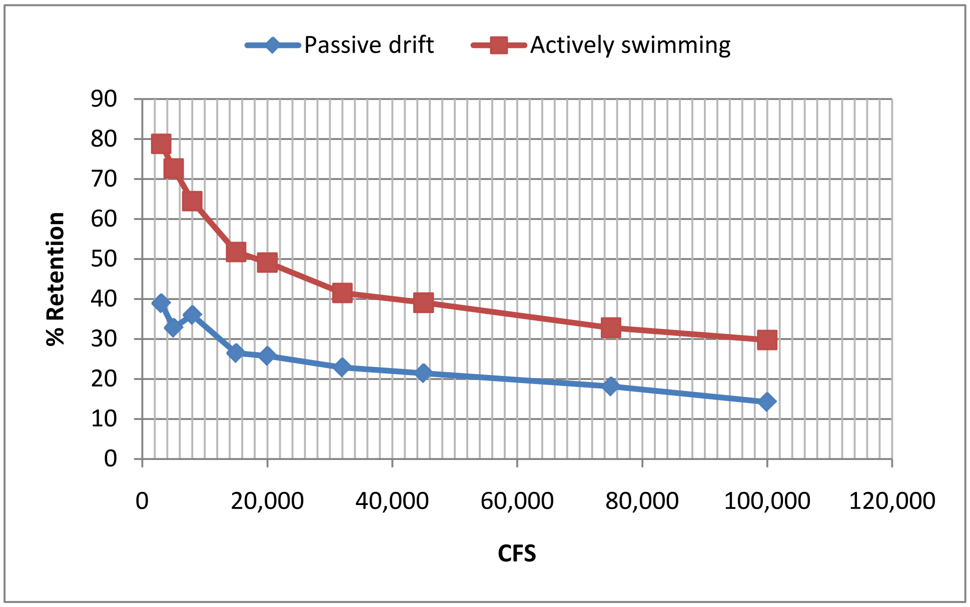

Figure 5. Average percent of simulated young-of-year fish retained within a given river reach over a range of river flows and swimming behavior assumptions. Legend refers to swimming performance assumptions (see text). Data are from Korman et al. 2004.

Effects on survival of these fish are unknown, although it is expected that these fish would be displaced to main-channel reaches below RM 65 (lowermost boundary of the simulation in Korman et al. 2004). Fate of these fish in downstream reaches is unknown, as neither the exact river reaches they are likely to arrive at nor habitat conditions therein are known. Numbers of fish displaced by high flows are expected to vary markedly by the distribution of fish among discrete shoreline types, as certain shoreline types afford more refuge from high flow velocities than others (i.e., talus slopes as compared to sandbars, etc.). Downstream displacement could possibly provide positive effects for humpback chub if they are carried to downstream aggregations, survive, and increase the size of these groups. The largest of these aggregations occurs at about RM 122 to RM 130 (60–68 miles downstream of LCR), which is the first time a transported fish would encounter shoreline complexity comparable to that of the LCR reach (Valdez and Ryel 1995). Chances of survival would increase with size of fish transported because of their greater swimming strength and ability to escape predators, as well as their ability to survive longer without feeding.

Korman et al. (2004) also used a 2-D hydrodynamic model to predict humpback chub preferred depth and velocity to the range of substrata, flows, and monthly volumes in the same study area described above. Based on that analysis, we expect total habitat availability (i.e., preferred depth and velocity over all substrate types) to decline by about 57 percent as flows increase from 12,000 cfs (an approximation of MLFF flows under No Action) to about 31,500 cfs and by 48 percent as flows increase to 45,000 cfs (Figure 6). These declines are due mainly to reductions in available habitat in cobble, bedrock and sandbar habitats. However, available habitat over more commonly utilized habitats such as talus and debris fan substrates is not expected to change during high flows as compared to No Action releases and area of vegetated shorelines would actually be near its maximum predicted values. Thus, if fish could exploit these unchanged or improved habitats as refuge from high flows, displacement could be minimized (see also Converse et al. 1998).

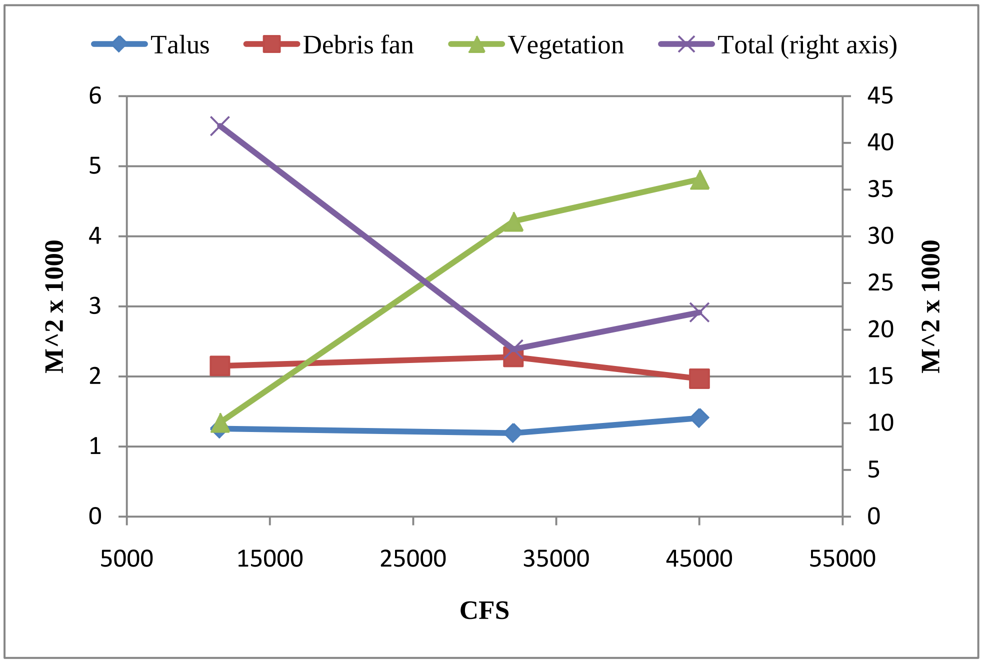

Figure 6. Total suitable shoreline habitats of humpback chub by river flow. Not shown are habitat areas for cobble bars, sand and bedrock and unmapped portions of transect.

3.3.1.4 Displacement of Other Species

It is also likely that repeated HFEs will disadvantage small-bodied warmwater non-native fish (fathead minnow, red shiner, plains killifish, small common carp, etc.) through physical downstream displacement by high flows. Displacement could be less pronounced for humpback chub than for warmwater non-native fish due to their preferences for lower water velocities (Table 5). Whereas average preferred velocity for juvenile humpback chub is about 0.25 m/s (Korman et al. 2004; Converse et al 1998; Bulkley et al. 1982; Valdez et al. 1990), non-native fish preferences average about 0.10 m/s, perhaps making them more susceptible to displacement by high flows. Hoffnagle et al. (1999) noted that the 1996 test had few discernable effects on native fish, but reduced numbers of fathead minnow and plains killifish, presumably by downstream displacement. Trammell et al. (2002) also documented displacement and slow re-colonization rates of fathead minnow as a result of the powerplant flows conducted during September 2000. Repeated HFEs could thus repeatedly disadvantage non-native fish to higher degrees than humpback chub, a species that evolved in a high-frequency disturbance regime.

Table 5. Preferred water velocities (m/s) for non-native fish found in the vicinity of the Little Colorado River.

Species	Velocity	Source
Black bullhead	0	Aadland 1993
Brown trout	0.03	Heggenes et al. 1990
Channel catfish	0.25	Aadland 1993
Common carp	0.11	Aadland 1993
Fathead minnow	0.15	Kolok and Otis 1995
Golden shiner	0.04	Aadland 1993
Green sunfish	0.05	Aadland 1993
Rainbow trout	0.13	Moyle and Baltz 1985
Rainbow trout	0.07	Korman et al. 2005
Rainbow trout	0.1	Baltz et al. 1991
Red shiner	0.15	Shyi-Liang and Peters 2002
Red shiner	0.09	Edwards 1997
Smallmouth bass	0.12	Aadland 1993
Smallmouth bass	0.1	Leonard and Orth 1988
Average velocity	0.1	

3.3.2 Effects on Critical Habitat

3.3.2.1 Background

Direct short-term reductions in habitat and food supply, as well as increases in rainbow trout abundance, have the potential to indirectly affect the humpback chub, as well as directly affect elements of critical habitat. For the purpose of this effects analysis, these environmental components are considered as part of critical habitat for the species, and Reclamation has determined that the proposed action may adversely affect designated critical habitat of the humpback chub. Critical habitat designation for the humpback chub is described in Section 2.4.1 of this document.

Effects on critical habitat in this BA relied on 50 CFR 402.02, in which "[d]estruction or adverse modification means a direct or indirect alteration that appreciably diminishes the value of critical habitat for both the survival and recovery of a listed species. Such alterations include, but are not limited to, alterations adversely modifying any of those physical or biological features that were the basis for determining the habitat to be critical." In its analysis of critical habitat, Reclamation has also relied on the 9th Circuit Court ruling of August 6, 2004 (Gifford Pinchot Task Force v. USFWS, 378 F.3d 1059) to consider whether the action appreciably diminishes the value of critical habitat for either the survival or recovery of a listed species (see p. 4-34, U.S. Fish and Wildlife Service and National Marine Fisheries Service 1998). We analyzed whether the proposed modification would adversely modify any of those physical or biological features that were the basis for determining the habitat to be critical. The physical or biological features that determine critical habitat are known as the primary constituent elements (PCEs). To determine if an action results in an adverse modification of critical habitat, we must also evaluate the current condition of all designated critical habitat units, as well as the PCEs of those units, to determine the overall ability of all designated critical habitat to support recovery. A more detailed description of critical habitat and its PCEs is provided in the original rule designating critical habitat (59 FR 13374) and in the 2009 Supplemental Opinion (USFWS 2009a).

