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Environmental Assessment Experimental Releases from Glen Canyon Dam, Arizona, 2008 through 2012

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

RECLAMATION

Managing Water in the West

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Salt Lake City, Utah

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Mission Statements

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

Environmental Assessment for Experimental Releases from Glen Canyon Dam, Arizona, 2008 through 2012

Proposed agency action:	Experimental releases from Glen Canyon Dam, Coconino County, Arizona, 2008 through 2012
Type of statement:	Environmental assessment
Lead agency:	Bureau of Reclamation, Upper Colorado Region
Cooperating agencies:	None
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1.0 Introduction

The Department of the Interior, acting through the Bureau of Reclamation (Reclamation), is proposing a series of experimental releases of water from Glen Canyon Dam to help native fish, particularly the endangered humpback chub, and conserve fine sediment in the Colorado River corridor in Grand Canyon National Park.

Glen Canyon Dam, authorized by the Colorado River Storage Project Act (CRSPA) of 1956 and completed by Reclamation in 1963, dams the Colorado River some 15 miles upstream from Lees Ferry, Arizona. Below Glen Canyon Dam, the Colorado River flows for 15 miles through Glen Canyon. This area is managed by the National Park Service as part of Glen Canyon National Recreation Area. Fifteen miles below Glen Canyon Dam, Lees Ferry, Arizona marks the beginning of Marble Canyon and the northern boundary of Grand Canyon National Park.

The primary purpose and major function of the dam is water conservation and storage. The dam is specifically managed to regulate releases of water from the Upper Colorado River Basin to the Lower Basin to satisfy provisions of the Colorado River Compact and subsequent water delivery commitments, and thereby allow states within the Upper Basin (Wyoming, Utah, Colorado, New Mexico, Arizona) to deplete water from the watershed upstream of Glen Canyon Dam and utilize their apportionments of Colorado River water.

In addition to the primary purpose of water delivery, another function of the dam is to generate hydroelectric power as an incident to other purposes of Glen Canyon Dam. Water released from Lake Powell through Glen Canyon Dam's eight hydroelectric turbines generates power marketed by the Western Area Power Administration (Western). Between the Dam's completion in 1963 and 1990, the dam's daily operations were primarily undertaken to maximize generation of hydroelectric power in accordance with Section 7 of the CRSPA, which requires production of the greatest practicable amount of power.

In 1970, the Criteria for Coordinated Long-range Operation of Colorado River Reservoirs were established to govern the operation of the mainstem reservoirs in the Colorado River basin. Annual operating plans prepared under the criteria include the requirement to:

> …reflect appropriate consideration of the uses of the reservoirs for all purposes, including flood control, river regulations, beneficial consumptive uses, power production, water quality control, recreation, enhancement of fish and wildlife, and other environmental factors. (Public Law 90-537 § I(2))

Over time, additional considerations have arisen with respect to the operation of Glen Canyon Dam, including concerns regarding effects of Glen Canyon Dam operations on species listed pursuant to the Endangered Species Act. Later, by 1992, recognizing that how the dam is operated might affect Glen Canyon National Recreation Area and Grand Canyon National Park, President George H.W. Bush signed the Grand Canyon Protection Act (GCPA) into law.

The Grand Canyon Protection Act of 1992 required the Secretary of the Interior to complete an environmental impact statement evaluating alternative operating criteria, consistent with existing law, that would determine how Glen Canyon Dam would be operated to both meet the purposes for which the dam was authorized and to meet the goals for protection of Glen Canyon National Recreation Area and Grand Canyon National Park [GCPA § 1804(a); S. Rep. No. 102-267, at 136 (1992)]. The final environmental impact statement (FEIS) was completed in March 1995. The Preferred Alternative (Modified Low Fluctuating Flow Alternative) was selected as the best means to operate Glen Canyon Dam in a Record of Decision issued on October 9, 1996.

Later in 1997, the Secretary adopted operating criteria for Glen Canyon Dam as required by Section 1804(c) of the Grand Canyon Protection Act of 1992. Passage of the Grand Canyon Protection Act of 1992 also requires the Secretary of the Interior to exercise:

> . . .authorities under existing law in such a manner as to pro[t]ect, mitigate adverse impacts to, and improve the values for which Grand Canyon National Park and Glen Canyon National Recreation Area were established, including, but not limited to natural and cultural resources and visitor use. (GCPA §1802(a))

Additionally, the Grand Canyon Protection Act of 1992 requires the Secretary of the Interior to undertake research and monitoring to determine if revised dam operations were actually achieving the resource protection objectives of the FEIS and ROD, i.e., mitigating adverse impacts, protecting, and improving the natural, cultural, and recreational values for which Grand Canyon National Park and Glen Canyon National Recreation Area were established. These provisions of the Grand Canyon Protection Act of 1992 were incorporated into the 1996 ROD and led to the establishment of the Glen Canyon Adaptive Management Program (GCDAMP) under Reclamation and the Grand Canyon Monitoring and Research Center (GCMRC) under the US Geological Survey.

Monitoring and research conducted by these organizations since 1996 have shown that some of the expected benefits of dam operations under the record of decision have not occurred, or have occurred to a lesser degree than anticipated, e.g., for the endangered humpback chub (*Gila cypha*) and conservation of fine sediment. In proposing these experiments, it is important to recognize that all operations including those proposed here, must be implemented in compliance with other specific provisions of existing federal law applicable to the operation of Glen Canyon Dam. These pre-1992 requirements are specifically mandated in the Grand Canyon Protection Act of 1992.

> The Secretary shall implement this section in a manner fully consistent with and subject to the Colorado River Compact, the Upper Colorado River Basin Compact, the Water Treaty of 1944 with Mexico, the decree of the Supreme Court in Arizona v. California, and the provisions of the Colorado River Storage Project Act of 1956 and the Colorado River Basin Project Act of 1968 that govern allocation, appropriation, development, and exportation of the waters of the Colorado River Basin. (GCPA § 1802(b))

This document has been prepared to serve as an environmental assessment and documents current conditions in Glen, Marble, and Grand canyons below Glen Canyon Dam and describes how the Proposed Action, i.e., the experimental high and steady flows are designed to help and assess the long-term benefits to the conservation of endangered humpback chub and fine sediment along the Colorado River downstream of Glen Canyon Dam.

As noted above, this document is an environmental assessment of experimental releases from Glen Canyon Dam, Coconino County, Arizona (Figure 1). The proposed experimental releases from the dam would be in effect from 2008 through 2012. This environmental assessment was prepared by the US Bureau of Reclamation (Reclamation) in compliance with the National Environmental Policy Act (NEPA) and the Council on Environmental Quality's regulations for implementing NEPA (40 CFR 1500-1508). This environmental assessment is not a decision document. The following outcomes could result:

1. a finding of no significant impact could be issued and the experiment could go forward as proposed;
2. a decision could be made to prepare an environmental impact statement;
3. a decision could be made to withdraw the proposal on the basis of environmental impacts disclosed in this document.

1.1 Background and Related Actions

Reclamation, an agency within the US Department of the Interior, operates Glen Canyon Dam as part of the Colorado River Storage Project, which was authorized by Congress in 1956 (43 USC § 620). In 1995 Reclamation finalized an environmental impact statement (EIS) on Glen Canyon Dam operations and in 1996 the Secretary of the Interior decided the dam would be operated using the modified low fluctuating flow alternative in the EIS. In 2007 Reclamation completed an EIS that defines interim guidelines for lower basin shortages and the coordinated operations for Lake Powell and Lake Mead (Reclamation 2007a). Releases from Lake Powell are based largely on the contents of these two reservoirs. Coordinated operations under the 2007 Record of Decision govern the annual release from Lake Powell, while the 1996 Record of Decision governs releases from Lake Powell at shortage time increments, primarily daily and hourly releases. These two records of decision form the basis for no action here. This environmental assessment is tiered (40 CFR 1502.20 and 1508.28) from the 1995 EIS (Reclamation 1995), the shortage and coordinated operations EIS described above (Reclamation 2007a), and from the National Park Service's (NPS) EIS and record of decision for managing visitor use for the Colorado River through Grand Canyon National Park (NPS 2005, 2006).

Reclamation's (1995) EIS and Interior's (1996) decision called for an adaptive management approach, wherein the relationship between dam operations and downstream resources was recognized as uncertain and an active experimental approach was adopted. As a result, the Glen Canyon Dam Adaptive Management Program was instituted and Reclamation and collaborators within the Glen Canyon Dam Adaptive Management Program conducted numerous experimental releases from Glen Canyon Dam, including previous high-flow and steady-flow experiments, which helped inform the design of the proposed experimental releases described in this analysis. Experimentation was designed to assess relationships between dam operations and resources in and along the Colorado River in Glen Canyon National Recreation Area and Grand Canyon National Park (Figure 1).

These experiments included a release of 45,000 cubic feet per second (cfs) beginning March 26, 1996, a powerplant capacity release of 31,000 cfs for 48 hours in 1997, and a combination of powerplant capacity releases and steady flows in 2000. From 2002 through 2004, a series of test flows with higher winter fluctuations was conducted. From 2003 to 2006, mechanical removal of nonnative fish was undertaken to study whether populations of native fish, particularly the endangered humpback chub (*Gila cypha*), could be conserved by reducing numbers of non-native fish, primarily trout.

Experimentation with dam releases also included high flows in November 2004 and alternating fluctuating and stable flows in the fall of 2005. The 2004 high flow test was timed to take advantage of enriched sediment in the Colorado River below the dam (Wiele et al. 2005). Suspended sediment concentrations during the 2004 experiment were 60 to 240 percent greater than during the 1996 experiment, although there was less sand in suspension below River Mile (RM) 42 (Topping et al. 2004). (River miles or RM are measured downstream from Lees Ferry, Arizona.)

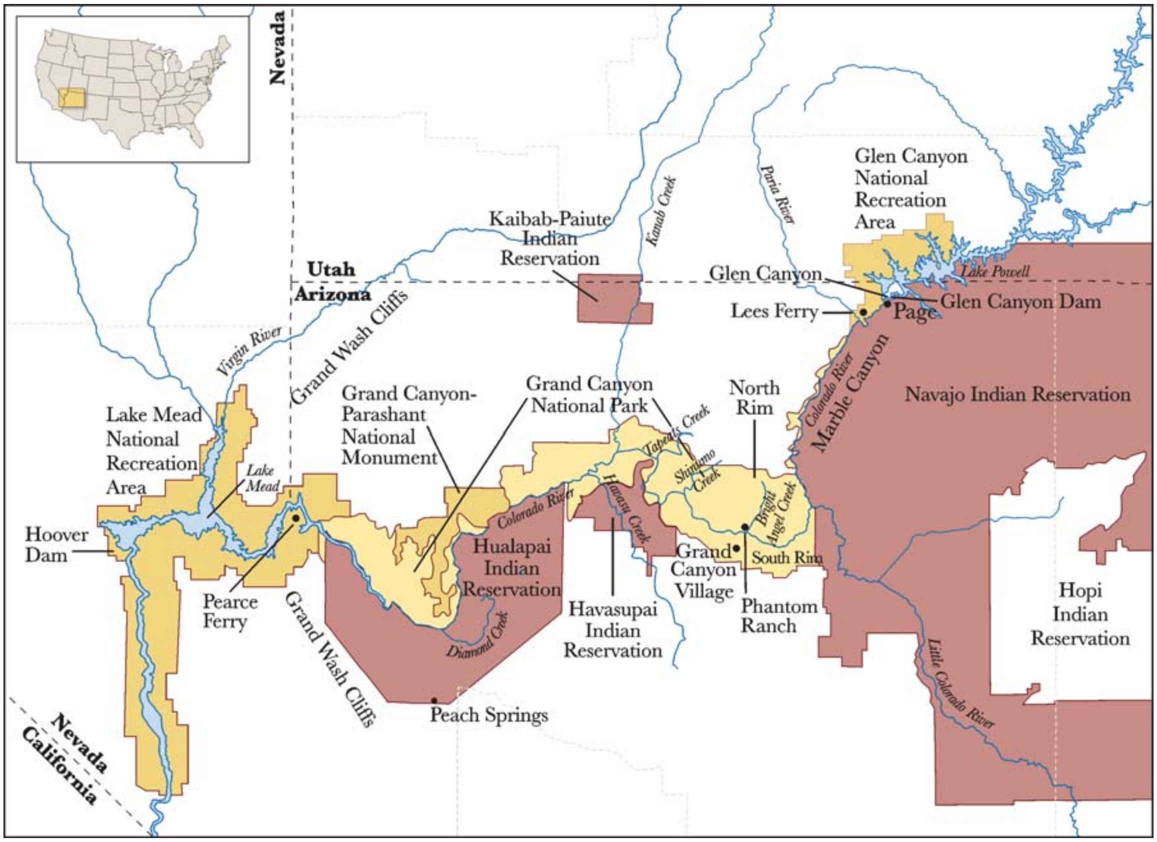

FIGURE 1 Geographic scope of the proposal, showing places referenced in the text. Map courtesy of USGS.

1.2 Purpose of and Need for Action

The purpose of the proposed experimental releases from Glen Canyon Dam is to determine if prescribed releases can benefit resources located downstream of the dam in Glen, Marble, and Grand canyons, Glen Canyon National Recreation Area and Grand Canyon National Park, respectively, while meeting the project purposes of the dam. While Reclamation has conducted two prior high flow tests with initial positive results, sandbars and backwaters reverted back to their previous state, but with recent significant increases in sediment concentration in the Colorado River below the Paria River (approximately three times the amount present in November of 2004, and the largest volume of sediment accumulation in approximately a decade, see section 3.1.4.2), Reclamation and collaborators in the Glen Canyon Dam Adaptive Management Program can test whether high flow releases from the dam can

1. remove or reduce predation of nonnative fish on endangered native fish;
2. rejuvenate backwater habitats for native fish, especially the endangered humpback chub (Gila cypha);
3. redeposit sand at higher elevations;
4. preserve and restore camping beaches; and
5. reduce near-shore vegetation.

