# GLEN CANYON DAM
# Beach/Habitat-Building Test Flow

*FINAL ENVIRONMENTAL ASSESSMENT*
*and*
*FINDING OF NO SIGNIFICANT IMPACT*

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U.S. Department of the Interior
Bureau of Reclamation
Upper Colorado Region

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United States Department of the Interior
Bureau of Reclamation

Upper Colorado Region
Salt Lake City, Utah

# FINDING OF NO SIGNIFICANT IMPACT

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# BEACH/HABITAT-BUILDING TEST FLOW

Recommended: ______________________________ __________
Regional Environmental Officer — Date

Approved: ______________________________ __________
Regional Director — Date

## FINDING OF NO SIGNIFICANT IMPACT

### Beach/Habitat-Building Test Flow
### Glen Canyon Dam, Arizona

In accordance with the National Environmental Policy Act of 1969, as amended, and the Council on Environmental Quality's Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act (40 CFR Parts 1500-1508), the Bureau of Reclamation has determined that an environmental impact statement (EIS) is not required for implementing a test of a beach/habitat-building flow from Glen Canyon Dam, Arizona.

### BACKGROUND

On July 27, 1989, the Secretary of the Interior (Secretary) directed that an EIS be prepared on the effects of Glen Canyon Dam operations on environmental and cultural resources on the Colorado River in Glen and Grand Canyons. The final EIS was filed with the Environmental Protection Agency on March 21, 1995. However, in order to comply with the Grand Canyon Protection Act of 1992 (Public Law 102-575, Section 1804 b), the Secretary cannot implement a record of decision until the General Accounting Office has completed an audit of ". . . the costs and benefits to water and power users and to natural, recreational, and cultural resources resulting from management policies and dam operations identified pursuant to the environmental impact statement . . .." It now appears that this audit will not be completed until late in calendar year 1996.

The preferred alternative analyzed in the final EIS includes as an integral element beach/habitat-building flows, which are described on page 40 of that document as ". . . scheduled high releases of short duration designed to rebuild high elevation sandbars, deposit nutrients, restore backwater channels, and provide some of the dynamics of a natural system." The final EIS states that a test flow ". . . would be conducted prior to long-term implementation of this element to test the predictions made in chapter IV."

Several conditions make the spring of 1996 an opportune time to conduct this test flow. The riverine system has not experienced flows of the proposed magnitude for almost a decade, and the limitations of the Interim Operating Criteria have accelerated the filling of backwaters and eddies with sediment. Releases in water year 1996 from Glen Canyon Dam are expected to be greater than the minimum required; therefore, the water required for the test could be more easily scheduled. Finally, a cadre of scientists who have gained much experience in Glen and Grand Canyons over the last 12 years is available to monitor and evaluate this experiment.

## PROPOSED ACTION

The test of the beach/habitat-building flow would begin on or about March 22, 1996. The first 4 days would consist of a constant 8,000-cubic-foot-per-second (cfs) flow. On or about March 26, 1996, releases would be increased at a maximum rate of 4,000 cubic feet per second per hour (cfs/hr) until a maximum flow of 45,000 cfs is reached. Flows would be held essentially constant at 45,000 cfs for 7 days. On or about April 2, 1996, releases would be decreased to 8,000 cfs in the following manner:

- Between the maximum release and 35,000 cfs, releases would decrease at a maximum rate of 1,500 cfs/hr.
- Between 35,000 cfs and 20,000 cfs, releases would decrease at a maximum rate of 1,000 cfs/hr.
- Between 20,000 cfs and 8,000 cfs, releases would decrease at a maximum rate of 500 cfs/hr.

This staggered downramping would mimic the reduction of flow after a natural flood. Discharge would be maintained at 8,000 cfs for 4 days (through April 7, 1996). The constant 8,000-cfs flows preceding and following the 45,000-cfs release would permit aerial photography and onsite evaluation of sedimentation patterns and effects on other downstream resources. Interim operations would resume at Glen Canyon Dam on or about April 8, 1996.