The proposed action is likely to affect the following primary constituent elements: water (water quality W1), physical habitat including nursery (P2) and feeding habitat (P3), and the biological environment including food supply (B1), predation from non-native fish species (B2), and competition from non-native fish species (B3). Water quality (W1), specifically temperature, is a function of the amount of nearshore habitat in which water velocity is absent or near zero, such as backwaters. Owing to slightly warmer temperatures and greater organic matter standing stocks (Behn et al. 2010); backwaters also provide humpback chub with both nursery (P1) and feeding habitat (P2). Elements W1, P1 and P2 are directly linked through formation and maintenance of backwaters and other low-velocity nearshore habitats, which are highly sediment dependent. Food supply (B1) is a function of nutrient supply, productivity, and availability of food to each life stage of the species. Predation and competition (B2 and B3) are normal components of the ecosystem, but are out of balance in these units because of introduced fish species. Despite the possible short-term adverse effects to critical habitat of humpback chub, periodic HFEs are expected to rejuvenate the habitat and benefit the species.

3.3.2.2 Creation of Backwater Rearing Habitats (W1, P2, P3)

Since the 1995 FEIS, backwaters in Grand Canyon have been promoted as a habitat that is essential to young life stages of the humpback chub (e.g., AGFD 1996a; Hoffnagle 1996; Brouder et al. 1999; Stevens and Hoffnagle 1999; Gloss and Coggins 2005). One of the principal objectives for high-flow releases from Glen Canyon Dam has been to rebuild sandbars in eddy-return channels that help to form and maintain backwaters (e.g., Reclamation 1995a, 1995b; U.S. Department of the Interior 1996; Schmidt et al. 1999; Goeking et al. 2003). Backwaters have also been recognized as important foundations for marsh-like habitats (Stevens and Hoffnagle 1999) and as important sources for nutrients (Parnell et al. 1997; Parnell and Bennet 1999).

Impacts of high flow tests on near-shore and backwater habitats manifest both at short-term (i.e., weeks to months following high flow tests) and long-term time scales. While a good deal of information exists on short-term impacts to backwaters (Brouder et al. 1999; Parnell et al. 1997; Wiele et al. 1999), long-term impacts are more difficult to predict because of varied sediment availability prior to the test and uncertainties of post-test flow regimes. Effects of high flow tests will be evaluated qualitatively and will weigh short-term impacts to backwater habitats against potential long-term outcomes, as well as impacts to the non-native fish community and other aspects of the proposed action.

In this biological assessment, the assumption is that number of backwaters is correlated with those of reattachment sandbars in eddy complexes. That is, since backwaters in Grand Canyon are mostly inundated, but non-flowing, eddy return current channels, sandbars are a requisite condition for their occurrence. Another assumption is that elevation of sandbars and depth of recirculation channels are significant correlates reflecting the availability of backwaters over range of flows (Brouder et al. 1999; Grams et al. 2010). First, the higher the sandbar elevation, the more likely the separation of the backwater from main-channel currents would occur over a range of flows. The depth of the recirculation channel serves the same function as height of the sandbar, with the greatest depths creating availability that is more frequent over the greatest range of flows. Finally, high flow tests tend to increase the elevation of the sandbar and deepen the return current channel (Andrews et al. 1999; Goeking et al. 2003), although there are exceptions to this general pattern (Parnell et al. 1997).

Weight-of-evidence approach using unpublished information and limited findings conclude that backwaters are not exceptionally high-quality rearing habitat for juvenile humpback chub relative to other potential rearing habitats (Kennedy and Ralston in press). This determination is based on an unreported nearshore ecology study in Grand Canyon that compares shoreline habitats with backwaters, and on two recent studies (Behn et al. 2010; Rosi-Marshall et al. 2010) which indicate that high turnover rate limits the productivity of backwaters. Data and information from prior studies (e.g., AGFD 1996a; Johnstone and Lauretta 2007) were not incorporated into the determination. We assume for the purpose of this BA that backwaters in Grand Canyon continue to be valuable habitats for young humpback chub, as well as other native fishes, since the ecological value of backwaters in Grand Canyon has not been scientifically reconciled.

One of the desired outcomes of HFE protocol implementation is frequent rebuilding of sandbars and beaches through resuspension and deposition of channel sediment deposits at higher elevations. Sandbars are formed in eddies, which are commonly associated with tributary debris fans (Schmidt and Graf 1990; Schmidt and Rubin 1995). Nearly all sandbars in Grand Canyon are associated with recirculation zones that consist of one or more eddies. Sandbars are highly valued for their role as camping beaches and their occurrence is frequently accompanied by backwaters in the eddy return channel. Backwaters are created as water velocity in eddy return channels declines to near zero with falling river discharge, leaving an area of stagnant water surrounded on three sides by sand deposits and open to the main-channel environment on the fourth side. Reattachment sandbars are the primary geomorphic feature that functions to isolate nearshore habitats from the cold, high velocity main-channel environment.

Due to their low water velocity, warm water, high levels of benthic organic matter and high levels of biological productivity, backwaters provide potential ideal rearing habitats for humpback chub and other native fish. During summer months, backwaters offer low velocity, relatively warm, protected, food-rich environments when compared to nearby mainstream habitats (Maddux et al. 1987; Grabowski and Hiebert 1989; AGFD 1996a; Hoffnagle 1996). Humpback chub and other native fish consistently use backwaters with the same or greater frequency than main-channel habitats. During 1990–1995, 2,619 age-0 and 1,521 juvenile humpback chub were caught along shorelines between the LCR and Bright Angel Creek for a total of 4,140 fish (Valdez and Ryel 1995). This compares to a total of 3,734 humpback chub caught in backwaters in the same reach during 1991–1994 (AGFD 1996a). Although these numbers are not directly comparable because of different gear types and sampling effort, the fish were taken in nearly the same time period and for the same amount of time (6 years).

Within individual sampling trips, AGFD (1996a) consistently documented greater abundance of native fish and humpback chub in backwaters compared to similar samples from main-channel habitats, and similar trends were observed in zooplankton and benthic invertebrate standing stocks. In more recent years, numbers of humpback chub captured from backwaters were similar to those captured from main-channel habitats during 2003, 2004 and 2006 (Johnstone and Lauretta 2007); when standardized by total numbers of samples collected, humpback chub were always more abundant in backwater samples than those from main-channel habitats during 2000 through 2006 (SWCA 2002, 2003, 2004a, 2004b, 2006, 2007; Table 6).

Table 6. Numbers of humpback chub collected from main-channel habitats and backwaters by SWCA, Inc., during 2000-2006. Numbers in parentheses are average number of fish caught per sample.

Year	Main-channel habitats	Backwaters
2000	241 (0.15)	76 (0.20)
2001	n/a	n/a
2002	38 (0.02)	13 (0.09)
2003	142 (0.06)	125 (0.39)
2004	161 (0.07)	163 (0.55)
2005	847 (1.53)	231 (3.6)
2006	160 (0.11)	169 (0.68)

Immediate physical impacts of high flow tests (1996, 2004, and 2008) on backwater habitats were positive and included increased relief of bed topography, increased elevation of reattachment bars and deepened return current channels (Andrews et al. 1999; Topping et al. 2006; Grams et al. 2010; Hazel et al. 2010). While dam releases following historic high flow tests have had a significant effect on newly created sandbar deposits (and hence backwaters), high flows which followed the 1996, 2004, and 2008 HFEs have been implicated in the rapid erosion of these sandbars (Schmidt et al. 2004; Topping et al. 2010). Whereas the 1996 high flow test resulted in creation of 26 percent more backwaters potentially available as rearing areas for Grand Canyon fishes, most of these newly created habitats disappeared within two weeks due to reattachment bar erosion (Brouder et al. 1999; Hazel et al. 1999; Parnell et al. 1997; Schmidt et al. 2004). Nearly half of the total sediment aggradation in recirculation zones eroded during the 10 months following the experiment and was associated in part with relatively high fluctuating flows of 15,000–20,000 cfs (Hazel et al. 1999).

The March 2008 HFE caused widespread sand deposition at elevations above the 8,000 cfs stage and resulted in greater area and volume of associated backwaters than before the HFE (Grams et al. 2010; Hazel et al. 2010). Total sand volume in all sediment-flux monitoring reaches was greater following the 2008 HFE than following the two previous HFEs (Hazel et al. 2010). Analysis of backwater habitat area and volume for 116 locations at 86 sites, comparing one month before and one month after the HFE, shows that total habitat area increased by 30 percent to as much as a factor of 3 and that volume increased by 80 percent to as much as a factor of 15 (Grams et al. 2010). These changes resulted from an increase in the area and elevation of sandbars, which isolate backwaters from the main channel, and the scour of eddy return-current channels along the bank where the habitat occurs. In the months following the 2008 HFE, erosion of sandbars and deposition in eddy return-current channels caused reductions of backwater area and volume. However, sandbar relief was still 5 to 14 percent greater in October 2008 than in February 2008, prior to the HFE. Sandbar relief was also sufficient to afford backwater persistence across a broader range of discharges than in February 2008. Native fish (including humpback chub) use of these backwaters increased during the first 6 months after creation of these backwaters (Grams et al. 2010), although this might be a seasonal effect.