These are the stated objectives of prior experimental high releases from the dam (Schmidt et al. 1999:30). The temporary aspect of side-channel sediment in the Grand Canyon has led to expedited consideration of a potential March 2008 high flow experimental release.

As part of the year-long effort lead by the USGS to develop a science plan for the proposed high-flow experimental release, greater emphasis is devoted to understanding the potential benefits of backwaters created by the high-flow release for native fish. The Science Plan describes the elements devoted to native fish monitoring and experimentation.

Complementing the enhanced elements of the Science Plan that focus on the native fish, this proposed action has a second element that has been developed to assess potential benefits for conservation of endangered humpback chub in the Grand Canyon. The purpose of proposed fall steady flows is to determine the effect that steady and fluctuating releases have on native fish habitat, survival, and recruitment. While recent population estimates show an improving humpback chub population, the experiment is needed to better understand the cause of this improvement and methods by which further improvement could occur. This document assesses whether these objectives could be accomplished during 2008 through 2012 without significant adverse impacts to natural, cultural, or socioeconomic resources.

1.3 Relevant Resources

Reclamation utilized the scoping results from the prior NEPA analyses, as well as knowledge gained from prior experimental releases from the dam (e.g. Valdez et al. 1999), to determine relevant issues or resources for this environmental assessment. In 2000, a longer period of steady flows was conducted within existing NEPA compliance coverage, and in 2002 and 2004 Reclamation, NPS, and GCMRC prepared an environmental assessment on a proposed high flow test. Consistent with these earlier experiments Reclamation has now prepared a biological assessment and an environmental assessment on the proposed action. Issues related to high magnitude releases from the dam are relatively well-known. In fact, one of the major purposes of this proposal is to replicate selected elements of the 1996, 1997, and 2004 experimental high flow tests, but under highly enriched sediment conditions. Also, this new proposal follows the high flow with steady fall flows; building on knowledge learned during previous steady-flow experiments in 2000. Based on prior scoping and experimental results, Table 1 lists the issues or resources considered in this environmental assessment. The effects to these resources are described following a description of the alternatives under consideration.

TABLE 1 Summary of resources evaluated

Environmental Issue
Air Quality
Birds
Cultural Resources
Environmental Justice
Fish, Sport Fish, Endangered Fish
Floodplains and Wetlands
Hydropower
Indian Trust Assets
Invertebrates, Herptofauna
Population Growth
Public Health and Hazards
Recreation
Sediment, Soils, and Geomorphology
Transportation and Traffic
Vegetation
Water Resources or Dam Operations
Wilderness

1.4 Authorizing Actions, Permits or Licenses

Implementation of this proposal would require a number of authorizations or permits from various federal and state agencies and Indian tribal governments. Any field work within the boundaries of Glen Canyon National Recreation Area or Grand Canyon National Park would necessitate permits from the NPS. Researchers working with threatened or endangered species would have to obtain a permit from the US Fish and Wildlife Service (Service). Researchers working with resident fish or wildlife species would need an Arizona Game and Fish Department (AGFD) permit. Tribal permits from the Hualapai Indian Tribe or Navajo Nation would be needed should any field work be proposed within reservation boundaries; permits might also be required by the Bureau of Indian Affairs (BIA). No other permits are known to be required at this time.

2.0 Alternatives

In light of recent population increases and new information about humpback chub, Reclamation re-initiated consultation under the Endangered Species Act with the Service on November 13, 2007. The proposed action included in Reclamation's biological assessment was developed during informal consultation with the Service in November 2007. The proposed action in this environmental assessment prepared under NEPA is identical to that contained in Reclamation's biological assessment dated December 2007. Following the conclusion of this environmental assessment and the anticipated completion of Section 7 consultation with the Service (including anticipated issuance of a new biological opinion), Reclamation will reassess work on the long-term experimental plan. This environmental assessment considers two experimental alternatives: no action and the proposal, synonymous with proposed action.

2.1 No Action Alternative

Reclamation would continue to operate the dam as described in prior NEPA analyses (Reclamation 1995, 2007a). No experimental flows or actions would occur from 2008-2012. Projected monthly dam releases for various annual releases are summarized in Table 2, with the data from Reclamation (2007a). Annual and monthly release volumes would continue to be projected for different hydrologic conditions prior to the beginning of the water year and described in annual operating plans and in new operating guidelines (Reclamation 2007a). Scheduled monthly release volumes would continue to be updated at least monthly.

TABLE 2 No Action Glen Canyon Dam releases under dry (7.48 million acre-feet or maf), median (8.23 maf), and wet (12.3 maf) conditions, 2009-2012

	Annual Releases								
	7.48 maf			8.23 maf			12.3 maf		
Month	Mean (cfs)	Min (cfs)	Max (cfs)	Mean (cfs)	Min (cfs)	Max (cfs)	Mean (cfs)	Min (cfs)	Max (cfs)
Oct	7,502	5,300	10,300	9,758	6,800	12,800	9,378	6,800	12,800
Nov	7,563	5,900	10,900	10,083	7,100	13,100	9,075	7,100	13,100
Dec	9,378	6,800	12,800	13,011	9,000	17,000	12,503	9,000	17,000
Jan	12,503	9,000	17,000	13,011	9,000	17,000	17,510	14,200	22,200
Feb	8,470	7,800	13,800	10,804	7,800	13,800	13,903	13,700	21,700
Mar	9,378	6,800	14,800	9,758	6,800	12,800	14,776	11,400	19,400
Apr	7,563	5,900	10,900	10,083	7,100	13,100	14,551	12,200	20,200
May	9,378	6,800	12,800	9,758	6,800	12,800	14,880	11,500	19,500
Jun	9,075	7,100	13,100	10,924	7,900	13,900	17,009	14,900	22,900
Jul	12,503	9,000	17,000	13,824	9,800	17,800	19,776	16,600	24,600
Aug	12,503	9,000	17,000	14,637	10,600	18,600	23,883	20,900	25,000
Sep	9,075	7,100	13,100	10,588	7,600	13,600	21,056	19,400	25,000

2.2 Proposed Action

The proposal consists of two types of experimental flows to be implemented beginning in 2008 and concluding in 2012: 1) an experimental high flow test of approximately 41,500 cfs for a maximum duration of 60 hours beginning March 4, 2008, and 2) steady flows in September and October of each year, 2008 through 2012. The overall concept of the experiment is to determine the effectiveness of sandbar building and backwater formation using a high flow test during highly enriched sediment conditions, and the subsequent impact on humpback chub in those backwaters during fluctuating flows in the spring and summer and steady flows in the fall. The timing of fall steady flows follows young-of-year emergence of humpback chub from the Little Colorado River into the mainstem. Intense monitoring and research conducted throughout this period will identify resultant effects on these geomorphic features and aquatic species. This experimental design is fully reflected in the science plan developed by GCMRC.[1]

To gain a better understanding of the relationships between high releases and downstream resources, the March 2008 high flow test hydrograph (Figure 2) is proposed to partially replicate the November 2004 high flow test hydrograph with the following elements:

- on March 4, 2008 at 2200 hours the modified low-fluctuating flows described in Reclamation (1995) would increase at a rate of 1,500 cfs/hour until powerplant capacity is reached;
- on March 5 once powerplant capacity is reached, each of the four bypass tubes would be opened, where once every three hours bypass releases would be increased by 1,875 cfs until all bypass tubes are operating at full capacity for a total bypass release of 15,000 cfs;
- an essentially constant flow of 41,500[2] cfs would be maintained for 60 hours;
- discharge would then be decreased at a down-ramp rate of 1,500 cfs/hour until the normal powerplant releases scheduled for March have been reached (Figure 2).[3]

[1] This proposed action was developed and builds on previous adaptive management experiments analyzed in Environmental Assessments prepared by Reclamation and other Interior agencies.

[2] The sum of powerplant capacity (approximately 26,500 cfs) plus the capacity of the four bypass tubes (15,000 cfs). Maximum powerplant capacity value calculated from the November 24-Month Study projected March 2008 Lake Powell reservoir elevation of 3586 feet and interpolated from the maximum full gate turbine capacity for seven units. One of the powerplant units will be off-line for repairs and unavailable for use in the experiment.

[3] If this element of the proposal is undertaken, implementation of the high flow experiment will not affect the annual volume of water released from Glen Canyon Dam during water year 2008.

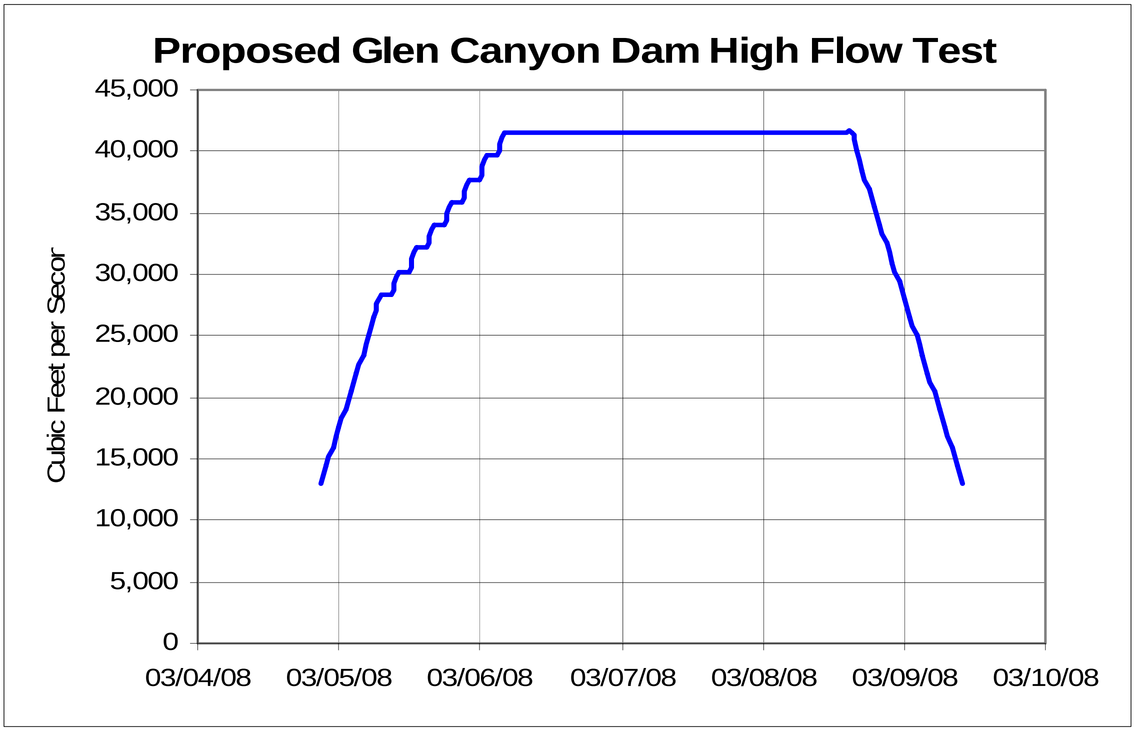

FIGURE 2 Hourly hydrograph of Glen Canyon Dam releases during the March 2008 high flow test

The proposal also includes steady flows in the fall. Steady flow releases during September and October of 2008 through 2012 would include the following constraints:

- typical monthly dam release volumes would be maintained in all water years except 2008, where reallocation of water would occur due to the high flow test in March;
- dam releases for September and October would be steady[4] with a release rate determined to yield the appropriate monthly release volumes;
- if possible, dam operations would be managed so September and October releases would be similar (Table 3), but September releases may be structured to provide a transition between August and October monthly volumes.

Annual water volumes are established pursuant to the recently adopted Interim Guidelines for Coordinated Operations of Lake Powell and Lake Mead (approved

[4] Regulation release capacity of ± 1,200 cfs within each hour will be available if needed for hydropower system regulation during the fall steady flow periods. Each hourly average release is expected to be very close to the steady flow target for the day. Also, spinning reserves will be available if needed for emergency response purposes.

December 13, 2007) and would not be affected by any aspect of this proposal, but monthly release volumes during 2008 would be adjusted due to the 41,500 cfs peak in March (Table 2). Tables 3 and 4 project monthly release volumes and mean, minimum, and maximum daily releases for 10th, 50th, and 90th percentiles. Statistically, the 7.48 maf release pattern corresponds to the 10th percentile category (dry hydrology), the 50th percentile corresponds to the 8.23 maf pattern, and the 12.3 maf monthly release pattern (wet hydrology) corresponds to the 90th percentile volume. All monthly volumes are modeled values and subject to change based on actual hydrology and operations. Descriptions of the model, its limitations and assumptions, are in prior documents (Reclamation 1988, 1995, 2007a).

The interim guidelines for coordinated operations of Lake Powell and Lake Mead define four operation tiers: 1) the Equalization Tier, 2) the Upper Level Balancing Tier, 3) the Mid-Elevation Tier, and 4) the Lower Elevation Balancing Tier. Releases greater than 9.5 maf would occur during the Equalization Tier. Annual releases of 7.48 maf occur in the Mid-Elevation Tier. Annual releases between 7.48 and 9.5 maf generally occur in the two balancing tiers. Implementation of equalization and balancing will follow descriptions in the Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead Record of Decision (Reclamation 2007a,b). Of note is that when operating in the Equalization Tier, the Upper Elevation Balancing Tier, or the Lower Elevation Balancing Tier, scheduled water year releases from Lake Powell would be adjusted each month based on forecast inflow and projected September 30 active storage at Lakes Powell and Mead.