## ENVIRONMENTAL IMPACT

The proposed action would not constitute a major Federal action having significant effects on the quality of the human environment. The environmental assessment indicates that impacts to the human environment are justified for research purposes, short-lived, and entirely consistent with natural processes in Glen and Grand Canyons.

Determining adverse or beneficial impacts requires value judgments. For this assessment, impacts on downstream resources that are consistent with natural processes are considered to be beneficial, and those that are inconsistent with natural processes are considered to be adverse. Because all impacts of the proposed action on downstream resources are consistent with natural processes, they are considered to be beneficial to the overall ecosystem. The predicted impacts of the one-time test of the beach/habitat-building flow are summarized below.

1. The pattern of monthly releases from Glen Canyon Dam would differ slightly from no action (interim operations). Annual water releases and water quality would not be impacted by the proposed action.

2. Impacts on sediment would include sandbar deposition of 1 to 3 feet throughout Grand Canyon. Some sandbars would experience net erosion, but most would experience deposition.

3. Non-native fish life cycles would be temporarily disrupted. Backwaters would be reformed and subsequently available for use by native and non-native fish after the test flow. Research data would be obtained on the relationships between flow duration and magnitude and backwater formation.

4. The proposed action would likely result in a temporary reduction in the aquatic food base—most notably *Cladophora*, associated diatoms, and *Gammarus*—in the Glen Canyon reach, with increased drift downstream. Research data would be gathered on relationships between short-term high flows and the aquatic food base.

5. It is likely that some trout eggs, fry, and young would be lost downstream. This temporary loss could be mitigated by stocking this non-native fish. There is some risk that the aquatic food base would be reduced, subsequently affecting adult trout for a period following the test flow.

6. Some riparian vegetation in the new high water zone would be lost through scouring or burial by sediment transported by the test flow. Both emergent marsh and woody vegetation would recover quickly in the months and years, respectively, following the test flow and return to no action conditions.

7. Wildlife use riparian vegetation as habitat, and some habitat would be temporarily lost during the test flow. Patches of bare sand created by the test flow would add diversity to the new high water zone habitats. Habitat conditions would return to no action levels as riparian vegetation returns to no action conditions.

8. The endangered humpback chub and razorback sucker would likely benefit from the test flow through the reforming of return-current channels (backwater habitats). The endangered Kanab ambersnail would likely sustain short-term population and habitat impacts, although the allowable incidental take would not be exceeded. The northern leopard frog, a State candidate for threatened status, also would likely sustain some population and habitat impacts. The test flow would not affect the remaining special status species.

9. Sandbar deposition could be generally beneficial to some cultural resources by covering and stabilizing sites.

10. All river-based recreation activities would be affected to some degree by the test flow, although little or no impact outside of the test flow period is expected. There is some risk of longer-term adverse impacts on trout fishing.

11. No change in Interim Operating Criteria would occur except during the test flow. Two-percent less energy would be generated during water year 1996. The proposed action would have an economic cost of $0.5 to 2.2 million and a total financial cost of $3.1 to 4.3 million (less than 1-percent decrease in annual revenue). No impact on wholesale or retail power rates is expected.

12. The proposed action would result in a negligible increase in powerplant emissions relative to variations during the water year.

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CHAPTER I

# Purpose of and Need for Action

The proposed action analyzed in this environmental assessment (EA) is a research test of the beach/habitat-building flows proposed as an element of the preferred alternative in the *Operation of Glen Canyon Dam Environmental Impact Statement* (U.S. Department of the Interior [USDI] 1995). In the final environmental impact statement (EIS), it was intended that this type of flow would become part of the long-term operational program for the dam.

## PURPOSE AND NEED

The purposes of the test flow—sometimes referred to as a "spike flow"—are related to Glen Canyon Dam operations and resource management in Glen and Grand Canyons. These test purposes include rebuilding eroded sandbars, reforming backwater habitats for native fish, and mimicking the natural processes that create a dynamic Grand Canyon ecosystem. Periodic high flows are needed to maintain ecosystem diversity.