Biologically, the 1996 high flow caused an immediate reduction in benthic invertebrate numbers and fine particulate organic matter (FPOM) through scouring of backwaters (Brouder et al. 1999;

Parnell and Bennet 1999). Invertebrates rebounded to pre-test levels by September 1996 and recovery of key benthic taxa such as chironomids and other Diptera was relatively rapid (3 months), certainly rapid enough for use as food by the following summer's cohort of young-of-year (YOY) native fish (Brouder et al. 1999). Also during the 1996 high flow test, Parnell and Bennet (1999) documented burial of autochthonous vegetation during reattachment bar aggradation, which resulted in increased levels of dissolved organic carbon, nitrogen and phosphorus in sandbar ground water and in adjacent backwaters. These nutrients are thus available for uptake by aquatic or emergent vegetation in the backwater. The proposed action is thus expected to have the same effects on backwaters: an immediate reduction in benthic invertebrate numbers and fine particulate organic matter, but over time, a potential beneficial change in backwaters.

3.3.2.3 Food Supply (PCE B1)

Short-term adverse modification of the aquatic foodbase is expected for single HFEs followed by a period of stimulated production. The food supply of humpback chub is not expected to be adversely modified by the proposed action if HFEs are implemented frequently (i.e., twice a year or more than two consecutive HFEs), based on findings from other rivers with artificial floods (Uehlinger et al. 2003; Robinson and Uehlinger 2008). Implementation of the proposed action to minimize foodbase impacts will require long term monitoring to detect impacts such that this information can be considered in decision-making processes on HFE frequency. Effects of fall HFEs on the aquatic foodbase are also an uncertainty that will likely require monitoring before and after such events, as well as among years. HFEs in fall would occur at a time of year when few historic high-flow events occurred. These HFEs are anticipated to temporarily reduce food supplies, especially in backwaters, but the foodbase is expected to recover within 2-4 months.

Based on available information, we do not expect powerplant capacity flows of 31,500 cfs to negatively impact the benthic community of the Colorado River ecosystem, either immediately downstream from the dam or further downstream in critical habitat of humpback chub. Shannon et al. (1998) reported no discernable impact on the benthic community in the Lees Ferry reach; similarly, Rogers et al. (2003) reported no short-term reduction in densities of aquatic macrophytes, periphyton, chlorophyll-*a* or macroinvertebrates associated with a 31,000 cfs spike flow in May 2000. Shannon et al. (2002) noted reductions in benthic invertebrate taxa as a result of the September 2000 powerplant flows, but these effects were not realized across all reaches and taxa.

We expect a large portion of the aquatic foodbase in the Lees Ferry reach to be scoured by a spring HFE of 41,000 to 45,000 cfs. The foodbase is expected to recovery within 1–4 months after a spring HFE, as was observed for the 1996 and 2008 HFEs (Blinn et al. 1999; Rosi-Marshall et al. 2010). *Gammarus lacustris*, a common food item of fish, will be slower to recover because of their greater susceptibility to export than other invertebrate species. Also, the New Zealand mudsnail (*Potamopyrgus antipodarum*) is expected to be exported in large numbers, which will be a benefit to the foodbase by making more digestible items available to the fish. Downstream of the Paria River, the effect of scouring from a spring HFE is expected to be less with distance downstream and recovery should be shorter, as was reported for the 2008 HFE (Rosi-Marshall et al. 2010).

Although effects of repeated HFEs on the foodbase have not been investigated, the more lasting effects of independent events (1996, 2004, and 2008) likely foretell some of the possible consequences of frequent, sequential high-flow releases. Although more information is needed on the effect of a fall HFE on the foodbase, it is likely that a fall HFE followed by a spring HFE could cause long-term damage to the foodbase. Only 4–5 months would separate the two events, which would preclude full recovery of most benthic invertebrate assemblages (although some key taxa such as chironomids may recover within 3 months; Brouder et al. 1999). This effect could be exacerbated if recovery from the fall HFE is delayed until the following spring by reduced photosynthetic activity during winter months. A second, spring HFE following a fall HFE could scour the remaining primary producers and susceptible invertebrates and further delay recovery. A spring HFE followed by a fall HFE may not have as great an effect because presumably recovery of the foodbase (for most taxa) from the first HFE would have occurred by fall.

A common theme of artificial floods in rivers is the scouring effect of high velocities on riverbed sediments and on the community of primary producers, as well as stored organic detritus. For the three HFEs in Grand Canyon, nearly 90 percent of instream plants, algae, and diatoms on sediments were uprooted and scoured, along with senescent plant material and detritus. In the River Spöl of the Swiss Alps, a series of 9 floods over 3 years (averaging 3 events/year) each reduced periphyton biomass by about 90 percent, but because of these multiple floods, disturbance impact and recovery patterns were not uniform (Uehlinger et al. 2003). In the years following this sequence of floods, moreover, taxa of primary producers shifted toward communities more resistant to flooding. The flood sequence also reduced particulate organic carbon, phosphorus, and P/R ratios periodically increased with each flood (Robinson and Uehlinger 2008).

In a another study of multiple flooding on the River Spöl, Robinson and Uehlinger (2008) found that the first few of 15 floods over 8 years (2000–2007; about 2/year) reduced macroinvertebrate abundance by about 50 percent (including dominant forms such as *Gammarus* sp. and chironomids, which are also key fish food items in the action area). Later floods had 30 percent less effect than early floods of similar magnitude, indicating that a new assemblage had established that was more resilient to flood disturbance. Taxa richness declined and stabilized at a lower level during the first three years of the study, during which flood frequency was at its highest, which is consistent with other studies (Robinson and Minshall 1986).

Findings from the River Spöl and other studies suggest that more frequent floods in Grand Canyon could cause significant shifts in the primary producer community and shifts to more resistant macroinvertebrate taxa or to new taxa that would colonize the river. Analysis of the proposed action suggests that as many as 1.3 to 1.4 HFEs may be conducted per year; at least 3 consecutive HFEs could occur under any combined hydrologic and sediment scenario, and as many as 5 or 6 consecutive HFEs could conceivably occur (average of 1.1 per year), although the likelihood of this is low. Nevertheless, these frequencies are comparable to the artificial flood regime of the River Spöl, and so risks encountered in that example should be considered in implementation of the proposed action in Grand Canyon. Additionally, many of these flows could approach levels known to scour benthic communities and their substrates (ca. 45,000 cfs) and occur during months when recolonization potential is low (i.e., in the fall).

Similar to the River Spöl example, shifts induced by frequent, large (ca. 45,000 cfs) floods in the action area could involve declines of large-bodied taxa such as *Gammarus lacustris* which are more adapted to low frequency disturbances (and an important fish food organism) and replaced by more resistant taxa. However, if these resistant taxa are not present, if a source of new taxa is not available, or source taxa are not adapted to other aspects of the Colorado River ecosystem (such as low water temperatures), then the result of frequent floods may be a reduction in macroinvertebrate diversity and abundance. Robinson and Uehlinger (2008) suggest that the response of macroinvertebrates to experimental floods occurs over a period of years rather than months, as species composition adjusts to the new and more variable habitat template.

Whereas the preceding assessment of impacts to the benthic community applies mainly to those communities colonizing substrates in the free-flowing component of the river ecosystems, these findings are probably not transferable to communities found in areas of little or no water velocity associated with eddy complexes and backwaters. Biologically, the 1996 high flow caused an immediate reduction in benthic invertebrate numbers and fine particulate organic matter (FPOM) through scouring (Brouder et al. 1999; Parnell and Bennet 1999), but invertebrates rebounded to pre-test levels by September 1996 and recovery of key benthic taxa such as chironomids and other Diptera was relatively rapid (3 months), certainly rapid enough for use as food by the following summer's cohort of young-of-year (YOY) native fish (Brouder et al. 1999). Also during the 1996 high flow test, Parnell and Bennet (1999) documented burial of autochthonous vegetation during reattachment bar aggradation, which resulted in increased levels of dissolved organic carbon, nitrogen and phosphorus in sandbar ground water and in adjacent backwaters. These nutrients are thus available for uptake by aquatic or emergent vegetation in the backwater.

Spring HFEs are expected to result in an immediate reduction in benthic invertebrate numbers and fine particulate organic matter, but could also benefit a potential beneficial change in backwaters due to replenishment of nutrients and particulate organic matter. Effects of more frequent disturbances (such as fall followed by spring HFEs) are largely unknown but presumably would be similar to those observed in flowing-water habitats and also depend on ability of HFEs to export organic matter and nutrients relative to the rate at which it enters the system.

We expect that the food supply of humpback chub to be adversely modified by the proposed action if HFEs are implemented too frequently (i.e., twice a year or more than two consecutive HFEs). Frequencies of HFEs under the proposed action are not possible to predict, but our analysis of protocol implementation over a range of sediment availability and hydrology modeling indicates that HFE frequency would be an overall average of 1/year. This is less than the frequency observed in the River Spöl example, which included 15 high flows over 8 years with at least one flow every year (Robinson and Uehlinger 2008), and many of these flows would be of low intensity and duration (i.e., 31,500 cfs for one hour). However, our simulation of protocol implementation shows that multiple instances of HFEs occurring within 4–5 months of each other are possible within the 10-year timeframe of the proposed action. It is also possible for as many as two HFEs to occur within one year, which is similar to the frequency observed during the early years of the River Spöl study when taxa richness and abundance declined rapidly. Therefore, extreme shifts in community composition or lasting reductions in abundance could occur under the proposed action if such disturbance frequency thresholds are neglected in the decision making process.

3.3.2.4 Predation and Competition (PCE B2, B3)
The proposed action is expected to increase predation by rainbow trout on humpback chub, particularly if HFEs are implemented during March-April. The effect of an October-November HFE on the trout population is uncertain and cannot be determined from the fall 2004 HFE because of the confounding effects of dam operations, non-native fish control activities, and warm releases from a low reservoir (Korman et al. 2010; Makinster et al. 2010b). Single HFEs could contribute to greater rainbow trout abundance, and repeated HFEs could compound this problem by expanding the trout population long-term. Piscivory rates by salmonids on other fish calculated by Yard et al. (2008) range from 1.7 to 7.1 prey/rainbow trout/year, and 18.2 to 106 prey/brown trout/year. Of prey fish consumed, Yard et al. (2008) estimated that 27.3 percent were humpback chub.