TABLE 3 Comparison of alternative releases, water year 2008

	No Action				Proposed Action			
Month	Monthly volume (maf)	Mean (cfs)	Min (cfs)	Max (cfs)	Monthly Volume (maf)	Mean (cfs)	Min (cfs)	Max (cfs)
Oct	600	9,758	6,800	12,800	601	9,774	6,800	12,800
Nov	600	10,083	7,100	13,100	604	10,134	7,200	13,200
Dec	800	13,011	9,000	17,000	800	13,011	9,000	17,000
Jan	800	13,011	9,000	17,000	800	13,011	9,000	17,000
Feb	600	10,804	7,800	13,800	600	10,804	7,400	13,400
Mar	600	9,758	6,800	12,800	830	13,499	7,200	13,200[1]
Apr	600	10,083	7,100	13,100	550	9,243	6,200	12,200
May	600	9,758	6,800	12,800	555	9,042	6,000	12,000
Jun	650	10,924	7,900	13,900	650	10,924	7,900	13,900
Jul	850	13,824	9,800	17,800	820	13,336	9,300	17,300
Aug	900	14,637	10,600	18,600	820	13,336	9,300	17,300
Sep	630	10,588	7,600	13,600	600	10,083	10,083	10,083

[1] Maximum releases during normal MLFF operations in March 2008. During the high flow test the maximum release would be 41,500 cfs.

TABLE 4 Proposed Glen Canyon Dam releases under dry (7.48 maf), median (8.23 maf), and wet (12.3 maf) conditions, 2009-2012

	Annual Releases								
	7.48 maf			8.23 maf			12.3 maf		
Month	Mean (cfs)	Min (cfs)	Max (cfs)	Mean (cfs)	Min (cfs)	Max (cfs)	Mean (cfs)	Min (cfs)	Max (cfs)
Oct	7,502	7,002	8,002	9,758	9,258	10,258	9,378	8,878	9,878
Nov	7,563	5,900	10,900	10,083	7,100	13,100	9,075	7,100	13,100
Dec	9,378	6,800	12,800	13,011	9,000	17,000	12,503	9,000	17,000
Jan	12,503	9,000	17,000	13,011	9,000	17,000	17,510	14,200	22,200
Feb	8,470	7,800	13,800	10,804	7,800	13,800	13,903	13,700	21,700
Mar	9,378	6,800	14,800	9,758	6,800	12,800	14,776	11,400	19,400
Apr	7,563	5,900	10,900	10,083	7,100	13,100	14,551	12,200	20,200
May	9,378	6,800	12,800	9,758	6,800	12,800	14,880	11,500	19,500
Jun	9,075	7,100	13,100	10,924	7,900	13,900	17,009	14,900	22,900
Jul	12,503	9,000	17,000	13,824	9,800	17,800	19,776	16,600	24,600
Aug	12,503	9,000	17,000	14,637	10,600	18,600	23,883	20,900	25,000
Sep	9,075	8,575	9,575	10,588	10,088	11,088	21,056	20,556	21,556

2.2.1 Mitigation Measures in the Proposal

Under NEPA, mitigation means reducing, eliminating, or compensating for the impact of an alternative (40 CFR 1508.20). Mitigation measures incorporated into the proposal are designed to accomplish these objectives. More complete descriptions of potential impacts of the proposal are contained in the various resource areas in section 3.0. One aspect of mitigation involves the timing of the experimental releases. As discussed under Socioeconomics in section 3.3, increased hydropower costs that would result should the proposal be implemented would have a disproportionate adverse effect on low-income households. Recognizing that this would be a significant adverse environmental justice impact, the impact was reduced by proposing a steady flow test during the fall rather than the summer when much higher economic impacts would occur. Likewise, the timing of the high flow test was designed to minimize impacts to recreation, tamarisk seedling dispersal, the aquatic foodbase, and the Kanab ambersnail.

With respect to the high-flow experiment conducted in November 2004, conservation measures were designed to mitigate any adverse impacts on endangered Kanab ambersnail (*Oxyloma haydeni kanabensis*) at Vaseys Paradise in Grand Canyon National Park as a result of temporary high-flow inundation of ambersnail habitat. These efforts included moving 4 percent of the total habitat of plants and animals. The current proposal repeats the 2004 mitigation measures for the Kanab ambersnail. Reclamation proposes to temporarily relocate snails that would be inundated by a 41,500 cfs flow to higher elevations at Vaseys Paradise. Further mitigation commitments could develop as a result of the completion of formal consultation with the Service under the Endangered Species Act of 1973, as amended (ESA).

As part of information gathering during the formulation of the proposed action, Service, NPS, Western, and AGFD conducted a meeting with fishing guides and small business owners in the Marble Canyon area. Their concerns were primarily socioeconomic and associated with public perception of impacts to fishing success in the Lees Ferry reach. To minimize potential adverse economic impact, Reclamation agreed to shift the timing of the proposed high flow test as early in 2008 as possible and to work with FWS, NPS and AGFD to propose measures within the AMP dedicated to improving communication between management agencies and the angling guides, dependent local businesses, and the public. These proposed measures include:

Ongoing compliance with the National Historic Preservation Act (NHPA) necessitates that one archaeological site located in Glen Canyon National Recreation Area be excavated as part of an overall NHPA compliance treatment plan. Data recovery is currently being contracted by Reclamation. This mitigating measure will continue under either alternative.

3.0 Environmental Impacts of the Proposal

This chapter describes environmental impacts of the proposal compared with taking no further experimental flow actions over the next five years. The action area or geographic scope of is from the tail water below Glen Canyon Dam downstream along the Colorado River to Lake Mead, as shown in Figure 1. The lateral extent of the action area is up to the ground surface that would be inundated by the proposed high release of 41,500 cfs or any indirect or cumulative effects.

Reclamation convened an interdisciplinary team of resource specialists to review alternatives and consider potential effects to natural, cultural, and socioeconomic resources listed in Table 1. They concluded that should the proposal be implemented, most resources would be temporarily and beneficially affected; however, implementing the proposal would result in adverse impacts to hydropower and this would in turn cause a disproportionate and significant adverse impact on low-income power customers. By definition, this economic or social effect does not require preparation of an EIS (40 CFR 1508.14). Detailed information on resources affected by the proposal is provided below. The chapter is organized by resources, with natural resources described first, followed by cultural, then socioeconomic resources.

3.1 Natural Resources

Natural resources reviewed to determine effects of the proposed action include air quality, floodplains and wetlands, geology and soils (including prime farmlands), threatened and endangered species, vegetation, water resources (including water rights, hydrology, water delivery systems, water quality), and wildlife. Based on this review of all natural resources in the action area, only those natural resources likely to be directly, indirectly, or cumulatively affected by the proposal are described here.

Of particular importance in evaluating effects of the proposal is humpback chub habitat, especially nursery backwaters, and the possible downstream transport of young humpback chub. Evaluation of the steady fall flow is important to better understand the contrast between fluctuating and steady flows with respect to the extent of longitudinal warming, warming of shoreline habitats and nursery backwaters, stability of shoreline habitats, and the effect to humpback chub survival, growth, and bioenergetic expenditure. Full evaluation of this aspect of the proposed action is important to better understand how discretionary releases from the dam might affect humpback chub and long-term species conservation. In the sections below, the relevant natural resources are presented by trophic levels.

3.1.1.1 Climate Change

The hydrologic model, Colorado River Simulation System (Reclamation 1988, 2007a), used to present future dam releases under both alternatives does not project future flows or take into consideration climatic projections, but rather relies on historic records of the Colorado River to depict a range of possible future storage levels in Lakes Powell and Mead and dam releases. Using the Colorado River Simulation System, projections of future Lake Powell reservoir elevations are probabilistic, based on the 100-year historic record. This record includes years of under and over average flow. Studies of proxy records, in particular analyses of tree-rings throughout the upper Colorado River basin, indicate droughts of greater severity and duration than those in the 100-year historic record. Such findings, when coupled with today's understanding of decadal cycles brought on by the el Niño-Southern Oscillation, Pacific Decadal Oscillation, upstream consumptive use, and improved understanding of millennial-scale climate cycles (Bond et al. 1997), suggest the current drought could continue over the action period or there could be a shift to wetter conditions (Webb et al. 2005). Thus, the action period for this environmental assessment may include wetter or drier conditions than today or wetter or drier conditions than modeled in CRSS. A continued drought like those documented in proxy records could result in decreased mean annual inflow to Lake Powell and decreased average storage in Lake Powell. This could affect downstream water resources and the effects on water resources under no action or the proposal.

3.1.2 Water Resources or Glen Canyon Dam Operations under No Action

As mentioned above, this environmental assessment is tiered off prior NEPA analyses. Full descriptions of the methods used for water resources modeling and other resources are described in these prior documents. The details of annual and monthly projected water resources and dam operations through the experimental period are in Reclamation

(2007a). Only a summary is provided here. Annual releases from the dam would be the same under either alternative as noted in section 2.2, only monthly and hourly release volumes would differ. Tables 2 and 3 present the most probable future values if no action is taken.

3.1.3 Water Resources under the Proposal

One of the differences examined by Reclamation hydrologists was the level of Lake Powell and Lake Mead should the proposal be implemented. Projected differences in Lake Powell elevation with the proposal would be less than projected seasonal change within a given water year. The greatest differences in the elevation of Lake Powell would occur in March 2008 when the reservoir would decrease a projected 2.6 feet as a result of the proposed high-flow release. The effect on Lake Mead would be an increase by 2.5 feet in March. However because the 2008 water year release from Lake Powell is unchanged under the proposal, elevations of both Lakes Powell and Mead would be the same elevation under either alternative by September 30, 2008.

In terms of dam releases, Table 3 contrasts monthly volumes under the two alternatives. Tables 2 and 4 show proposed releases if the water year is dry (7.48 maf), median conditions (8.23 maf), or wet (12.3 maf). Predicted changes in levels of Lakes Powell and Mead or Glen Canyon Dam releases are minor, temporary effects. (Hydropower effects are covered under Socioeconomic Resources.)

3.1.3.1 Water Quality

Effects of the 2008 high flow are projected based on prior experiments and knowledge of water quality processes. Prior experimental high flows weakened the persistent chemical and thermal stratification below the depth of the penstock-withdrawal zone. The volume of water below this zone is normally relatively isolated from the convective and advective mixing processes of the upper portions of the reservoir. The water below the penstock withdrawal zone is typically cooler than the upper level of the reservoir and more saline with a marked reduction of dissolved oxygen concentrations. Releases from the powerplant following the 1996 high flow test had reduced water density and higher dissolved oxygen concentrations, the result of lowering the depth of chemical stratification in the reservoir. Similar positive water quality effects are projected under the proposal.

Water quality effects during a high flow test in 2008 would likely include a slight reduction in downstream temperature and a slight increase in salinity. During the year following the high flow test, salinity levels would probably decrease slightly, downstream temperatures would return to the no-action condition, and dissolved oxygen concentrations could increase slightly. Based on model results, the release temperatures of the proposed September and October steady flows would not be significantly different from normal fluctuating releases. Determining the effect of subsequent downstream warming in near shore and backwater areas is one of the important purposes of this portion of the experiment.

3.1.4 Sediment and Geomorphology

The proposal is designed to test the hypothesis that sediment may be entrained from the channel bed and debris fans and deposited at higher elevations along river channel margins after a high flow, preserving or enhancing camping beaches and sediment conservation.

Significant sediment research in the Grand Canyon has occurred during the past 25 years. While this proposal builds on that monitoring, research and experimentation, this assessment does not intend to fully summarize all that information. During that period of time, there has never been a high flow test conducted during highly enriched sediment conditions. Such an experiment is essential in determining the potential for long-term sustainability of the sediment resource. In addition, if no action is taken, recent tributary sediment inputs will be transported downstream to Lake Mead.

While it is generally expected that significant positive sandbar building will occur during the high flow test, it is uncertain where that sandbar building will occur, how long those effects will persist, and what benefits will accrue. It is expected that monitoring and research activities will be followed by analysis and modeling to answer these questions.

3.1.4.1 Sandbars under No Action

Some geomorphologists believe that Grand Canyon sandbars will continue to degrade due to the existence of the dam; others hypothesize that dam operations, particularly high flows, may be used to rebuild, conserve, or enhance sandbars. As stated above, an underlying purpose of this and prior experimental dam releases is to test such hypotheses, measure rates of sand deposition and erosion, as well as to observe changes in sandbar topography over time in relation to dam operations.

3.1.4.2 Sandbars under the Proposal

Based on prior experimental flows, sediment would likely be entrained quickly and efficiently by the proposed 41,500 cfs release. Suspended sediment concentrations within the river and eddies would be expected to decrease after the first 48-72 hours after the river stage reaches its peak and would continue to decline at a slower rate thereafter. This response is expected to vary from that measured in 1996 due to current abundant sediment supply in the river. In 2007, sand inputs from the Paria River measured at least 2.5 million metric tons or about 2.5 times the historic average (Topping and Melis 2007). Together with sand from the Little Colorado River, sand storage from these inputs are currently at least three times the amount that triggered the 2004 high flow test and greater since at least 1998. These conditions present an opportunity to evaluate effects of a high flow test under more sediment-rich conditions than observed during previous experiments.