This test flow would be a deviation from the current Interim Operating Criteria, which were established in November 1991. This test is needed to scientifically verify the predictions stated in the final EIS on Glen Canyon Dam operations. That is, to test the hypothesis that the dynamic nature of fluvial landforms and aquatic and terrestrial habitats can be restored by short-duration releases substantially greater than powerplant capacity. The beach/habitat-building test flow would provide the opportunity to measure essential geomorphic and ecologic processes during flood passage and flood recession. Results of this test flow would provide information needed to verify an operational flow regime intended to maintain, manage, and protect the riparian and aquatic resources of the Colorado River in Glen and Grand Canyons.

Several conditions make the spring of 1996 an opportune time to conduct this test flow. The riverine system has not experienced flows of the proposed magnitude for a decade, and the limitations of the Interim Operating Criteria have accelerated the filling of backwaters (used by native fish as rearing habitat) with sediment. Releases from Glen Canyon Dam in water year 1996 are expected to be greater than the minimum required; therefore, water required for the test could be more easily scheduled. Finally, a cadre of scientists who have gained much experience in Glen and Grand Canyons over the last 12 years is available to monitor and evaluate this experiment.

## BACKGROUND

On July 27, 1989, the Secretary of the Interior (Secretary) directed the preparation of an EIS to evaluate the effects of Glen Canyon Dam operations on the downstream ecological and cultural resources of Glen Canyon National Recreation Area and Grand Canyon National Park (figure 1). The Bureau of Reclamation (Reclamation) filed the final EIS with the Environmental Protection Agency on March 21, 1995. The Grand