Estimated rainbow trout remaining in the LCR inflow reach after a 3-year mechanical removal effort in March 2009 was 427 to 1,427 fish (Makinster et al. 2010b), although no brown trout were collected. In some years, impacts to humpback chub due to predation by rainbow trout could be substantial. Additionally, based on high degrees of dietary overlap, rainbow trout are known to compete directly with humpback chub for food resources in the action area (Valdez and Ryel 1995; Valdez and Hoffnagle 1999). Thus, the degree of predation and competition experienced by humpback chub is directly related to rainbow and brown trout abundance. Past and ongoing investigations show that most brown trout in Grand Canyon, and in the LCR reach, originate from the Bright Angel Creek area (Valdez and Ryel 1995; Makinster et al. 2010a).

Multiple lines of evidence indicate that the March 2008 HFE resulted in a large increase in early survival rates of age-0 rainbow trout because of an improvement in habitat conditions and possibly increased food availability (Korman et al. 2010). A stock-recruitment analysis demonstrated that age-0 abundance in July 2008 was more than fourfold higher than expected, given the number of viable eggs that produced these fish. A hatch-date analysis showed that early survival rates were much higher for cohorts that hatched about 1 month after the 2008 HFE (about April 15, 2008) relative to those fish that hatched before this date. A substantial fraction of the cohort originating from the peak spawn period (February 21–March 27) was thus fertilized after the 2008 HFE and would have emerged into a benthic invertebrate community that had recovered and was possibly enhanced by the HFE. Inter-annual differences in growth of age-0 trout, determined based on otolith microstructure, support this hypothesis. Korman et al. (2010) speculate that the 60-hour 2008 HFE increased interstitial spaces in the gravel bed and food availability or quality, leading to higher early survival of recently emerged trout and better growth of these fish through summer and fall. Finally, Korman et al. (2010) presented evidence that enhancement of rainbow trout year class strength due to spring HFEs could be sustained from one year to the next, as suggested by higher than predicted survival of age-1 rainbow trout in 2009 (which had hatched in spring of 2008).
Results from the 1996 HFE were not studied in as much detail as those from 2008, but available information shows that catch rates of age 1 rainbow trout declined immediately following the 1996 high flow test (McKinney et al. 1999). This information, combined with increased catches of young rainbow trout about 80 miles downstream (Hoffnagle et al. 1999) suggest some downstream displacement, but overall McKinney et al. (1999) observed no lasting impacts to either trout abundance or condition. Numbers of age-1 rainbow trout increased during 1997, suggesting that enhanced survival of age-0 trout may have occurred after the 1996 HFE as well

(McKinney et al. 2001). However, this increase was not nearly as dramatic as that observed in 2008, and no information exists linking the 1997 increase to the 1996 HFE.

There is a risk of increased predation on native and endangered fish due to enhanced young-of-year rainbow trout survival resulting from HFEs conducted in March, but the magnitude of such a risk from an April HFE may be lower. The date of peak rainbow trout spawning from 2004–2009 ranged from February 21 to March 27 and the average peak spawning date was March 6. The 2008 HFE was conducted on March 5–9, which coincided almost perfectly with peak spawning activity; thus, a substantial fraction of the rainbow trout eggs deposited in spring 2008 were fertilized after the HFE and, after emergence a month or two later, benefited from cleaner gravel substrate and perhaps enhanced food availability. However, if spring HFE's take place in April, approximately one month or more after the peak spawning period, a larger fraction of that year's eggs would have been fertilized prior to the HFE. Korman et al. (2010) speculated that if the bulk of fertilization were to take place prior to an HFE, the resulting fry would not benefit from cleaner gravel and enhanced food availability as was observed in 2008 and their survival would be lower. Most of these fish would still be in the gravel when the HFE occurs in April and would be vulnerable to scour or burial, or would be vulnerable to displacement and mortality because of increased water velocity (Einum and Nislow 2005).

The November 2004 HFE resulted in lower apparent survival of age-0 rainbow trout compared to that observed during more typical MLLF operations observed in 2008 (i.e., decline in abundance between November and December in 2004 was 1.7-fold greater than in 2008; Korman et al. 2010), however the cause of this effect is not clear. Electrofishing catch rates for all sizes of trout before and after the November 2004 HFE were not significantly different, however, indicating that mortality and downstream displacement did not affect the population (Makinster et al. 2007). Since fall HFEs could occur slightly more often than spring HFEs, it is possible that negative effects to trout accrued during this period may counterbalance enhanced survival rates resulting from spring flows. However, if the effect of enhanced spring survival is cumulative among years as postulated by Korman et al. (2010) and the mechanism of decline due to fall HFEs is in fact downstream dispersal, negative consequences for humpback chub are expected to result from repeated HFEs of any magnitude or duration.

Inferences on the effect of HFEs on early survival and growth rates of trout from this analysis are limited by the fact that only one treatment has been conducted and studied using the above methods. The 1996 HFE consisted of a peak duration more than twice the 2008 HFE (7 days vs. 60 hours), but the rainbow trout monitoring methods used during the 2008 study had not yet been applied to the Lees Ferry reach. Korman et al. (2010) recommended that the monitoring effort employed in their study (i.e., estimate survival rates of gravel-stage and older age-0 rainbow trout) be repeated if future spring HFEs are conducted to determine the effect of timing on survival.

A second uncertainty of effects of enhanced rainbow trout survival is that downstream dispersal rate of rainbow trout from upstream reaches into areas populated by humpback chub (i.e., near the LCR at RM 61.5) have not been quantified and are hypothesized to range from 50 to 300 fish per month (Hilwig et al. 2010). Korman et al. (2010) reported that rainbow trout fry abundance in 2009 was twice what was expected given egg deposition estimates, suggesting positive effects on rainbow trout survival from the 2008 HFE persisted at least one year following the experiment. Although Hilwig and Makinster (2010) documented no downstream movement of acoustic-tagged trout during the 2008 HFE, Korman et al. (2010) suggests that a large fraction of the 2008 rainbow trout cohort (smaller fish than tracked by Hilwig and Makinster) may have migrated downstream into reaches occupied by humpback chub. Thus, if the rate of trout migration downstream increases with upstream abundance, repeated HFEs could increase the risk of rainbow trout predation on or competition with humpback chub. This assumes that no negative impacts to the foodbase offset age-0 rainbow trout survival.

Preliminary results from energetic-based models (EcoPath, EcoSim) show that the rainbow trout population in the Lees Ferry reach is likely to respond positively (i.e., increased survival of young) to either spring or fall HFEs with a subsequent increase in numbers. This increase in trout population size could result in downstream movement of young trout (Korman et al. 2010) that could occupy the nursery habitat of humpback chub near the LCR, compete with, and prey on the young chubs. The net effects of the HFE protocol from predation are uncertain because of uncertainties in the frequency of HFEs and the actual response by the trout population. Reclamation is developing an environmental assessment for non-native fish control downstream of Glen Canyon Dam concurrent with this EA (see Section 1.2). One of the purposes of the non-native fish control EA will be to assess the effect of and mitigate for increased predation and competition by rainbow trout and brown trout on humpback chub.

The proposed action is expected to increase predation and competition on humpback chub through from increased survival of rainbow trout, particularly if HFEs are implemented during the months of March or April. Reclamation intends to implement non-native control during 2011–2020 through an EA being developed concurrent to the HFE EA (see Section 1.2). Non-native fish control would be implemented through further consultation with USFWS and in cooperation with GCMRC, NPS, and GCDAMP members. The net effect of non-native control actions implemented in these future years potentially could benefit the biological environment constituent element of critical habitat to a greater degree than the original proposed action depending on the efficacy of those actions in conserving humpback chub.

3.3.3 Effects to Humpback Chub Population

Mark-recapture methods have been used since the late 1980s to assess trend in adult abundance and recruitment of the LCR aggregation of humpback chub, the primary aggregation constituting the Grand Canyon population and the only population in the lower Colorado River Basin. These estimates indicate that the adult population declined through the 1980s and early 1990s but has been increasing for the past decade (Coggins et al. 2006a, Coggins 2008a, Coggins, and Walters 2009) (Figure 7). Coggins (2008) summarized information on abundance and analyzed monitoring data collected since the late 1980s and found that the adult population had declined from about 8,900- 9,800 in 1989 to a low of about 4,500-5,700 in 2001.

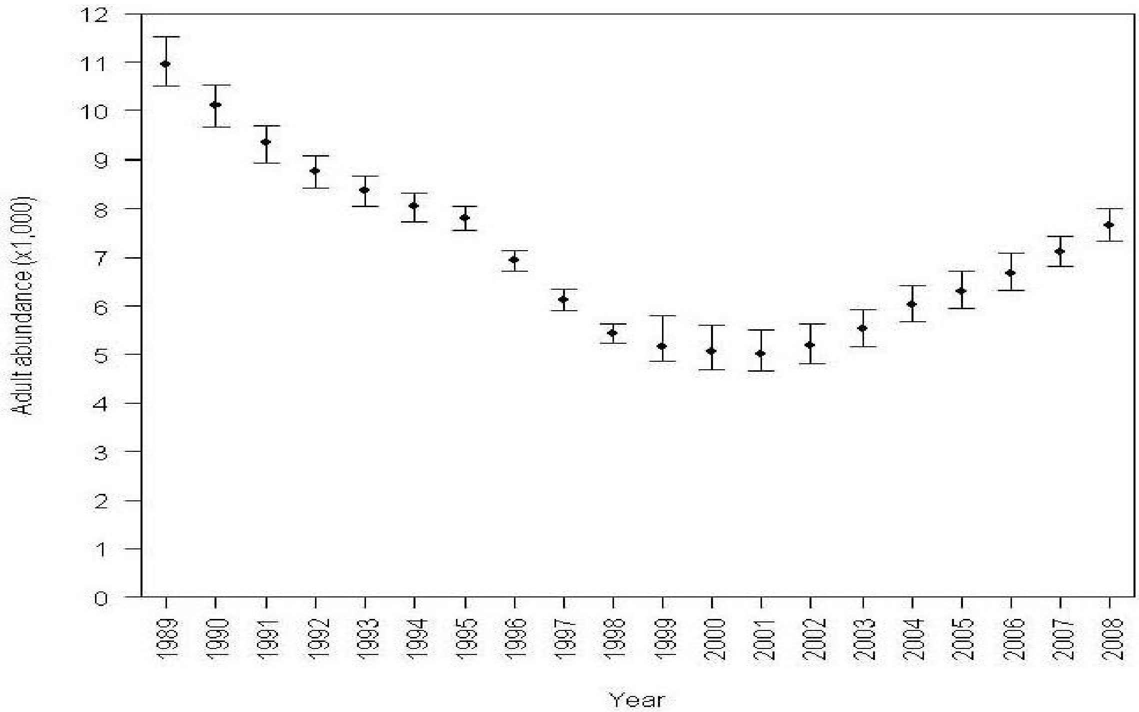

Figure 7. Estimated adult humpback chub abundance (age 4+). Point estimates are average values and error bars represent maximum and minimum 95 percent confidence intervals. From Coggins and Walters (2009).