Based on the results of high releases conducted in 1996, 1997, and 2004, a controlled high flow would likely increase the number and size of sandbars and campsites immediately after the event. For example, the 1996 flood created 84 new campsites, while destroying three others (Kearsley et al. 1999). A key question is whether a high flow under sediment enriched conditions might result in more lasting effects.

3.1.4.3 Debris Fans and Rapids under No Action

Nearly all the rapids in Grand Canyon result from the accumulation of large boulders on debris fans at the mouths of some 736 tributaries of the Colorado River in Grand Canyon between Lees Ferry and the Grand Wash Cliffs (RM 0 to 276) (Webb et al. 1999). Debris flows from these tributary canyons are deposited during tributary floods, which have occurred at a constant rate since 1923 (Magirl et al. 2005). The concern with debris fans under no action is that many of the rapids in the Colorado River have become more severe (for river running) because individual boulders cannot be totally removed by typical dam releases (Webb et al. 1999:39). For instance, the water surface elevation at the head of 91 rapids increased by a mean of 0.26 ± 0.15 m from 1923 to 2000 (Magirl et al. 2005), although several rapids and debris fans eroded over time, with consequent lowering of the pools at the head of the rapids. This trend can be expected to continue under no action.

Turning from individual rapids and debris fans to the entire river profile, comparison of LIDAR measurements from the 2000 experiment with survey data from 1923, Magirl et al. (2005) have shown the trend along the whole river is toward aggradation. This trend is expected to continue under no action.

3.1.4.4 Debris Fans and Rapids under the Proposal

One of the hypotheses to be tested by the high flow is the extent to which releases of 41,500 cfs can rework debris fans. The 1996 flood moved boulders as large as two meters in diameter and transported particles with diameters of less than 0.5 meters off the margins of debris fans (Pizzuto et al. 1999:65). Prior controlled flows have shown that releases around 40,000 cfs can change area and volume of recently aggraded debris fans, such as those at Monument and Hermit creeks. Research has shown that most of the reworking of more recent debris fans occurs during the rising limb of floods, leading to Webb et al.'s (1999:50) conclusion that a seven-day high flow is unnecessary for reworking more recent debris fans. Based on prior experiments, older debris fans are predicted to show less response to reworking than more recently formed debris fans and rapids. No measurable changes are expected from the proposal at older, stable debris fans. Likewise, no measurable changes are expected at high terraces or to the sediment delta at the inflow to Lake Mead, although there would probably be a more rapid accumulation of sediment in the Lake Mead delta under the high flow.

3.1.4.5 Backwaters under No Action

Backwaters may be important rearing habitat for native fish due to low water velocity, warm water, and high levels of biological productivity. The importance of backwaters in Grand Canyon with respect to native fish is uncertain, and this is one of the key questions associated with the proposal. 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 near shore habitats from the cold, high velocity main channel environment.

Backwater numbers vary spatially among geomorphic reaches in Grand Canyon and tend to occur in greatest number in river reaches with the greatest active channel width, including the reach immediately downstream from the Little Colorado River (RM 61.5-77; McGuinn-Robbins 1995). Numbers and size of backwaters also vary temporally as a function of sediment availability and hydrology, and their size can vary within a year at a given site. Under no action, backwaters would continue to fluctuate with ongoing geomorphic and hydrologic processes.

3.1.4.6 Backwaters under the Proposal

Persistence of backwaters created during 1996 appeared to be strongly governed by post-high flow dam operations. 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 away 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). One of the key tests of this proposal is whether moderate fluctuating flows and steady flows might increase backwater persistence (USGS 2007).

Goeking et al. (2003) found no relationship between backwater number and flood frequency, although backwater size tends to be greatest following high flows and less in the absence of high flows due to infilling. Considering both area and number, however, no net positive or negative trend in backwater availability was noted during 1935 through 2000. At the decadal scale, several factors confound interpretation of high flow effects on backwaters bathymetry, including site-specific relationships between flow and backwater size, temporal variation within individual sites, and high spatial variation in reattachment bar topography (Goeking and Schmidt 2003). Efficacy of high flow tests at creating or enlarging backwaters also depends on antecedent sediment load and distribution, hydrology of previous years (Rakowski and Schmidt 1999) and post-high flow river hydrology, which can shorten the duration of backwaters to a few weeks depending on return channel deposition rates or erosion of reattachment bars (Brouder et al. 1999).

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 et al. 1999). Invertebrates rebounded to pre-test levels by September 1996, but researchers thought that the rate of recolonization was hindered by a lack of FPOM. Still, 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 et al. (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 proposal is 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. Another key purpose of the proposal is to determine the effect that flow stability has on backwater temperature, and consequential impacts to productivity and native and nonnative fish.

3.1.5 Vegetation

Vegetation along the river is distributed along a gradient with the first 60 miles classified as Upper Sonoran or cold desert plants, gradually shifting to warm desert species typical of Lower Sonoran vegetation. At any one location where cross-sections are taken, the more xerically adapted species such as four-wing saltbush (*Atriplex canescens*), arrowweed (*Pluchea sericea*), and rubber rabbitbrush (*Chrysothamnus nauseosus*), are found on the terraces away from the river. These upland plants would be largely unaffected by the proposal and are therefore not considered here.

Within the area that would be inundated by a flow of 41,500 cfs, vegetation has changed over time in response to changes in the water-levels of the Colorado River, increased soil salinity, climatic changes, and other factors. Prior to 1963, riparian vegetation was common in Glen Canyon and along the lower Colorado River, but relatively rare in Grand Canyon due to the combination of high flows, sediment deposition, and entrained debris scouring the floodplain (Kearsley and Ayers 1999:310; Stevens and Waring 1988, Stevens et al. 1995). By 1973 after 10 years of regulated flows, species that were ephemeral pre-dam occupants (Clover and Jotter 1941) expanded into the newly stable habitat. From 1983 to 1985, summer flows were maintained at or above 40,000 cfs, altering the composition, density, and location of riparian plants. Since then, the total size of the riparian zone or new high water zone has increased to 10 square miles (2,500 hectares) (Kearsley and Ayers 1999; Schmidt and Graf 1988) with salt cedar or tamarisk (*Tamarix ramosissima*), arrowweed (*Pluchea sericea*), black willow or Gooding willow (*Salix goodingii*), coyote willow (*Salix exigua*), and Emory seepwillow (*Baccharis emeroyi*), the dominant phreatophytes (taxomony is after Welsh et al. 1987).

Stands of emergent marsh vegetation in the riparian zone tend to be dominated by a few species, depending on soil texture and drainage. A cattail (*Typha domingensis*) and common reed (*Phragmities australis*) association grows on fine-grained silty loams while a horseweed (*Conyza canadensis*), knotweed (*Polygonum aviculare*), and Bermuda grass (*Cynodon dactylon*) association grows on loamy sands. Most of the plants in these marsh associations have relatively high stress tolerance, although Stevens et al. (1995) and

Stevens and Waring (1988) have shown that the marshes, and in fact all riparian species, are influenced by too much water as well as too little water.

3.1.5.1 Vegetation under No Action

If no action were taken by Reclamation through 2012, riparian vegetation would continue to change due to processes of colonization by invasive species such as tamarisk, camelthorn, Russian-thistle (*Salsola iberica*), red brome or foxtail brome (*Bromus rubens*), cheatgrass (*Bromus tectorum*), yellow sweet-clover (*Melilotus officinalis*), spiny sow-thistle (*Sonchus asper*), and Bermuda grass (*Cynodon dactylon*). Other natural processes would continue to result in alternation of the riparian zone. Within Grand Canyon, Bowers et al. (1997) and Webb (1996) have demonstrated that short-lived plants such as *Brickellia longifola, Stephanomeria pauciflora, Gutierrezia sarothrae, Encelia frutescens*, and *Baccharis emoryi*, are actively colonizing the youngest and more disturbed surfaces. Longer-lived species are not as quick to colonize disturbed areas. For example, *Ephedra* spp., *Opuntia* spp., *Prosopis glandulosa*, and *Acacia gregii* are found on surfaces older than seven years and as young as 28 years. Without the disturbances caused by the proposal or on-going formation of debris fans at tributary mouths, the longer-lived species will continue to expand towards the river edge.

Of course, some changes to riparian vegetation are occurring due to management actions. Executive Order 13112 defines invasive species as alien species whose introduction is likely to cause economic or environmental harm or harm to human health. This executive order calls on federal agencies to work to prevent and control the introduction and spread of invasive species. Both Glen Canyon National Recreation Area and Grand Canyon National Park support programs of noxious and invasive plant control and these programs are projected to continue.

3.1.5.2 Vegetation under the Proposal

Effects of prior experimental flows on riparian vegetation were minimal (Valdez 1999:346) so effects of the new experiment are also predicted to be minor. Prior high flow experiments showed that sedimentation along channel margins and in eddy deposition zones buried low-growing plants; however, this effect was of insufficient magnitude, duration, or both, to restructure most vegetation patches (Ayers and Kearsley 1996; Valdez 1999:345).

In terms of effects to individual species, an increase in the density of cattails was noted in lower reaches of Grand Canyon following the 1996 high flow test (Ayers and Kearsley 1996), but this may have been a result of high sustained releases that followed the high flow. Also, total foliar cover was diminished as a result of the 1996 flood, but no localities showed a significant change in area covered by wetland plants (Ayers and Kearsley 1996). The proposed 2008 flood would likely result in similar minor effects: short term burial of seeds and plants on existing sandbars, some scouring of riparian vegetation, a short-term increase in groundwater and soil nutrient concentrations, but over time, recolonization would occur with long-lived species dominating.

The proposed high flow would increase the rate at which sediment is deposited at the delta of Lake Mead, as predicted in the Sediment section. However, because of the short duration of the flow, the extensive area available for sediment deposition in Lake Mead, and the highly fluctuating water levels, effects on riparian vegetation would be minor.

Established tamarisk and camelthorn located on sand bars and along channel margins are expected to survive a flood, growing up through newly deposited sand and vigorously resprouting and recolonizing sandbars. This expansion is likely to continue whether there is an experimental flood or not (Valdez 1999:346). One effect of prior floods on riparian vegetation was the burial of the seed bank by new sediment deposits (Kearsley and Ayers 1999; Valdez 1999), although, it is unclear whether the newly buried seeds remain viable, leading to further expansion of undesired plants onto sandbars.

In conclusion, there might be changes in individual plants or patches of plants, but over time these changes would be minor against the larger changes wrought by processes of succession and adaptation along a gradient.

3.1.6 Terrestrial Invertebrates and Herptofauna

In this section, effects of the proposal are analyzed for specific terrestrial invertebrates or herptofauna of interest, particularly those listed as endangered, threatened, or of concern to states or tribal managers. A separate biological assessment of these effects has been submitted to the Service and is currently undergoing consultation under Section 7 of the ESA. (The effects of the proposal on aquatic invertebrates are included under the discussions of fish and birds.)

The Kanab ambersnail (*Oxyloma haydeni kanabensis*) was listed as endangered in 1992. Populations of Kanab ambersnail presently occur at three springs, one at Three Lakes near Kanab, Utah; one at Vaseys Paradise, a small spring-fed riparian area adjacent to the Colorado River in Grand Canyon at RM 31.8; and a translocated population at Upper Elves Chasm, RM 116.6. Kanab ambersnails located at Elves Chasm would not be affected by this action.

Over 27 species of herpetofauna have been documented in the riparian zone of the Grand Canyon (Kearsley et al. 2006). Within this area, herpetofauna densities are highest where riparian vegetation has developed since construction of Glen Canyon Dam, i.e., between the more xeric terraces and the river shoreline. Toads and tree lizards use the shoreline proportionally more than other species (Carpenter 2006).

Common lizards in the riparian zone are the side-blotched lizard (*Uta stansburiana*), Western whiptail (*Cnemidophorus tigris*), desert spiny lizard (*Sceloporus magister*), and the tree lizard (*Urosaurus ornatus*). The collared lizard (*Crotaphylus insularis)* and chuckwalla (*Sauromalus obesus)* are less common in the riparian zone than in the more xeric terraces. Warren and Schwalbe (1986) reported lizard densities during June averaged 858/hectare in the riparian zone versus 300/hectare in the old high water zone. Kearsley et al. (2006) suggested that the high density of lizards in the riparian zone may be attributed to increased abundance of food resources (insects) and to some degree to organic debris left on popular camping beaches.

Snakes are common in the higher and drier elevations of the riparian zone and in the more xeric terraces and hillsides. Eight snake species have been documented within the riparian zone; the most common of these are the Grand Canyon rattlesnake (*Crotalus viridis abyssus*), the southwestern speckled rattlesnake (*C. mitchellii pyrrhus)* and the desert striped whipsnake (*Masticophis taeniatus)*.

Amphibians include frogs, spadefoots, and true toads. Recent surveys have found abundant populations of Woodhouse's toad (*Bufo woodhousii*), red-spotted toad, (*B. punctatus*), canyon treefrog, and tiger salamander (*Ambystoma tigrinum*) (Kearsley et al. 2003, 2006). Northern leopard frog (*Rana pipiens*) populations, on the other hand, have declined (Drost 2004, 2005). Listed as a candidate species in Arizona, the northern leopard frog is declining throughout its range. Leopard frogs have disappeared from 70 percent of the known sites above and below Glen Canyon Dam and there appear to be declines among some of the remaining populations (Drost 2004). The only known population below the dam is located in Glen Canyon in a series of off-channel pools. Inundation at this site occurs at approximately 21,000 cfs. This population has experienced wide year-to-year fluctuations in numbers, but recent survey indicates a sharp decline in population with only two adult individuals found in 2004 (Drost 2004).

The canyon treefrog is confined to relatively steep side canyons, while the two toad species are found in the active riparian zone in spring and fall and along the shoreline in summer (Kearsley et al. 2003). For amphibians, egg deposition and larval development generally occurs in the backwaters or along the shallow water at the boundary of the aquatic and riparian habitats.

3.1.6.1 Terrestrial Invertebrates and Herptofauna under No Action

Kanab ambersnails are found in the riparian vegetation associated with the spring at Vaseys Paradise. Through analysis of historic photographs, an increase in the vegetative cover along the river in Grand Canyon has occurred since the completion of Glen Canyon Dam in 1963 (Turner and Karpiscak 1980). The increase in cover, reduction in beach-scouring flows, and introduction of non-native water-cress, *Nasturtium officinale,* has led to a greater than 40 percent increase in suitable Kanab ambersnail habitat area at Vaseys Paradise from pre-dam conditions (Stevens et al 1997a). Under the no action alternative Kanab ambersnails are expected to maintain their population at Vaseys Paradise.

Herpetofauna densities are generally highest where riparian vegetation has developed since construction of Glen Canyon Dam. However, Carpenter (2006) found that, other than the resident frogs, herpetofuana utilize habitats from the river up to the xeric terraces. Toads and tree lizards use the shoreline proportionally more than any of the other species (Carpenter 2006). Amphibians and reptiles are not expected to change under the no action.

3.1.6.2 Terrestrial Invertebrates and Herptofauna under the Proposal

The proposed 2008 high flow test would result in a minor loss of the Vaseys Paradise habitat of Kanab ambersnail. But pre-dam, the Kanab ambersnail population in the Grand Canyon survived and recovered from innumerable flows equal to or higher than the proposal. The population of Kanab ambersnail at Vaseys Paradise and the effects of the proposal on them are currently under consultation with the Service. Reclamation's finding is that the proposal "may affect, is likely to adversely affect" a percentage of snails and their habitat during the high flow test. No effect on snails or habitat would result from fall steady flows. At flows of 45,000 cfs, approximately 17 percent of Kanab ambersnail habitat would be inundated. This habitat varies from high to low suitability for Kanab ambersnail. If the proposed high flow is implemented, Reclamation would move 25 percent of affected habitat, including higher quality vegetation and snails within the flood zone, as was done in 2004. The vegetation and snails would be replaced after the flood waters have receded. Moving snails and their habitat, as mentioned under the section on mitigation measures, could result in an adverse effect or "take" of the species. This potential for take is the reason for the "may affect" finding in Reclamation's biological assessment.

Populations of northern leopard frog in the Glen Canyon reach were monitored before and after the 1996 flood and the populations were little affected in the short-run and recovered quickly over time (Spence 1997). However, since 1996 northern leopard frogs have declined dramatically in Glen and Grand canyons and in 2004 only two adults were found in an off-channel pool in Glen Canyon. Clearly other factors besides high flows have played a role in this decline. Using the conclusions of the 1997 report, no effects to populations of these species are expected from the proposal.

3.1.7 Fish under No Action

The river from the dam to the Paria River supports a self-sustaining fishery of rainbow trout (*Oncorhynchus mykiss)* and occasional brown trout (*Salmo trutta)*. Management of trout in this reach, as agreed to by the management agencies is for rainbow trout and not for brown trout; the latter is a particularly piscivorous predator on native fish. This reach of river also supports small numbers of bluehead sucker (*Catostomus discobolus*), flannelmouth sucker (*Catostomus latipinnis*), and speckled dace (*Rhinichthys osculus*). The flannelmouth sucker spawns in this reach and up the Paria River (McIvor and Thieme 2000; McKinney et al. 1999; Thieme 1998), although the water is too cold in the mainstem for survival of eggs and larvae.

From the Paria River to the Little Colorado River, rainbow trout are the dominant nonnative species (Ackerman 2007; Johnstone and Lauretta 2007), but this 61 miles of the Colorado River supports low to moderate numbers of native bluehead sucker flannelmouth sucker, humpback chub, and speckled dace (*Rhinichthys osculus*) (Hoffnagle et al. 1999). Most native fish in the mainstem from the dam to the Little Colorado River are large juveniles and adults. Earlier life stages rely extensively on more protected nearshore habitats, primarily backwaters (Lauretta and Serrato 2006; Trammel et al. 2002). Native fish spawning may occur in warm springs at RM 30-32 (Valdez and Masslich 1999). Other nonnative species sporadically found in that reach include brown trout, common carp (*Cyprinus carpio*), red shiner (*Cyprinella lutrensis*), plains killifish (*Fundulus zebrinus*), fathead minnow (*Pimephales promelas*), and channel catfish (*Ictalurus punctatus*).

The 174 miles from the Little Colorado River to Bridge Canyon has six major tributaries and supports a diverse fish fauna of cool- to warm-water species to about Havasu Creek, including the three non-listed native species and seven known aggregations of humpback chub. Non-listed native fish are also well represented in the tributaries: Bright Angel, Shinumo, Tapeats, Kanab, and Havasu creeks (Leibfried et al. 2006), especially during spawning periods.

Below the Little Colorado River, warm water nonnative species such as common carp, channel catfish, and fathead minnow increase in numbers and are most abundant between Shinumo and Diamond creeks (Ackerman 2007). Red shiner and plains killifish are common in backwaters immediately below the Little Colorado River and occur sporadically downstream from that point (Johnstone and Lauretta 2007; Lauretta and Serrato 2006).

The 45-mile reach of the Colorado River from Bridge Canyon to Pearce Ferry is flat and muddy due to high lake elevation sediment deposition on the old river channel. Abundance of flannelmouth suckers, speckled dace, and bluehead suckers are limited due to lack of spawning habitat and large numbers of predators (Valdez 1994; Valdez et al. 1995).

All fish above the Paria River rely heavily on benthic production in the Lees Ferry reach as a food source; food resources for fish in lower reaches are presently being investigated by GCMRC and cooperators. Year-to-year variance in algae, macrophytes, and macroinvertebrates (amphipods, chironomids, oligochaetes and snails) is primarily due to differences in hydrology and sediment discharges from tributaries (Blinn et al. 1994; Shaver et al. 1997). Invertebrate production and abundance has typically decreased during the fall and winter seasons (McKinney et al. 1999, Rogers et al. 2002). Under the No Action Alternative, the food base should continue to demonstrate seasonal patterns of varying abundance dependent on the invertebrate species. Drift magnitudes would continue as at present under record of decision flow constraints.

The razorback suckers in Grand Canyon are old and no reproduction has been documented. Razorback suckers evolved under a water regime featuring high spring flows, and adult suckers would be able to locate refuge areas during the proposed flow and would suffer no adverse effects. There is no indication that young razorback suckers occur in Grand Canyon today. The status of this species is currently under consultation with the Service.

3.1.8 Fish under the Proposal

Effects of the proposal are expected to be comparable to those from other experimental flow tests (Hoffnagle et al. 1999; Makinster et al. 2007; McKinney et al. 1999; Valdez and Hoffnagle 1999). Catch-per-unit effort (CPUE) of humpback chub and flannelmouth sucker did not differ in 1996 pre- versus post-flood periods. Valdez and Hoffnalge (1999) concluded there were no significant adverse effects on movement, habitat use, or diet of humpback chub. The CPUE of plains killifish, bluehead sucker, and fathead minnow decreased following the high flow while the CPUE of speckled dace and rainbow trout increased. There were some shifts in the distribution of fish within the river from prior high flow tests, changes indicative of downstream displacement, but most changes were short-term. Hoffnagle et al. (1999) concluded that catch rates of all species before and after the high flow test were similar to those recorded in previous years. In other words, high flows did not significantly affect fish distributions or abundances through Glen or Grand canyons.

A March high flow test would probably temporarily disrupt native flannelmouth suckers and native bluehead suckers in the area from the dam to the Paria River, but these species were largely unaffected by the 1996 and 2004 floods. Speckled dace is the most common native fish species in the mainstream and in most tributaries. Little is known about population size, distribution, reproductive success, movement, or survival for this species in Grand Canyon, although there were shifts observed in habitat use by speckled dace during the 1996 flood (Valdez and Cowdell 1996).

High flow tests are not expected to significantly impact standing biomass of benthic invertebrates. During the 1996 high flow test, benthic algal and invertebrate standing stocks on cobble bars and in backwaters were reduced immediately following the test but had rebounded to pre-test levels within a few months afterwards (Blinn et al. 1999; Brouder et al. 1999; McKinney et al. 1999). Stabilization of flows during September and October has the potential for maximizing the food base production because of the absence of negative effects brought about from desiccation and dewatering that occurs in the zone of fluctuation. Drift during steady flows may be reduced compared to fluctuating flows (Blinn et al. 1992; Rogers et al. 2002; Shannon et al. 1996). Diminished drift rates will be short-lived and should not affect higher trophic levels, however, and steady flows should allow for greater standing biomass of algal and invertebrate prey overall. Small native fish in low velocity nearshore habitats intended to be positively affected by the steady flows will not be dependent on drift for their food resources.

In terms of species listed under the ESA and under consultation with the Service, Reclamation's conclusion in its biological assessment (Reclamation 2007b) is that the proposed action is not likely to result in the destruction or adverse modification of designated critical habitat for the humpback chub or razorback sucker (the latter should be considered unoccupied critical habitat). Reclamation's finding is that the proposal may affect, and is likely to adversely affect the humpback chub due to the "take" that is likely to result from downstream transport of young humpback chub during the high flow. The long-term effects on humpback chub from creation and improvement of rearing habitats are expected to be positive.

Creation and improvement of backwater rearing habitats expected from the high flow test could expand spatial extent of backwater habitat. Steady flows could result in more hydraulically stable nearshore rearing habitats, slightly warmer temperatures and increased abundance of invertebrate prey items (Reclamation 2007b). Collectively, these effects should result in improved growth and survival of young-of-year humpback chub and other native fish prior to the onset of winter. However, the same benefits could be accrued to predatory or competitive nonnative fish, primarily small-bodied cyprinids which utilize the same backwater habitats as young native fish. Thus, in order for the proposal to be most beneficial to humpback chub and other native fish, it is essential that a non-native fish control plan (coldwater and warmwater) be developed and implemented. This effort was referenced in the Shortage EIS biological opinion as a conservation measure. Progress to this end is being made at this time by USGS, and active management of warm and cold water non-native fish should begin as soon as possible.

Effects of high flows on rainbow trout in the Lees Ferry reach suggest at most a temporary reduction in abundance of smaller sizes classes, but no lasting impacts to the fish population size, size structure, body condition or diet. McKinney et al. (1999) noted a decline in proportion of <152 mm (age 1) fish following the 1996 high flow test suggesting some downstream displacement, but overall found no lasting impacts to either trout abundance or condition. Speas et al. (2004) noted no change in age 1 fish abundance following powerplant capacity flows in 1997 and 2000. Similar results were observed during the 2004 high flow test (AGFD, unpublished).

Lasting effects of stable flows on the rainbow trout population are likely to be minimal. Korman et al. (2005) noted increased growth of young-of-year rainbow trout during periods of relatively stable daily flows, suggesting similar results may be seen due to the proposed action. However, Speas et al. (2004) noted no clearly defined response by the rainbow trout population (including fish growth rates) to low steady summer flows conducted in 2000.

3.1.9 Birds under No Action

More than 30 species of birds have been recorded breeding in the riparian zone along the Colorado River in Grand Canyon (Brown 1989). Most birds in this area nest and forage for insects within the riparian zone and the adjacent upland area. Of the 15 most common riparian breeding bird species, 10 are neotropical migrants that breed in the study area but winter primarily south of the United States-Mexico border. The rest of the breeding birds that use the canyon are year-round residents or short-distance migrants that primarily winter in the region or in nearby southern Arizona (Brown 1989; Brown et al. 1987).

Eleven of the breeding birds in Glen and Grand canyons are considered obligate riparian birds due to their complete dependence on the riparian zone. Obligate riparian birds nesting within the riparian zone include the neotropical migrants Lucy's warbler (*Vermivora luciae*) and Bell's vireo (*Vireo bellii*), two species identified as "high priority" under regional Partners-in-Flight bird plans and area state bird plans. The remaining riparian obligates include common yellowthroat (*Geothlypis trichas*), yellow warbler (*Dendroica petechia*), yellow-breasted chat (*Icteria virens*), black-chinned hummingbird (*Archilochus alexandri*), the endangered Southwestern willow flycatcher (*Empidonax trailii extimus*), and Bewick's wren (*Thryomanes bewickii*), a sometimes permanent resident of Grand Canyon (Spence 2004). Black Phoebe (*Sayornis nigricans*) is a common permanent resident of the canyon with a close association to water (Spence 2004).

Winter songbirds include ruby-crowned kinglet (*Regulus calendula*), white-crowned sparrow (*Zonotrichia leucophrys*), dark-eyed junco (*Junco hyemalis*), and song sparrow (Spence 2004). Spence (2004) found that winter species diversity increased below RM 205. Breeding and wintering songbirds are not expected to be impacted by no action.