The most recent estimate of humpback chub abundance (Coggins and Walters 2009) shows that it is unlikely that there are currently less than 6,000 adults or more than 10,000 adults, and that the current adult (age 4 years or more) population is approximately 7,650 fish. This is an increase from the 2006 estimate of 5,300-6,700 (Coggins 2008a). These estimates indicate that there has been increased recruitment into the population from some year classes starting in the mid- to late-1990s. Increased humpback chub recruitment has previously been attributed in part to the results of non-native fish mechanical removal, increases in temperature due to lower reservoir elevations and inflow events, the 2000 low steady summer flow experiment, and/or other experimental flows (USGS 2006a). However, the most recent population modeling indicates the increase was due to increased recruitment as early as 1996 but no later than 1999 (Coggins 2008a), which coincides with a period of increasing rainbow trout abundance (Figure 8; McKinney et al.1999, 2001; Makinster et al. 2010b). The increase in recruitment began at least four and as many as nine years prior to implementation of non-native fish control, incidence of warmer water temperatures, the 2000 low steady summer flow experiment, and the 2004 high flow test (Speas 2004). It is also unclear as to whether this increase is attributable to conditions in the mainstem or in the LCR. Population dynamics of non-native fish, humpback chub, hydrology, and other environmental variables in the LCR may have influenced the observed recruitment trends.

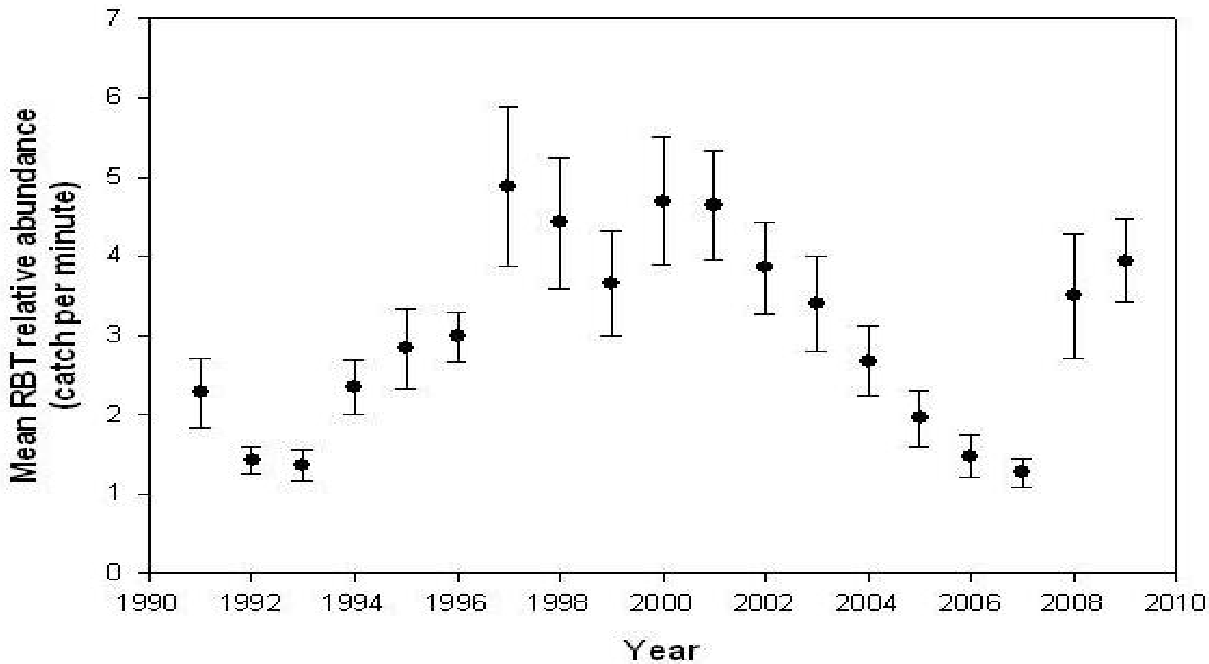

Figure 8. Rainbow trout mean relative abundance (catch per minute) in the Lees Ferry tailwater fishery, 1991-2009. Figure represents data from all size classes in both fixed and random transects. Points represent the average among sites and seasons while bars represent ± 2 standard errors of the average, an approximation for a 95 percent confidence interval. See Makinster et al. (2010b) for details.

Although some negative impacts of the proposed action are expected from potential displacement of young-of-year or juvenile humpback chub, these effects are not expected to register at the population level. Results of before and after investigations of humpback chub associated with HFEs conducted to date suggest that such flows have negligible effects at the population level. This assumption is based largely on the positive population size trajectory documented during 2001–2009, during which two HFEs in excess of 41,500 cfs were conducted (Figure 8). Catch-per-unit effort (CPUE) of humpback chub did not differ in 1996 pre- versus post-flood periods. Valdez and Hoffnagle (1999) concluded there were no significant adverse effects on movement, habitat use, or diet of humpback chub. Catch rates of humpback chub declined immediately following the 2004 HFE (GCMRC, unpublished), but several studies (Coggins 2008a; Coggins and Walters 2009; Lauretta and Serrato (2006) and Ackerman and Valdez (2008) showed that numbers of humpback chub have been stable or increasing since 2004, suggesting negligible effects of fall or spring HFE on these fish at the population level.

Under the proposed action, effects of repeated HFEs over a 10-year period will manifest differentially on humpback chub depending on their frequency, which is driven by year-to-year variation in water and sediment availability. Based on results from prior experiments, HFEs conducted during 1996, 2004 and 2008 were fundamentally independent events with 8 years, 7 months, and 3 years, 4 months between events. Effects to biological resources of one HFE were likely dissipated by the time of the next event, and there is little information by which to determine the effect of more frequent HFEs. However, the more lasting effects of independent events (1996, 2004 and 2008) likely foretell some of the possible consequences of frequent, sequential high-flow releases.

Although there is little or no evidence that isolated HFEs impart significant impacts to humpback chub at the population level through displacement of age-0 or juvenile fish, effects of repeated HFEs are unknown but would stem from the cumulative effect of displacing multiple cohorts of age-0 or juvenile fish. Although humpback chub and other native fish evolved under highly variable environmental conditions, including high spring flows well beyond the magnitude of the proposed action, nothing is known of the response of these fish to frequent flow disturbances in the context of post-dam environmental conditions such as lower temperatures, daily flow fluctuations, clear water, and presence of non-native fish. For example, impairment of swimming ability due to sub-optimal water temperatures could make humpback chub more susceptible to displacement than under natural conditions, and coldwater predators such as trout could further reduce their survival through predation.

3.4 Razorback Sucker Effects Analysis

The proposed action is likely to adversely affect the razorback sucker, although the action may also be beneficial to some aspect of the life history of the species. A reproducing and self-sustaining population of razorback sucker exists in Overton Arm of Lake Mead, and adults have been found as recently as June 2010 in the Colorado River inflow, about 9 miles downstream from the lower end of this proposed action area near Pearce Ferry (Albrecht et al. 2010). Spawning is believed to have occurred in April 2010 on rock and gravel points between North Bay and Devil's Cove, which is in the lake interface about 10 miles downstream from Pearce Ferry. A total of seven recently hatched larvae were found in the area on April 13-14, 2010, at a water temperature of 14–16ºC. Although razorback sucker have not been reported between Glen Canyon Dam and Pearce Ferry since 1990 (Valdez 1996), it is possible that individuals from the Lake Mead population use lower Grand Canyon transiently or a few currently reside in the reach. Recent fish sampling in lower Grand Canyon has not reported razorback sucker in the area (Makinster et al. 2010a), but this sampling may not be sufficient to detect small numbers of individuals.

Direct short-term effects of the proposed action are expected to the razorback sucker from modifications in habitat, changes in foodbase, possible burial of spawning bars, and potential displacement of young. The numbers of larvae in the Lake Mead inflow are likely to be small, based on numbers captured in recent years in 10-mile reach below Pearce Ferry (RM 282); i.e., 11 in 2000, 22 in 2001, and 7 in 2010 from ongoing annual sampling (Kegerries et al. 2009; Albrecht et al. 2010). These effects are expected to be temporary for single HFEs and for two consecutive HFEs, where the habitat and the foodbase are expected to be restored shortly after each HFE. However, the effects of more than two consecutive HFEs are not known. For single or two HFEs, habitat would change with increases in water velocity and river stage, but the effect to adults is expected to be minimal. The large amount of material scoured and dislodged by an HFE could deliver a large amount of diverse food items for razorback suckers in the Lake Mead inflow, which are omnivorous and can feed on detritus and insects. An HFE is likely to carry a large amount of sediment that can bury spawning bars with eggs and newly hatched larvae. The only known spawning habitat for razorback sucker is about 11 miles downstream of the action area near Devil's Cove, as described above, where a spring HFE has the potential to deposit sand and sediment on spawning areas.