The aquatic bird community is almost exclusively made up of winter residents (Spence 2004, Yard and Blake 2004). Thirty-four species of wintering waterfowl along with loons, cormorants, grebes, herons, rails, and sandpipers use the river corridor. Increases in abundance and species richness have been attributed to the increased river clarity and productivity associated with the presence of Glen Canyon Dam (Spence 2004; Stevens et al. 1997a). The majority of waterfowl tend to concentrate above the LCR due to the greater primary productivity that benefits dabbling ducks and greater clarity for diving, piscivorous ducks. Common waterfowl species include American coot (*Fulica americana*), American widgeon (*Anas americana*), bufflehead (*Bucephala albeola*), common goldeneye (*B. clangula*), common merganser (*Mergus merganser*), gadwall (*A. strepera*), green-winged teal (*A. crecca*), lesser scaup (*Aythya affinis*), mallard (*A. platyrhynchos*), and ring-necked duck (*A. collaris*). Other than great blue heron (*Ardea herodias*) and spotted sandpiper (*Actitis macularia*), which are fairly common winter and summer residents along the river, other shorebirds are rare in this area (Spence 2004, Yard and Blake 2004). Aquatic birds would be unaffected by no action.

The southwestern willow flycatcher (SWFL; *Empidonax traillii extimus)* was designated by the Service as endangered in 1995. Critical habitat for SWFL was redesignated in October of 2005 and no longer includes habitat within the action area (Service 2005). In recent years, SWFL have consistently nested along the river corridor in the Grand Canyon as new riparian habitat, primarily tamarisk, has developed in response to altered river flow regimes (Gloss et al, 2005). This expansion of riparian vegetation may have provided additional habitat for the flycatcher, but populations in the upper river corridor persist at a very low level at only one or two sites. Resident birds have been documented between Colorado RM 47 (RKM 76) and RM 54 (RKM 87), at RM 71 (RKM 114) (Sogge et. al. 1995, Tibbets and Johnson 1999, 2000; Unitt 1987), and at RM 259 (RKM 417). Population numbers have fluctuated between 5 breeding pairs and three territorial, but non-breeding pairs in 1995 to one single breeding pair in more recent years. 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. In 2006 two nests were detected in the 2006 breeding season at the inflow area to Lake Mead (Koronkiewicz 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.

The SWFL is an insectivorous riparian obligate. It breeds and forages in dense, multistoried riparian vegetation near surface water or moist soil (Whitmore 1977; Sferra et. al. 1995) along low gradient streams (Sogge 1995). Nesting in the Grand Canyon typically occurs in non-native tamarisk approximately 13-23 ft (4-7 m) tall (Tibbetts and Johnson 1999). Resident birds arrive in Grand Canyon in May. Under no action SWFL are not expected to be impacted.

The bald eagle (*Haliaeetus leucocephalus*) was listed as endangered under the ESA in 1967 and down-listed to threatened in 1995. Additionally, it was listed as endangered under the California Endangered Species Act in 1971. It is also a species of special concern in Arizona. The bald eagle was proposed for federal delisting in 1999 (Service 1999) and was delisted July 9, 2007 (Service 2007).

A wintering bald eagle concentration of bald eagles was first observed in Grand Canyon in the early 1980s and numbers have increased dramatically since 1985 (Brown and Stevens 1991, 1992; Brown et al. 1989). Territorial behavior, but no breeding activity, has been detected. This wintering population has been monitored since 1988 and it occurs throughout the upper half of the Grand Canyon (in Marble Canyon). Density of the Grand Canyon bald eagles during the winter peak (late February and early March) ranged from 13 to 24 birds between Glen Canyon Dam and the Little Colorado River confluence from 1993 to 1995 (Sogge et al. 1995). A concentration of wintering bald eagles often occurs in late February at the mouth of Nankoweap Creek (RM 52, RKM 83), where large numbers of rainbow trout spawn (Gloss et al. 2005). From 1986 to 1995, maximum daily eagle counts ranged from 4 to 26, with the number of eagles varying directly with the abundance and availability of trout in the creek (Brown and Stevens 1992). Under no action Bald Eagles are expected to benefit from current conditions and no changes are expected.

Following successful recovery efforts, the American peregrine falcon (*Falco peregrinus*) was removed from the endangered species list in 1999. The Endangered Species Act requires a minimum of five years of post-delisting monitoring to confirm recovery. Although peregrine falcons are uncommon year-round residents in the action area, the population has gradually increased since the 1970s (Brown 1991). In recent years, as many as twelve active eyries have been found in the canyon. Nest sites are usually associated with water. In Grand Canyon, common prey items in summer include white-throated swift (*Aeronautes saxatalis*), swallows, other song birds, and bats (Brown 1991), many of which feed on invertebrate species (especially Diptera) that emerge out of the Colorado River (Stevens et al. 1997b). In winter, a common prey item is waterfowl.

Under the no action alternative no effects are expected to the bird community in Glen and Grand canyons.

3.1.10 Birds under the Proposal

Many birds using the Colorado River below Glen Canyon Dam depend on the aquatic food chain associated with green alga (*Cladophora glomerata*). The proposed flood may increase the downstream drift of *Cladophora* and associated organisms, but *Cladophora* has withstood much higher flows for longer duration (e.g. 1983-1986), so no long-term adverse impact is anticipated. Although other algae and submerged plants use sand or silt as substrate and may be temporarily lost, they are expected to recover relatively quickly if there is no additional disturbance.

A March flood would probably have no negative effect on the bald eagle because wintering and migrant bald eagles have largely left the Grand Canyon region by the time of the proposal (Stevens et al. 1997b).

Birds were unaffected by prior high flows so no effects are expected from the proposal. Most wintering waterfowl have left the canyons by the time of the flood and would not be affected by it. However, mallard, mergansers, late migrating gadwall, and American widgeon may be present (Stevens et al. 1997). These birds are ground nesters and a spring flood might impact them, although adequate waterfowl nest cover exists at higher elevations. Furthermore, the timing of the high flow test is prior to the primary nesting period for all these species.

The SWFL are not found in the action area during the proposed high-flow test so no effects are expected. As with other endangered species, Reclamation and the Service are currently consulting on effects to the SWFL. The steady flows during September and October are also not expected to affect SWFL. Reclamation's finding for the proposed action is "may affect, is not likely to adversely affect" the SWFL. Numbers of bald eagles would continue to fluctuate around Nankoweap Creek, with or without the proposal, and no effects are anticipated.

3.1.11 Mammals under No Action

Within Grand Canyon National Park 34 species of mammals have been found (Carothers and Aitchison 1976; Frey 2003, Kearsley et al. 2003, 2006; Warren and Schwable 1986). Of these mammals only three are obligate aquatic mammals—beaver (*Castor canadensis*), muskrat (*Ondatra canadensis*), and river otter (*Lutra canadensis*). Despite occasional reported sightings of river otters in Grand Canyon, no reliable documentation exists since the 1970s (Kearsley et al. 2006). River otters are classified as extirpated and muskrats are considered extremely rare.

An increase in the population size and distribution of beaver in Glen and Grand canyons has occurred since the construction of the dam, likely due to the increase in riparian vegetation and relatively stable flows (Kearsley et al. 2006). Beavers cut willows, cottonwoods, and shrubs for food and can significantly affect riparian vegetation. Beaver in Grand Canyon excavate lodges in the banks of the river with the entrance located underwater and a tunnel leading up under the bank to a living chamber. Beaver are affected by fluctuating water levels since their lodges can become flooded by increases in water levels or the entrances can be exposed by falling water levels. Both situations can expose beaver to increased predation since they are forced to abandon the lodge if flooded or predators can enter the den if the opening is exposed.

Muskrats in Grand Canyon also construct and use bank dens or old beaver dens (Perry 1982) and can be affected by fluctuating water levels. Impacts to muskrats of current flow fluctuations from Glen Canyon Dam are unknown but could result in increased stress and exposure to predation (Perry 1982).

Bats in the Grand Canyon typically roost in desert uplands, but forage on abundant insects along Lake Powell, the Colorado River and its tributaries. Bats would continue to forage on the insects present in the riparian corridor.

3.1.12 Mammals under the Proposal

Beaver typically mate from January through March and the kits are born in March to June (Hill 1982). Young-of-year beaver occupy the lodge with the parents until their second year, when they leave their natal range and search for unoccupied habitat to colonize (Hill 1982). Because the proposal includes a relatively high flow that beaver have not experienced in several years, it is likely that the high flow would temporarily disperse sub-adult and adult beaver. Kits born prior to the high-flow-test would likely be killed due to drowning because they would be unable to disperse from the lodge. Steady flows in September and October would have little to no effect on beaver.

Muskrats in Grand Canyon would similarly be dispersed from their bank dens by high flows during March. However, muskrats rarely give birth before May (Perry 1982), and they are polyestrous and capable of producing multiple litters within the year. Muskrats would not be affected by steady flows in September and October.

Bats could be indirectly affected by the proposal. Insect production from steady flows in September and October could be altered, which might have an impact on foraging by bats. However, any change in insect abundance is not expected to have long-term consequences and will likely be minor.

3.2 Cultural Resources

Cultural resources include prehistoric and historic districts, sites, buildings, structures, and objects. The term includes sites of traditional religious and cultural significance to Indian tribes and communities. Section 106 of the National Historic Preservation Act of

1966, as amended, requires federal agencies to take into account the effects of their undertakings on those historic properties listed on or eligible for inclusion in the National Register of Historic Places. Cultural resources also include sacred sites as defined by Executive Order 13007.

3.2.1 Cultural Resources under No Action

Adverse effects of ongoing operations are currently being mitigated through a long-term treatment plan. Archaeological data recovery efforts are underway. No adverse effects to sacred sites have been documented as a result of dam operations and none are expected during through 2012.

3.2.2 Cultural Resources under the Proposal

Observations after the 1996 and 2004 experimental high flows suggest that releases above powerplant capacity may have resulted in loss of integrity to some National Register-eligible properties. One archaeological site in Glen Canyon may be adversely affected by a 41,500 cfs flow. This site is currently included in a data recovery contract and mitigation will be accomplished prior to the proposed experimental release. During consultation, the Hopi Tribe and other tribes have expressed concern with high flows impacting the salt mines. The Hualapai Tribe has expressed concern with native vegetation, but overall, the tribes believe variable flows benefit sacred sites and resources of tribal concern. Reviewing all available data, no adverse effects to cultural resources are expected from the proposal. Consultations under section 106 of the National Historic Preservation Act and E.O. 13007 are underway.

3.3 Socioeconomic Resources

Social and economic conditions were examined to determine whether the proposed action would affect them. The indicators reviewed include environmental justice (E.O. 13175), Indian trust assets, population growth and housing, public health (focusing on flood risk), recreation, the regional economy (focusing on economic cost associated with altering hydropower produced), and traffic and transportation.

3.3.1 Hydropower

One of the primary purposes of Glen Canyon Dam, as stated in 43 USC § 620, is the generation of hydropower or electric power. Glen Canyon Dam and Powerplant are part of the Colorado River Storage Project (CRSP), a federal project from which Western Area Power Administration (Western) markets power. The CRSP also directs that Glen Canyon Dam – along with other facilities be "operated in conjunction with other Federal powerplants … so as to produce the greatest practicable amount of power and energy that can be sold at firm power and energy rates." Western's Salt Lake City Area Integrated Projects Office (SLCA/IP) annually markets more than 4 billion kilowatt-hours (kWhr) from Glen Canyon Powerplant. The power is sold to end-use consumers across Arizona, Colorado, New Mexico, Nevada, Utah, and Wyoming. The power from Glen Canyon represents about three percent of the summer capacity in this six-state region. (Harpman 1999:351).

Demand for electric energy is known as "load." Load varies on a monthly, weekly, daily, and hourly basis, with the highest demand for electricity in the winter and summer when heating and cooling needs, respectively are greatest. Load is less in the spring and fall (Harpman 1999:352). The period when demand is highest is called "on peak." In the Glen Canyon service area, the on peak period is from 7:00 a.m. to 11:00 p.m., Monday through Saturday Mountain Standard Time (MST). All other hours are off peak. During normal operations at Glen Canyon Dam, water releases fluctuate from a low base flow during off peak hours to a high flow that corresponds to the largest electrical demand, subject to the limitations established in the 1996 ROD.

The maximum amount of electric energy than can be produced by a powerplant at a single moment in time is its "capacity," measured in megawatts (MW). Electrical energy or generation is the capacity in MW over a period of time or megawatt-hours (MWh). The rate at which a powerplant can change from one generation level to another is called a "ramp rate," measured in change in cubic feet per second (cfs) over a one-hour period.

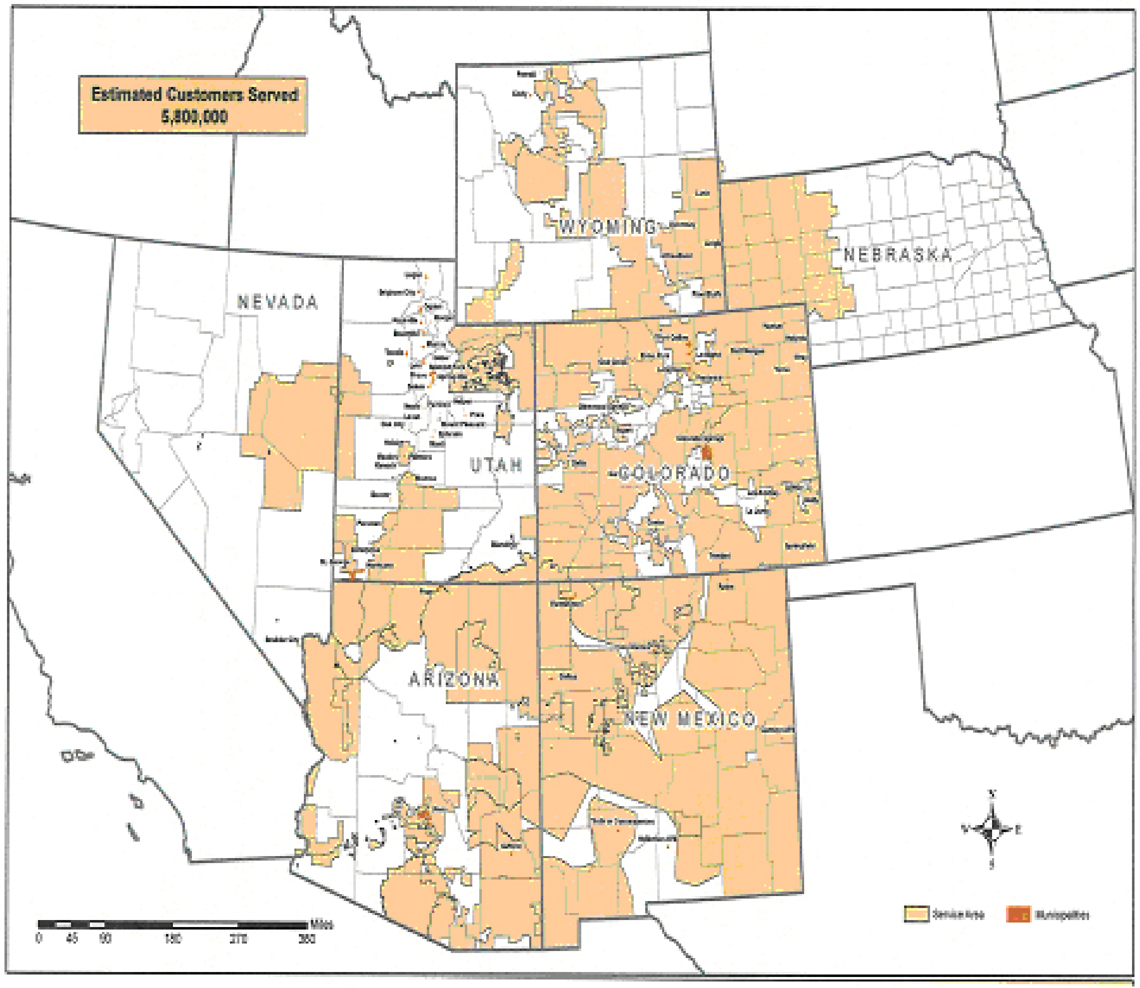

FIGURE 2 Colorado River Storage Project management center service territory. Map courtesy of Western.

3.3.1.1 Effects on Hydropower under No Action

Methods, models, and the amount of hydropower expected to be generated through 2012 are described in Reclamation (2007a:4-251-4-278). The description of the preferred alternative in that EIS serves as the description of hydropower under no action in this environmental assessment. If Reclamation takes no action, the selected alternative from the 2007 Shortage EIS (Reclamation 2007a) predicted an average annual energy generation of about 4.25 GWh with a present value 2008 – 2026 of $7.364 billion. This establishes a baseline against which effects of the proposal may be compared.

3.3.1.2 Effects on Hydropower under the Proposal

The economic effect of past experiments has been measured in "avoided costs," essentially the opportunity cost of the experiment. The avoided cost is the difference between the cost of satisfying the demand for electric energy with and without operating the hydropower plant (Harpman 1999:353). During steady flows, the ability to fluctuate water releases to match electrical demand ceases. This means that during periods of low electrical demand power must be sold at a reduced price and during high electrical demand power must be bought at an increased price on the spot market to meet customer contracts. When the volume of water released from the dam is greater than the capacity of the powerplant, the outlet works must be used to release flows. The powerplant is bypassed and water is "spilled" through the outlet works where it is unavailable to produce electric energy. During high flows, more power may be generated than would have been the case without the experiment, depending on the circumstances of the release.

Based on projections by Western of additional purchases required to meet the SLAC/IP contractual requirements, the projected total cost of the high flow test for water year 2008 is $4.1 million. This includes the effect of moving water from the summer months that have large electrical demand and high prices to “shoulder” months where electrical demand and prices are lower. Also, projections from the USGS are that scientific studies in 2008 and 2009 related to the experimental March high flow test would be another $3.7 million, resulting in a total cost for the high flow test of about $8 million. Replacement of power foregone through the experiment would likely come from carbon-producing sources such as coal or gas fired generation.

The steady flow portion of the experiment during September and October, 2008 - 2012 have a projected annual power replacement cost for both months of about $815,000 (Clayton Palmer personal communication). No adjustment of monthly water volumes occurs during the subsequent years of the experiment, other than potential minor adjustment of September release volumes. Additional scientific studies will be planned as part of the AMP for the succeeding years for fall steady flows but costs for these studies have not yet been determined.

Due to the reduction in annual energy generation of about 41 GWHr from the high flow test, it is estimated that replacement by carbon-producing power sources would produce additional carbon emissions of about 45,800 tons, or approximately 0.02 percent of the 261,687,000 tons annually emitted from coal-fired powerplants in the six-state region (eGRID 2006).

3.3.2 Recreation

Recreational resources of concern are the trout fishing and boating from Lees Ferry to below Glen Canyon Dam, whitewater boating through Grand Canyon, and the Hualapai Indian tribe's boating enterprise at the western end of Grand Canyon and into Lake Mead. No effects are expected within Lake Mead.

3.3.2.1 Fishing under No Action

The Colorado River from below the dam to Lees Ferry is a blue ribbon rainbow trout fishery, attracting anglers from the state and abroad. Most angling occurs from boats or is facilitated by boat access, including guide services, but some anglers wade in the area around Lees Ferry. Based on input from Lees Ferry fishing guides, the quality of the fishery has fallen and angler use has declined recently. In 2006, angler use was approximately 13,000 user days (Henson 2007). The monthly distribution of angling use is shown in Figure 3. The heaviest angling use in 2006 occurred in April.

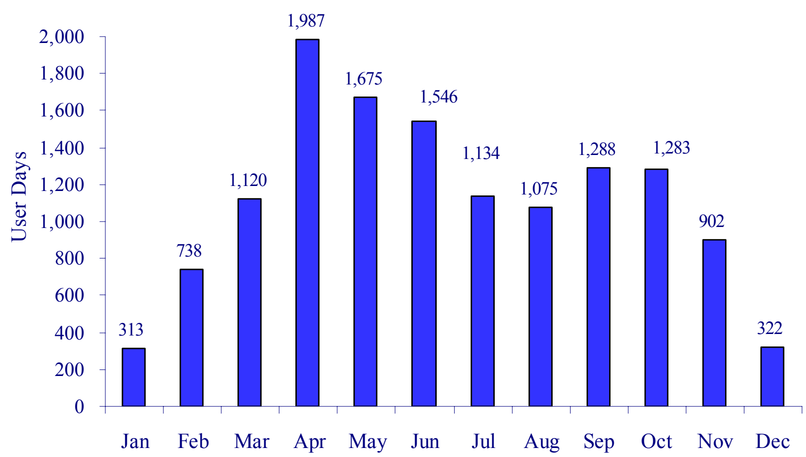

FIGURE 3 Fishing user days by month, 2006 in the Lees Ferry reach.

3.3.2.2 Fishing under the Proposal

Most anglers have elected not to fish during previous high flow tests. Approximately three days out of March, or 108 user days, would be lost due to the experiment. For those wading anglers who elected to fish during the event, rapid increases in river stage places them at risk, if they are unaware and unprepared. Advance publicity, onsite warnings provided by management agencies, and the obvious nature of the flow would allow anglers to make personal assessments of danger during this period.

During 1996 and 2004, most anglers did not or could not fish during the high release. For those who did, angler success was reduced. It is likely that the effects of a 2008 high flow test will be similar, although shorter in duration.

3.3.2.3 Boating under No Action

The 15-mile reach between Glen Canyon Dam and Lees Ferry is used by anglers who launch from Lees Ferry and visitors who take one day scenic raft trips offered by a NPS concessionaire. These commercial scenic raft trips launch at the base of Glen Canyon Dam. Day use rafting in 2006 amounted to more than 44,000 user days (Henson 2007), as shown in Figure 4. Most day-use rafting occurs during the summer; June is typically the peak use month.

Since 2007, the NPS's (2006) Colorado River management plan has governed recreational use from the Lees Ferry reach down to Diamond Creek and upper Lake Mead. Under this plan, total whitewater boating use increased and annual distribution of use was altered. Currently, only estimated river use data are available, with Figure 5 illustrating the 2007 distribution of expected Grand Canyon whitewater boating use for trips starting at Lees Ferry (Sullivan 2007).

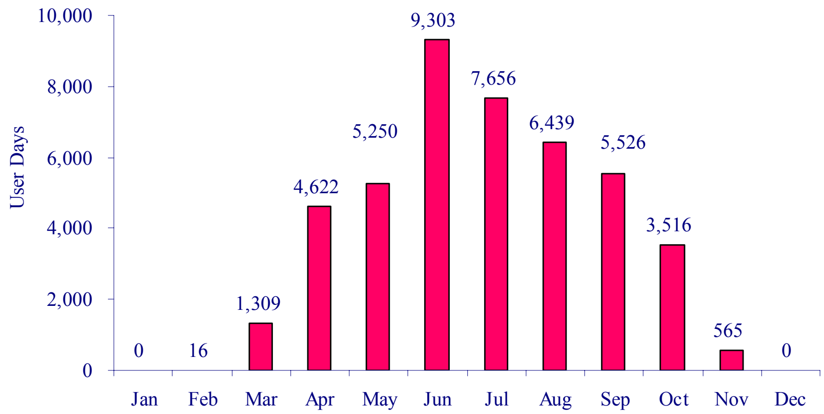

FIGURE 4 User days for day-use boaters, Lees Ferry reach, 2006.

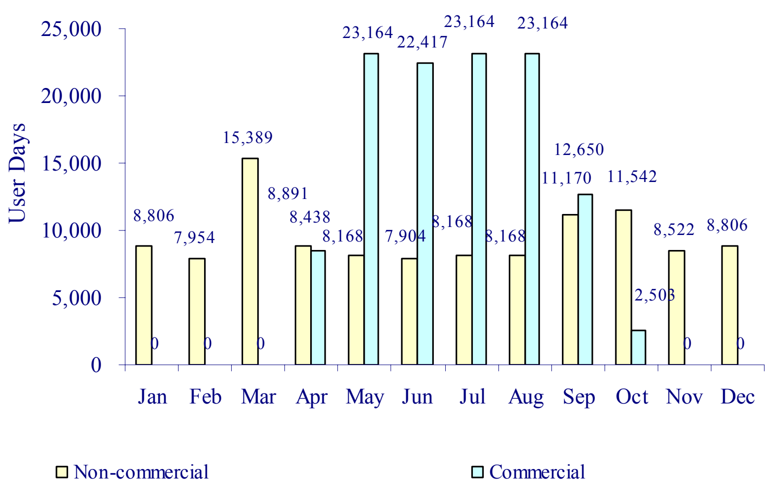

FIGURE 5 Whitewater boating user days, Grand Canyon, 2006.

Other characteristics of whitewater boating through Grand Canyon that may be affected by the proposal include wilderness values and safety. Wilderness characteristics of whitewater boating trips may be influenced by daily river fluctuations and by the conditions of beaches (Bishop et al. 1987; Shelby et al. 1992; Welsh et al. 1995). With no action taken by Reclamation, flows would vary within the constraints of the 1996 record of decision and daily change in flow would be no greater than 8,000 cfs. Reduced daily fluctuations of the 1996 record of decision makes the wilderness characteristics of a whitewater boating trip relatively high, but declines in sandbar area and volume reduce the overall recreational experience.

Whitewater boating safety depends on the type of craft, skill of the operator, the location, flow levels, and timing and variation of river stage (Brown and Hahn 1988; Jalbert 1992, 1996). Low flows make passage through some rapids difficult or impossible. High flows may create additional risks of flipping or capsizing.

The Hualapai Indian Reservation marks the southwestern end of the affected environment for this action. Diamond Creek is at about RM 227 and is a popular take out for many boating trips that begin at Lees Ferry. It is also the starting point for those commercial and noncommercial trips that originate on the Haulapai Indian Reservation. Private parties launching at this site pay launch and user fees to the Hualapai Indian Tribe. Commercial day and overnight trips run by Hualapai River Runners begin here and end at Quartermaster (RM 260) or Lake Mead (RM 277). The overnight trips make use of campsites (beaches) along the southern bank of the river (at RM 245) where the Hualapai Tribe has provided a composting toilet. There is also a concession pontoon boat operation, which uses helicopters to transport visitors into the canyon below, where they then walk down to a boat dock, and take a 20-minute, flat-water, river ride which launches and returns to Quartermaster.

Recreational use below Diamond Creek is managed in accordance with the NPS's new management plan. In 2007, the whitewater rafting season ran approximately from March 15 through October 31. During this past season, the Hualapai River Runners took over 19,000 visitors rafting on the Colorado River. The Hualapai River Runners pontoon boat operation is limited to five boats with a daily limit of 480 passengers on the water at any one time.[5] Approximately 175,200 passengers are expected annually.

3.3.2.4 Boating Under the Proposal

During the proposed 2008 high flow, no boats would be allowed to launch immediately below the dam. Day use rafting trips could still be launched from Lees Ferry and boats could move upstream under power. According to NPS estimates, approximately 190 boating user days would be lost during the proposed high flow. During the remainder of the year, day use rafting operations would be unaffected.

For the high flow portion of the proposal, the NPS studied river running risks and injuries during the 1996 experiment (Jalbert 1996). Jalbert reported that 45,000 cfs flows

[5] This limit could be raised to 600 passengers/day if monitoring reveals no adverse impacts to resources.

posed no greater risk of boating accidents than lower flows, in fact, the high flow enhanced visitor experience. She found the effects of the high flow on boaters were variable with location: the size of some waves and holes increased, others washed out.