A spring HFE also has the potential to increase water flow and stage in the inflow area used by razorback sucker; an HFE of 45,000 for 96 hours could increase the level of Lake Mead by 1–2 feet. Adults and juveniles are expected to adjust with changing water level, but high flows could displace recently hatched larvae (such as found in mid-April 2010) from nursery habitats. Larvae displaced from food-rich nursery habitats can starve in 2–3 days (Papoulias and Minckley 1990) or are eaten by predators (USFWS 2002). Alternatively, high flows could benefit larvae by transporting them into newly inundated high-water habitats where food production would be stimulated. The fate of newly hatched razorback sucker during an HFE should be investigated.

3.4.1 Effects to Critical Habitat

The proposed action may adversely affect designated critical habitat of the razorback sucker. Designated critical habitat extends through most of the action area, from the Paria River downstream to Hoover Dam. Razorback sucker have not been reported between Glen Canyon Dam and Pearce Ferry since 1995, and prior to that time, only 10 confirmed fish had been reported from Grand Canyon (Valdez 1996). However, razorback sucker have recently been documented near the lowermost (downstream) boundary of the action area (Albrecht et al. 2010), so adverse modifications to razorback sucker critical habitat is considered in this BA. The effects of Federal actions on the razorback sucker and its critical habitat in Grand Canyon had not been evaluated prior to the 2010 Opinion because of the presumed absence of the species from the area and the unknown habitat requirements for the area.

The primary constituent elements (PCE) addressed in this analysis include: water quality (W1), physical habitat including nursery (P2) and feeding habitat (P3), the biological environment including food supply (B1), predation from non-native fish species (B2), and competition from non-native fish species (B3). Depending on the magnitude of an HFE, a high release is not likely to alter water quality in a manner that detrimentally affects the razorback sucker. The only possible effect is to water quality during spawning and nursing of young in the inflow area of Lake Mead; razorback sucker larvae were found about 10 miles downstream from Pearce Ferry in April 2010 in a water temperature of 14–16ºC. A spring HFE is likely to cool river and inflow temperatures, which may delay spawning or temporarily slow feeding or growth of the larvae. Larval razorback sucker require quiet food-rich areas for nursery habitat. These may become inundated by high flows—or productivity of newly inundated areas may provide a food-rich environment. Predation from non-native fish is always a potential in a lake environment such as Lake Mead. At least bass (*Micropterus* spp.), common carp (*Cyprinus carpio*), channel catfish (*Ictalurus punctatus*), and sunfish (*Lepomis* spp.) have been documented as consuming larval razorback sucker in Lake Mead (Holden et al. 1997). Displacement of razorback sucker larvae could expose them to predation by these species.

3.4.2 Effects to Razorback Sucker Population

The razorback sucker population in closest proximity to the action area is found in Echo Bay, Las Vegas Wash, and the Virgin/Muddy confluence of Overton Arm in north-central Lake Mead. These areas are located about 100 miles down-reservoir from Pearce Ferry, the approximate southern boundary of the action area. In 2000 and 2001 larval razorback sucker were captured in the Colorado River inflow region of Lake Mead (about 11 miles from Pearce Ferry). During the

2002 and 2003 spawning periods, no larval razorback sucker was captured in this area, but in 2010, seven larvae and three adults were captured in the same area. Based on observations of other spawning areas, adults evidently shift locations to spawn depending on lake elevation. Alteration of spawning sites resulting from lake elevation changes may be responsible for the apparent incremental spawning in the Colorado River inflow region. Nevertheless, the spawning location and larval captures in the inflow region are within the area of influence of an HFE released from Glen Canyon Dam about 305 miles upstream.

The largest magnitude and duration of HFE (45,000 cfs for 96 hours) will deliver about 400,000 acre-feet into Lake Mead and likely increase the elevation of the reservoir by 1–2 feet. This increase in lake level in spring could either encourage or discourage spawning by razorback suckers in former spawning sites; the relationship of reservoir elevation to spawning locations is not currently known. Because one or more HFEs could be adverse or beneficial to the razorback sucker in Lake Mead, the effect to the population cannot be determined. It is likely however, that an HFE will enhance survival of larvae and post-larvae by increasing their food supply through inundation of areas and stimulated primary production. Increased turbidity at the river/lake interface will provide cover and is also likely to increase survival of young. The influx of large amounts of organic matter is also likely to bolster the food supply for all ages of razorback suckers.

The extent of impact to the razorback sucker depends on how far upstream they occur from the lower boundary of the action. While spawning of razorback sucker has been determined in the inflow region of Lake Mead, it is unclear whether these fish are actually spawning in the free-flowing reaches of the Colorado River or in Lake Mead itself. Thus, it is uncertain whether larvae resulting from this spawning activity will be displaced by HFEs. With regards to increased risk of predation due to enhanced rainbow trout survival, it is unlikely that razorback sucker overlap with the present distribution of rainbow trout, as no razorback sucker have been documented in areas occupied by trout for at least two decades.

3.5 Kanab Ambersnail Effects Analysis

The proposed action is likely to adversely affect the Kanab ambersnail because of the potential for high flows to inundate and scour habitat and snails at Vasey's Paradise. There is no designated critical habitat for the Kanab ambersnail, and an effects analysis of critical habitat was not done for this species. The majority of habitat occupied by the snails occurs above the elevation inundated by the maximum allowable MLFF flow of 25,000 cfs (Sorensen 2009). Based on the following analysis, there is potential for take of individual Kanab ambersnails and Reclamation has concluded that the proposed action may affect and is likely to adversely affect the species. During the 1996 high flow test (45,000 cfs) in the Grand Canyon, up to 119.4 m^2 (17 percent) of potential Kanab ambersnail habitat at Vasey's Paradise was inundated and scoured, hundreds of snails were lost, and it took 2.5 years for the habitat to recover to pre-flood conditions (Stevens et al. 1997b; IKAMT 1998). When habitat and snails were temporarily removed and relocated for the 2004 and 2008 HFEs, recovered of habitat and snail densities to pre-flood conditions occurred in approximately six months (Sorensen, 2009). Flows of 31,500 to 33,000 cfs are expected to scour and cover with sediment between 10 and 17 percent of the Kanab ambersnail primary habitat at Vasey's Paradise (Reclamation 2002; USFWS 2000).

During the normal course of events in any given year, Kanab ambersnail primary habitat is expected to increase somewhat as new plant growth begins, probably by mid-February. The most proximate estimate for snail habitat below the 45,000 cfs stage for this evaluation is the April 2002 estimate, which was 117 m^2 (Reclamation 2002), slightly less than the 120 m^2 present in March 1996 prior to the HFE. Irrespective of which month HFEs occur, high flows are expected to remove or damage most of the primary habitat and cause mortality of most Kanab ambersnails up to the stage of the flow. The actual numbers of Kanab ambersnail lost due to high flows will depend greatly on the amount of ensuing winter mortality, which can vary dramatically among years depending on the severity of winter temperatures (Stevens et al. 1997a; IKAMT 1998). Based on best available data, the area of primary habitat will not exceed the amount that was present in prior to the 1996 HFE of 45,000 cfs, and thus the amount of incidental take (17 percent) identified by the USFWS (2000) should not be exceeded. 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. Also, an HFE will not affect the population of Kanab ambersnail at Elves Chasm because the habitat for that population is located above the elevation that could be reached by a 45,000 cfs flow.

3.6 Southwestern Willow Flycatcher Effects Analysis

The proposed action may affect, but is not likely to adversely affect the southwestern willow flycatcher. The northern boundary of designated critical habitat for the species forms the southern boundary of the action area. Downstream flows as a result of the proposed action are not expected to have adverse effects below Separation Canyon. Breeding pairs are not likely to be present during HFE periods in March-April or October-November. Individuals have been observed in May, June, and July, outside of proposed HFE release windows. Nesting flycatchers have not been confirmed in Grand Canyon since 2003.

Southwestern willow flycatchers are known to nest in tamarisk along the Colorado River in the Grand Canyon. The southwestern willow flycatcher can be affected by high flows through scouring and destruction of willow-tamarisk shrub nesting habitat or wetland foraging habitat. The southwestern willow flycatcher nests primarily in tamarisk shrub in the lower Grand Canyon, which is quite common along the river corridor. An important element of flycatcher nesting habitat is the presence of moist surface soil conditions. Moist surface soil conditions are maintained by overbank flow or high groundwater elevations supported by high river stage. Willow flycatcher nests in the Grand Canyon are typically above the 45,000 cfs stage (Gloss et al. 2005), which will not be exceeded by the high-flow experimental releases.

3.7 Effects of Climate Change

The Fourth Assessment Report (Summary for Policymakers) of the Intergovernmental Panel on Climate Change (IPCC 2007), presented a selection of key findings regarding projected changes in precipitation and other climate variables as a result of a range of unmitigated climate changes projected over the next century. Although annual average river runoff and water availability are projected to decrease by 10–30 percent over some dry regions at mid-latitudes, information with regard to potential impacts on specific river basins is not included. Recently published projections of potential reductions in natural flow on the Colorado River Basin by the mid 21st century range from approximately 45 percent by Hoerling and Eischeid (2006), to approximately 6 percent by Christensen and Lettenmaier (2006). As documented in the Shortage EIS (Reclamation 2007a), however, these projections are not at the spatial scale needed for CRSS, the model used by Reclamation to project future flows for the Colorado River.