Judging by NPS permit data, there are likely to be about 35 white-water boating groups on the river during a March high flow. The NPS is working closely with these permit holders to provide visitation flexibility to minimize adverse visitor impacts. Boaters on these trips would need to be cautious in selecting campsites, but the duration of the experiment relative to the length of a typical non-motorized trip (18 days), suggests effects on boaters would be limited. While fluctuations have been reported to decrease wilderness values, past high flows had beneficial effects on boater experiences.

The fall steady flows should have no measurable effect on visitor experiences in the canyon. As shown by Figures 4 and 5, visitation is relatively low during these months and the magnitude of change from no action should have no measurable effect on visitor experience.

3.3.2.5 Net Economic Use Value under No Action

Net economic use value is a measure of the value over and above the costs of participating in a recreation activity. The total net economic value is related to the number of recreationists who participate in each activity, the time of year in which they participate, and the value of each trip taken (King and Mazzotta 2007; National Research Council 2004).

The net economic value of recreation in Grand Canyon was estimated for a number of different flow scenarios by Bishop et al. (1987) and reported in Reclamation (1995). Hammer (2002) later estimated the net economic value of whitewater boating using the (secondary) data collected by Stewart et al. (2000), and Hall and Shelby (2000).

Regional economic activity refers to expenditures and their impacts within the study area. River-based recreational users, such as anglers and white-water boaters, spend large sums of money in the region purchasing gas, food, lodging, guide services, and outdoor equipment during their visits. While these expenditures do not represent a benefit measure, they nonetheless are important because they support local businesses and provide employment for local residents.

The annual regional economic activity that results from nonresident anglers, whitewater boaters, and day rafters who visit Glen and Grand canyons has been estimated (Reclamation 1995) at approximately $25.7 million (1995 nominal dollars). Douglas and Harpman (1995) estimated that Glen Canyon and Grand Canyon recreational use in the region comprised of Coconino and Mojave Counties supports approximately 585 jobs. A more recent study by Hjerpe and Kim (2003) estimated that recreational use in Coconino County supports approximately 394 jobs.

3.3.2.6 Net Economic Value under the Proposal

The net effect of the proposed high flow on regional economic activity is likely to be negative due to the loss of angling and boating user days in the Lees Ferry reach. With the high flow test preventing three to five days of use in March, incomes of local fishing guides and day use rafting guides and companies would be decreased. The high flow test would also result in a reduction in local expenditures by anglers and day use rafters of approximately $75,000 - $100,000 and $15,000 respectively (Norm Henderson personal communication). As a result, local hotel and restaurant revenues would be reduced during or following the test. In response to concerns expressed by local guides and business owners, Reclamation will assist in implementing the measures described in section 2.2.1. The fall steady flows should have no measurable effect on the economic values of Lees Ferry angling or boating.

No net change in whitewater boating use or significant change in trip value in the Lees Ferry reach is expected to result from the proposed high flow test or the steady fall flows. Therefore, net economic value is expected to be reduced less than one percent of the annual total revenues.

3.3.3 Indian Trust Assets

Indian trust assets are legal interests in property held in trust by the US government for Indian tribes or individuals. Examples of such resources are lands, minerals, or water rights. Review of the alternatives revealed that water rights would not be affected, but given that the action area is bounded on the east by the Navajo Indian Reservation and on the south by the Hualapai Indian Reservation, these tribes were consulted regarding potential effects of the proposal on their trust assets and reserved rights.

During consultation, both tribes were concerned that high flows could affect trust lands. Based on the 1883 Executive Order establishing the Hualapai Indian Reservation, the northern boundary of the reservation is the high water mark of the Colorado River (NPS 2005, Appendix M). Most of the Navajo Indian Reservation is more distant from the river bank, but the tribe is still concerned with adverse impacts of the proposal.

3.3.4 Environmental Justice

To implement Executive Order 12898, *Environmental Justice in Minority Populations and Low Income Populations*, the Council on Environmental Quality (1997) instructs agencies to determine whether minority or low-income populations or Indian tribes might be affected by a proposal, and if so, whether there might be disproportionately high and adverse human health or environmental effects on them.

While the affected area is bounded by the Navajo Indian Reservation and the Hualapai Indian Reservation, hydropower is the only environmental justice issue identified in this environmental assessment. The issue arises because increases in energy costs could disproportionately affect low-income households (defined by Bureau of the Census annual statistical poverty levels; Current Population Reports, P-60) because of their greater expenditures on energy than higher-income households). Appendix A lists CRSP power customers by state. Table 5 lists households by state in 2005 and 2006 requiring federal energy assistance. While CRSP power accounts for less than four percent of the total power in these states, Table 5 provides some indication of the number of tribal[6] or low-income households requiring energy assistance in the past and how these numbers might increase into the future.

3.3.5 Environmental Justice under No Action

The need for federal energy assistance continues to grow rapidly due to a combination of rising energy costs and other economic factors affecting the US economy (Wolfe 2006, 2007). Table 5 shows the number of households in states served with CRSP power that have required federal heating assistance in years 2005 and 2006. As shown, the minimum increase is 12 percent, the maximum is 34 percent.

TABLE 5 Number of households per state requiring heating assistance, 2005 to 2006

State	2,005	2006	% Increase
Arizona	18,563	24,824	33.7
Colorado	96,127	107,500	11.8
Nebraska	32,514	39,000	19.9
Nevada	17,557	22,177	26.3
New Mexico	55,685	67,000	20.3
Utah	34,647	40,000	15.5
Wyoming	9,550	11,653	22.0

Source: Wolfe 2006.

3.3.6 Environmental Justice under the Proposal

The proposal might increase the number or percent of households seeking energy assistance from the federal government if the action results in an increase in the CRSP power rate. This effect would likely be short-term, but it could become long-term if the experiment results in a permanent change in the management of Glen Canyon Dam and the flow regimes of the Colorado River. In comparing the effects of the proposal with no action, rising electric costs would create a slight, but disproportionately adverse economic impact among low-income households lasting through fall of 2012. The timing of fall steady flows was selected to minimize impacts on low-income households to the extent practicable, while benefiting natural resources. As stated by the Council on Environmental Quality (1997:10) and their regulations implementing NEPA, the identification of a disproportionately high and adverse economic effect on a low-income or minority population or Indian tribe does not preclude a proposed agency action from being implemented, nor does it necessarily compel a conclusion that a proposed action is environmentally unsatisfactory and require preparation of an EIS.

[6] Western markets CRSP power to 24 tribes or tribal subdivisions located in New Mexico, 18 in Arizona, 4 in Nevada, 4 in Utah, 2 in Colorado, and 1 in Wyoming (Appendix A).

3.4 Other NEPA Considerations

In addition to reviewing direct, indirect and cumulative effects on resources in the preceding sections, section 102(2)(C) of NEPA requires consideration of unavoidable impacts, the relationship between short-term uses of the environment and the maintenance and enhancement of long-term productivity, and any irreversible and irretrievable commitments of resources. Bypassing the powerplant during the high flow test in 2008 would cause an unavoidable loss of power generation and a reduction of fishing guide and scenic day use rafting revenues. Steady flows in the fall would cause an increase in replacement power costs. However, timing of these elements of the proposal was designed to minimize economic and environmental justice impacts, while maintaining and enhancing the long-term productivity of the local environment.

Some endangered Kanab ambersnail could be inundated or displaced downstream under the proposed flood; however, these actions will be minimized or mitigated through the actions described in section 2.2.1. Non-essential foraging habitat for southwestern willow flycatcher might be impacted. However, no irreversible, long-term impact on any of these snail or bird populations is anticipated. Juvenile trout and young of year humpback chub could be displaced downstream and lost, but again, the effects to the long-term condition of the populations are not considered irreversible.

4.0 List of Agencies and Persons Consulted

Following requirements of 40 CFR 1508.9(b), this section lists agencies and persons consulted regarding this proposed federal action. Table 6 lists federally-recognized Indian tribes who have been or are being consulted regarding the proposal. On January 10, 2008, one multi-tribal meeting was held regarding the proposal. Formal government-to-government consultation letters and follow-up phone calls and face-to-face meetings with tribes listed in Table 6 are in progress. Table 7 lists agencies and persons and outside Reclamation who were consulted during the preparation of this environmental assessment. Of particular note is a conference call held on January 17, 2008 with members of the Glen Canyon Dam Adaptive Management Program. One meeting was held with Lees Ferry fishing guides on December 2, 2007. While individual recipients are not listed, this environmental assessment will be mailed to over 200 agencies, organizations and individuals concerned with dam operations.

TABLE 6 Federally-recognized Indian tribes being consulted

Federally Recognized Indian Tribe
Havasupai Tribe of the Havasupai Reservation, Arizona
Hopi Tribe of Arizona
Hualapai Indian Tribe of the Hualapai Indian Reservation, Arizona
Kaibab Band of Paiute Indians of the Kaibab Indian Reservation, Arizona
Las Vegas Tribe of Paiute Indians of the Las Vegas Indian Colony, Nevada
Moapa Band of Paiute Indians of the Moapa River Indian Reservation, Nevada
Navajo Nation, Arizona, New Mexico & Utah
Paiute Indian Tribe of Utah
San Juan Southern Paiute Tribe of Arizona
Yavapai-Apache Nation of the Camp Verde Indian Reservation, Arizona
Zuni Tribe of the Zuni Reservation, New Mexico

TABLE 7 List of federal/state agencies and private organizations consulted

Agencies
Arizona Department of Water Resources
Arizona Game and Fish Department
Bureau of Indian Affairs
Colorado Division of Water Resources
Colorado River Board of California
Colorado River Commission of Nevada
Colorado River Energy Distributors Association
Department of Energy, Western Area Power Administration
Federation of Fly Fishers, Northern Arizona Flycasters
Grand Canyon River Guides
Grand Canyon Trust
Grand Canyon Wildlands Council
National Park Service
New Mexico Interstate Stream Commission
US Fish and Wildlife Service
Utah Associated Municipal Power Systems
Utah Division of Water Resources
Wyoming State Engineer

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6.0 Appendix A

Appendix A. CRSP power customers by state

Arizona State	Colorado State	Nebraska State
Arizona Electric Power Coop	Aspen City	Tri-State Nebraska:
ED2 Pinal	Center City	Northwest Rural Public PD
Mesa City	Colorado Springs Utilities	Panhandle REA
Ak-Chin Indian Community	Delta City	Chimney Rock Public PD
Chandler Heights ID	Fleming City	Wheat Belt Public PD
Cocopah Indian Tribe	Frederick City	The Midwest Electric Cooperative Corp.
Colorado River Agency (BIA)	Fort Morgan City	Roosevelt Public PD
Colorado River Indian Tribes	Glenwood Springs	
ED3-7	Grand Valley Rural	Nevada State
Fort Mohave Indian Tribe	Gunnison City	Colorado River Commission of Nevada:
Fort McDowell Yavapai Nation	Haxtun City	Valley EA
Gila River Indian Community	Holy Cross Electric Cooperative	Overton PD
Havasupai Tribe	Holyoke	Boulder City
Hualapai Tribe	Intermountain Rural Electric Association	AMPAC
Luke AFB	Lamar Utilities Board (ARPA)	Duckwater Shoshone Tribe
Maricopa County Municipal WCD	Oak Creek City	Ely Shoshone Tribe
Navopache Electric	Platte River Power Authority:	Las Vegas Paiute Tribe
Navajo Tribal Utility Authority	Ft. Collins	Mt. Wheeler Power
Ocotillo ID	Loveland	Yomba Shoshone Tribe
Page City	Longmont	
Pascua Yaqui Tribe	Estes Park	Wyoming State
Quechan Indian Tribe	Pueblo Army Depot	Bridger Valley EA
Queen Creek ID	Southern Ute Indian Tribe	Torrington City
Roosevelt ID	Tri-State Colorado:	Tri-State Wyoming:
Roosevelt WCD	Delta-Montrose Electric Assoc.	Big Horn REC
Safford City	Empire Electric Assoc.	Carbon Power & Light
Salt River Pima-Maricopa Indian Community	Gunnison County Electric Assoc.	Garland Light & Power Co.
Salt River Project	Highline Electric Assoc.	High Plains Power
San Carlos Apache Tribe	K.C. Electric Assoc.	High West Energy
San Carlos IP (BIA)	LaPlata Electric Assoc.	Niobrara Electric Assoc.
San Tan ID	Morgan County REA	Wheatland REA
Thatcher City	Mountain Parks Electric, Inc.	Wyrulec County
Tohono O'Odham Utility Authority	Mountain View Electric Assoc.	Willwood City
Tonto Apache Tribe	Poudre Valley REA	Wind River Indian Reservation
Welton-Mohawk ID	San Isabel Electric Assoc.	Wyoming Municipal Power Agency:
White Mountain Apache Tribe	San Luis Valley REC	Cody
Yavapai Apache Nation	San Miguel Power Assoc.	Powell
Yavapai Prescott Indian Tribe	Sangre de Cristo Electric Assoc.	Ft. Laramie
Yuma Proving Grounds	Southeast Colorado Power Assoc.	Guernsey
	United Power	Lingle
	White River Electric Assoc.	Lusk
	Y-W Electric Assoc.	Pine Bluff
	Ute Mountain Ute Tribe	Wheatland
	Wray City	
	Yampa Valley REA	
	Yuma City	

Key: AFB=Air Force Base; Assoc=association; ED=electric district; ID=irrigation district; WCD=water conservation district; continued on next page.