The hydrologic model, CRSS, used as the primary basis of the effects analysis does not project future flows or take into consideration projections such as those cited above, but rather relies on the historic record of the Colorado River Basin to analyze a range of possible future flows. Using CRSS, projections of future Lake Powell reservoir elevations are probabilistic, based on the 100- year historic record. This record includes periods of drought and periods with above average flow. However, studies of proxy records, in particular analyses of tree-rings throughout the upper Colorado River Basin indicate that droughts lasting 15–20 years were not uncommon in the late Holocene. Such findings, when coupled with today's understanding of decadal cycles brought on by El Niño Southern Oscillation and Pacific Decadal Oscillation (and upstream consumptive use), suggest that the current drought could continue for several more years, or the current dry conditions could shift to wetter conditions at any time (Webb et al. 2005). Thus, the action period may include wetter or drier conditions than today. An analysis of hydrologic variability and potential alternative climate scenarios is more thoroughly discussed in the Shortage EIS (Reclamation 2007a) and is incorporated by reference here.

Although precise estimates of the future impacts of climate change throughout the Colorado River Basin at appropriate spatial scales are not currently available, these impacts may include decreased mean annual inflow to Lake Powell, including more frequent and more severe droughts. Such droughts may decrease the average storage level of Lake Powell, which could correspondingly increase the temperature of dam releases. Maximum temperature of water released from Glen Canyon Dam during recent low reservoir elevation (3603 asl) was 15°C in November of 2005. Depending on time of year, a temperature of 15°C at the dam could translate to about 18°C at the LCR because of downstream warming. Increased release temperatures have been cited as one potential factor in the recent increase of juvenile humpback chub (USGS Fact Sheet 2007) but concerns also exist that warmer aquatic environment would also increase the risk of warm water non-native fish predation. Reclamation has committed in the 2007 Opinion to the monitoring and control of non-native fish in coordination with other Interior agencies and working through the GCDAMP (USFWS 2007).

3.8 Effects Determination

A summary of effects determinations for the four listed species is presented in Table 7. Analysis of effects determination are based 50 CFR 402.02, in which "[e]ffects of the action refers 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 or interdependent with that action, that will be added to the environmental baseline. The environmental baseline includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process."

Based on the evaluation contained in this BA, Reclamation has determined that the proposed action may affect and is likely to adversely affect the humpback chub, and may adversely affect its designated critical habitat. This determination is based on short-term adverse effects on habitat and foodbase from high flows and on the potential downstream displacement of young-of-year and juveniles. These combined effects could result in lower survival of young fish and less recruitment to the adult population. The unintended consequence of an increased rainbow trout population that could result from especially spring HFEs would likely increase downstream dispersal of trout into the vicinity of the LCR where they could prey on and compete with young humpback chub. This effect would also reduce recruitment of humpback chub and possibly the overall population size. A concurrent EA on control of non-native fish downstream of Glen Canyon Dam would reduce numbers of rainbow trout and brown trout in the vicinity of the LCR and is expected to reduce this predation and competition effect on humpback chub.

The HFEs are also expected to have long-term beneficial effects to the humpback chub population. Although periodic high flows would likely temporarily affect habitat and reduce the foodbase, multiple HFEs would be expected to rebuild and maintain backwater habitats, so long as sufficient fine sediment was available, and stimulate productivity in backwaters and nearshore habitats. A large number of consecutive HFEs could reduce populations of flood-sensitive invertebrate species and reduce overall densities of organisms that comprise the foodbase. This could have a detrimental effect on humpback chub condition, increase competition among fish species, and reduce reproductive capability. The number of consecutive HFEs that would benefit the ecosystem (e.g., rebuilding and maintenance of habitat, stimulate foodbase productivity)—or adversely modify or alter the ecosystem from periodic scouring is unknown and needs to be investigated as part of this HFE protocol.

Reclamation has also determined that the proposed action may affect and is likely to adversely affect the razorback sucker, and may adversely affect its designated critical habitat. This determination is based on potential short-term effects of high flow on habitat of areas in the Lake Mead inflow that were confirmed spawning sites in 2001, 2002, and 2010 (ripe fish and larvae were found; Albrecht et al. 2010). A high inflow could inundate spawning and nursery areas, transport larvae (recently hatched fish) from safe habitats, and make them more susceptible to starvation or predation. A large HFE of 45,000 cfs for 96 hours could raise the level of Lake Mead by over 1 foot and cover spawning and nursery areas with sediment that could suffocate the embryos. The HFEs could also have beneficial effects on the razorback sucker. Increase sediment load will increase turbidity that larvae use as cover from predators (Kegerries et al. 2009). Increased levels of Lake Mead could inundate vegetated areas and stimulate productivity that larvae could use as sheltered food sources. The large volume of water will also carry a large volume of organic matter that can supplement food for all ages of razorback suckers.

Reclamation has also determined that the proposed action may affect and is likely to adversely affect the Kanab ambersnail. There is no designated habitat for this species, and this analysis did not evaluate primary constituent elements. This determination is based on short-term adverse effects on habitat and snails located in the inundation zone at Vasey's Paradise. Habitat and snails below the high water line are expected to be scoured and transported downstream with little or no survival of snails. The proportion of habitat and the number of snails affected would vary with the magnitude of the high release. For the past HFEs, Reclamation has removed habitat and snails from the projected inundation zone. When the habitat was relocated, the vegetation recovered within about 6 months, but when the habitat was not relocated, recovery was delayed about 2.5 years.

Reclamation has determined that the proposed action may affect and is not likely to adversely affect the southwestern willow flycatcher. This determination is based on the fact that the birds are not expected to be in the action area during the spring HFE release window—March-April—and high flows of 45,000 cfs or less are not likely to adversely affect their nesting and feeding sites. Nesting activity, nests, or young would not be expected to be present during an HFE and no indirect effects are expected since nests of southwestern willow flycatchers have not been found below an elevation equivalent to the 45,000 cfs stage. Designated critical habitat for the southwestern willow flycatcher does not occur in the area of the proposed action.

Table 7. Summary of effects determinations for the four listed species.

Species	Determination	Basis for Determination
Humpback chub	May affect, likely to adversely affect species and critical habitat	• Take could occur from downstream displacement of young into unsuitable habitat, especially during fall HFEs. Effects of displacement, if it occurs, are largely unknown. • Direct short-term reductions in near-shore habitat could occur in the vicinity of the LCR with changes in flow stage, but long-term benefit is expected from sand redeposition that rebuilds and maintains near-shore and backwater nursery habitats. • Direct short-term reductions in food supply could occur with scouring and changes in flow stage, but long-term benefit is expected from stimulated food production. • Increased predation from expanded population of rainbow trout is expected, especially with spring or multiple HFEs.
Razorback sucker	May affect, likely to adversely affect species and critical habitat	• Short-term beneficial impacts to food supply from large influx of organic material during HFEs. • Short-term beneficial effect from inundated vegetation and increased turbidity as protective cover from predators. • Potential displacement of young in Lake Mead inflow by spring HFEs, but possible creation of productive nursery habitats from increased reservoir level and reshaping of near-shore deposits. • Potential short-term burial of spawning bars and other habitats by fine sediment during HFEs.
Kanab ambersnail	May affect, likely to adversely affect; no critical habitat designated	• Up to 119.4 m^2 (17 percent in 1996) of potential habitat may be inundated by 45,000 cfs. • Proportionally less habitat area scoured and fewer numbers of snails would be displaced by lower magnitude HFEs. • Sequential HFEs could reinundate and scour primary habitat prior to full recovery from previous HFE.
Southwestern willow flycatcher	May affect, not likely to adversely affect; critical habitat not in area of proposed action	• Birds will not be present during spring HFEs, and nesting and feeding sites are not expected to be adversely affected. • Birds will be off nests by Sept-Oct, but birds will be foraging and there could be some indirect effect to their food supply.

4 Incidental Take

The USFWS has issued seven biological opinions related to the operation of Glen Canyon Dam between 1978 and 2010. The most recent is the 2008 Opinion for the Operation of Glen Canyon Dam (February 27, 2008; USFWS 2008), supplemented on October 29, 2009 as a result of the Court Order of May 26, 2009, with a revised Incidental Take Statement on November 9, 2010. A summary of these opinions is provided below.

In this biological assessment, Reclamation has evaluated the effects of the proposed action on each of the four listed species. We have identified the potential effects of the different attributes of HFEs, including effects to the species and their respective critical habitats. Reclamation has not attempted to estimate incidental take, as this is the responsibility of the USFWS under Section 9 of ESA. However, Reclamation is interested in providing information that helps to gauge the amount of incidental take and continues to strive to reduce this take where possible and through conservation measures.

As acknowledged by the USFWS in prior opinions, measuring take as a consequence of dam operations, or similar experimental actions, is difficult to detect because of the inaccessibility of the vast mainstem river and because the effect is expected primarily on small fish that are difficult to mark and track. Hence, Reclamation would like to continue to work with the USFWS in designing and implementing studies that will help to better discern take as a consequence of these proposed actions.

Reclamation and the USFWS have defined the humpback chub consultation trigger for reinitiation contained in the conservation measure as being exceeded if the population of adult humpback (≥200mm [7.87 in] TL) in Grand Canyon declines significantly, or if in any single year, based on the age-structured mark recapture model (ASMR; Coggins 2008a), the population drops below 6,000 adult fish within the 95 percent confidence interval. The abundance of adult humpback chub increased approximately 50 percent between 2001 and 2008. The most likely estimate of the population in 2008 was 7,650 adults with a likely range of 6,000 to 10,000 adults (Coggins and Walters 2009), which exceeds the consultation trigger. The level of 6,000 adults was used because that was the number of adult humpback chub estimated in the action area when the USFWS received the biological assessment for the project (April 30, 2010). Conversely, if the population of humpback chub expands significantly, USFWS and Reclamation will consider the potential for reinitiation of consultation to determine if steady flows continue to be necessary, in accordance with standard reinitiation triggers as found in 50 CFR 402.14.

The following summarize the effects determinations and incidental take statements contained in each opinion for the four species addressed in this BA:

1. ***1978 Biological Opinion of the Effects of Glen Canyon Dam on the Colorado River as it Affects Endangered Species (May 25, 1978; USFWS 1995)***

    a. Humpback chub

        i. Jeopardizing continued existence by limiting distribution and population size.

2. ***1995 Biological Opinion on Operation of Glen Canyon Dam (January 7, 1995; USFWS 1995)***

    a. Humpback chub and razorback sucker

        i. Likely to jeopardize continued existence and likely to destroy or adversely modify designated critical habitat.

        ii. Incidental take: some young humpback chub could be transported downstream, but difficult to detect due to inaccessibility.

    b. Kanab ambersnail

        i. Likely to jeopardize continued existence.

        ii. Incidental take: 10 percent of habitat with snails expected to be scoured.

3. ***1996 Biological Opinion for Proposed High Flow Test (January 7, 1996; USFWS 1996)***

    a. Humpback chub (razorback sucker not addressed)

        i. Not likely to jeopardize continued existence and not likely to destroy or adversely modify designated critical habitat.

        ii. Incidental take: some young humpback chub could be transported downstream, but difficult to detect due to inaccessibility.

    b. Kanab ambersnail and southwestern willow flycatcher

        i. Not likely to jeopardize continued existence.

        ii. Incidental take: 10 percent of habitat with snails expected to be scoured.

4. ***1997 Biological Opinion for a Fall Test Flow (January 7, 1996; USFWS 1996)***

    a. Humpback chub (razorback sucker not addressed)

        i. Not likely to jeopardize continued existence and not likely to destroy or adversely modify designated critical habitat.

        ii. Incidental take: some young humpback chub could be transported downstream, but difficult to detect due to inaccessibility.

    b. Kanab ambersnail and southwestern willow flycatcher

        i. Not likely to jeopardize continued existence.

5. ***2002 Biological Opinion for Proposed Experimental Releases from Glen Canyon Dam and Removal of Non-native Fish (December 6, 2002; USFWS 2002a; revised August 12, 2003; USFWS 2003)***

    a. Humpback chub (razorback sucker not addressed)

        i. Not likely to jeopardize continued existence and not likely to destroy or adversely modify designated critical habitat.

        ii. Incidental take: 400 humpback chub expected to be captured; 20 expected to be killed.

    b. Kanab ambersnail and southwestern willow flycatcher

        i. Not likely to jeopardize continued existence.

        ii. Incidental takes of Kanab ambersnail: 117 m^2 of habitat with snails lost over the course of the two years.

6. ***2007 Final Biological Opinion for the Proposed Adoption of the Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (December 12, 2007; USFWS 2007)***

    a. Humpback chub (razorback sucker not addressed)

        i. Not likely to jeopardize continued existence and not likely to destroy or adversely modify designated critical habitat.

        ii. Incidental take: as surrogate measure , take exceeded if 50 percent increase in non-native fish species abundance in LCR reach from 2007 levels, if increase persists for five consecutive years, and significant decline in humpback chub recruitment or survivorship is solely attributable to proposed action.

    b. Kanab ambersnail and southwestern willow flycatcher

        i. Not likely to jeopardize continued existence.

        ii. Incidental take of Kanab ambersnail: as surrogate measure, take exceeded if reduction of more than 20 percent of habitat at Vasey's Paradise from 2007, and reduction continues over a 5-year period.

7. ***2008 Biological Opinion for the Operation of Glen Canyon Dam (February 27, 2008; USFWS 2008; Supplemented October 29, 2009; USFWS 2009;revised November 9, 2010; USFWS 2010)***

a. Humpback chub (razorback sucker addressed in the 2009 Supplemental Opinion at the request of Reclamation)

   i. Not likely to jeopardize continued existence and not likely to destroy or adversely modify designated critical habitat.

   ii. Incidental takes for 2008 Opinion: based on Humpback Chub Consultation Trigger, take exceeded if population drops below 3,500 adult fish within the 95 percent confidence interval.

   iii. Incidental take statement reissued September 1, 2010: take exceeded if population drops below 6,000 adult fish within the 95 percent confidence interval.

   iv. Incidental take for cancelling non-native fish removal for 13 months: 1,000 and 24,000 y-o-y or juvenile humpback chub will be lost to predation by trout.

b. Kanab ambersnail and southwestern willow flycatcher

   i. Not likely to jeopardize continued existence.

   ii. Incidental takes of Kanab ambersnail: as surrogate measure, take exceeded if the proposed action results in more than 117 m^2 (1259 ft^2) of Kanab ambersnail habitat, being removed at Vasey's Paradise and this loss is attributable to the high flow test.

5 Conservation Measures

Reclamation recognizes that conservation measures contained in the 2007 Opinion (Section 2.2.6) will materially contribute to the conservation and protection of listed species in the action area. Progress on these measures and other offsetting or mitigating actions are described in Section 1.3.

Humpback chub

There are currently eight conservation measures designed to reduce adverse effect to the humpback chub, including fish research and monitoring, non-native fish control, humpback chub translocation and refuge, parasite monitoring, sediment research, LCR watershed planning, and the monthly flow transition study. In addition to the anticipated positive benefits to humpback chub expected from the conservation measures and some aspects of the proposed action, during the ten-year experimental period, Reclamation will also use its available discretion in determining monthly release volumes so that releases during the proposed HFEs are transitioned. Our ability to achieve this transition depends not only on the state of the reservoir and on any need for equalization releases, but also the official inflow forecast received from the Colorado River Forecast Center throughout the water year and consultation within the Colorado River Management Work Group. A more gradual transition in the dam release volumes of those months should minimize sudden changes in humpback chub habitat type and any bioenergetic costs associated with their adaptation to the change. Notwithstanding the potential for modest variation in the monthly volumes during HFEs, Reclamation will implement the high releases as set forth in the proposed action.

Kanab ambersnail

In 1996, a controlled 45,000 cfs experimental flood from Glen Canyon Dam lasted for 7 days. Approximately 16 percent of the total habitat of Kanab ambersnail was lost as a result of this flood. A flow of 45,000 cfs resulted in the inundation, scouring, and destruction of occupied habitat and ambersnails. Despite predications that the habitat would recovery within one year of this high release, field studies indicated that less than half of the habitat lost (49 percent) had recovered in one year and appears to take over three years to fully recover.

In October of 1997, a fall test flow of 31,000 cfs for scoured an additional small area (approximately 29.8 m^2 or 3.5 percent) of the existing primary habitat. Individual snails that are not salvaged from the inundated habitat are expected to be displaced and lost by high velocity flows or floating debris. It is not known how long the snails survive inundation. Although it is possible that the Kanab ambersnail could be transported safely downstream to a new location, there is no evidence that any individuals have been survived this downstream transport and subsequently found suitable habitat to result in a new population. Consequently, snails transported downstream are considered unsalvageable.

Experience gained during the 1996 high flow test (45,000 cfs) revealed that nearly all vegetation and snails below the level of inundation were scoured and carried downstream. This experience also indicated that, without supplementation, it took nearly three years for the vegetation to reach its former area and volume. To alleviate this take of habitat and snails, a conservation measure was identified by Reclamation and the NPS in the 2002 BA and by the USFWS in the 2002 Opinion. This conservation measure was designed to decrease the incidental take from mortality during experimental flows.

A second potential agency action for Kanab ambersnail, which was identified in the September 2002 environmental assessment/biological assessment, was to augment the Elves Chasm population that was established by translocation of individuals from Vasey's Paradise in 1998. Periodic augmentation of translocated populations by Kanab ambersnails from Vasey's Paradise was identified in the biological opinion on the 1998 translocation as an action that the NPS may undertake. The primary purpose of augmentation would be to help ensure that the genetic identity of the translocated population does not deviate from the source population at Vasey's Paradise.

The Elves Chasm translocation was one of three undertaken by the NPS, AGFD, and cooperators in an attempt to achieve a goal of redundant populations in the recovery plan and to address a reasonable and prudent measure in the February 1996 biological opinion on the 1996 high flow test. Reclamation has supported monitoring of both Vasey's Paradise and Elves Chasm populations of Kanab ambersnail through the GCDAMP. This reasonable and prudent measure was removed by the USFWS on July 12, 2000, pursuant to their discovery that the level of incidental take for the beach habitat building flow had been underestimated.

For the November 2004 HFE, the action agencies proposed to temporarily remove and safeguard 25–40 percent (29–47 m^2) of the Kanab ambersnail habitat that would be flooded by a high experimental flow (41,000 cfs), if the sediment trigger occurred during the autumn months or anytime before December 31. The habitat and snails were held locally above the level of inundation until the high flow ended, approximately 60 hours. Habitat and snails were replaced in a manner that would facilitate regrowth of vegetation.

For the March 2008 HFE, Reclamation, through the AMP, temporarily removed and safe-guarded all Kanab ambersnails found in the zone that would be inundated during the high flow test, as well as approximately 15 percent (17 m^2 [180 ft^2]) of the Kanab ambersnail habitat that would be flooded by the experimental high flow test. The ambersnails were released above the inundation zone, and habitat was held locally above the level of inundation until the high flow test ended (approximately 60 hours). Habitat was replaced in a manner that would facilitate regrowth of vegetation. Subsequent monitoring of this conservation measure for the 2004 and 2008 HFEs has been coordinated with GCMRC.

The USFWS is in the process of evaluating the genetic status of the Vasey's Paradise population of Kanab ambersnail. Reclamation recommends that at the conclusion of this work that Reclamation and the USFWS discuss what measures, if any, should be taken with respect to the Elves Chasm population of Kanab ambersnail.

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