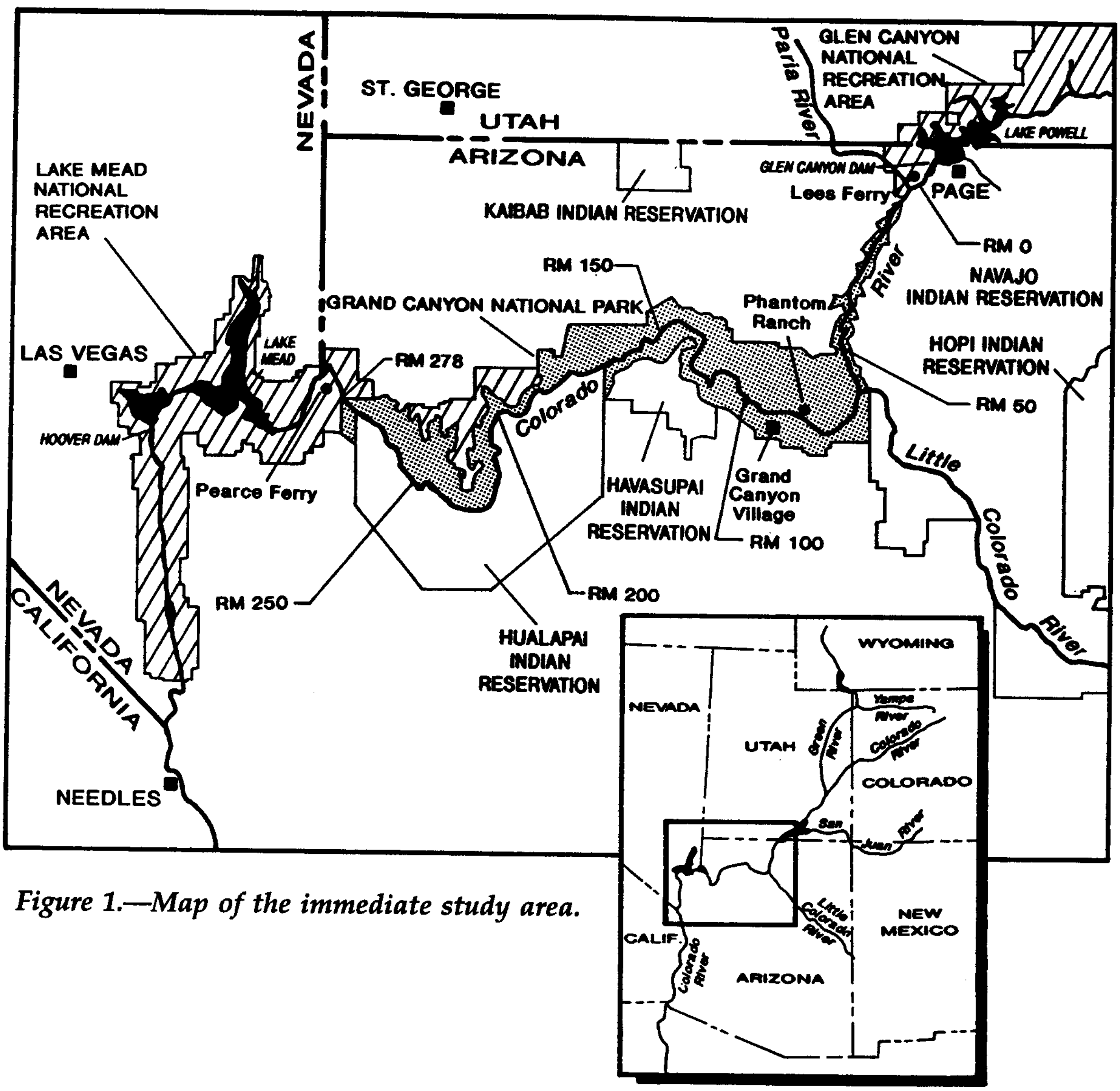


*Figure 1.—Map of the immediate study area.*

Canyon Protection Act of 1992 (Public Law 102-575, Section 1804 b) requires the General Accounting Office to complete an audit of

> *. . . the cost and benefits to water and power users and to natural, recreational, and cultural resources resulting from management policies and dam operations identified pursuant to the environmental impact statement . . .*

Current schedules show this audit being completed late in calendar year 1996.

In order to conduct the test flow, adequate National Environmental Policy Act (NEPA) compliance is required. Shortly after the draft EIS was issued in January 1994, detailed planning for a test flow began. Preliminary plans were formulated for a test in the spring of 1995. This flow was postponed because certain legal questions had not been resolved, and NEPA compliance for the test flow was needed because a record of decision (ROD) was not signed. Because of the delay in implementing a ROD for the final EIS, that NEPA compliance is contained herein.

Six of the nine alternatives (including the preferred alternative) analyzed in the final EIS included beach/habitat-building flows, which are described on page 40 of that document as ". . . scheduled high releases of short duration designed to rebuild high elevation sandbars, deposit nutrients, restore backwater channels, and provide some of the dynamics of a natural system." The final EIS also states that a test flow ". . . would be conducted prior to long-term implementation of this element to test the predictions made in chapter IV" (USDI 1995).

## RELATIONSHIP TO NATIONAL PARK SERVICE RESOURCE MANAGEMENT OBJECTIVES

The Superintendent of Grand Canyon National Park—the Interior official responsible for managing and protecting the natural, cultural, and recreational resources within the primary affected area—was consulted directly and concurs that the expected benefits derived from the proposed action are consistent with National Park Service (NPS) resource management objectives for the Colorado River within Grand Canyon National Park.

## PERMITS REQUIRED

Researchers would have to obtain permits from NPS to conduct studies in the river corridor during the test flow. In addition, those working with threatened or endangered species would have to obtain a permit from the U.S. Fish and Wildlife Service (FWS), and researchers working with resident fish or wildlife species would need an Arizona Game and Fish Department permit. Tribal permits would be obtained as appropriate. No other permits would be required.

## SCOPING SUMMARY

A test of the beach/habitat-building flow has been a topic of discussion among researchers, cooperating agencies, and other stakeholders in the Glen Canyon Dam EIS process since early in 1991, when the Interim Operating Criteria were being formulated.

The Glen Canyon Dam EIS Transition Work Group, which includes representatives of virtually all stakeholders in this process, has discussed the beach/habitat-building flow test at several of their meetings. One such Transition Working Group meeting was specifically identified as a consultation to deviate from interim operations. These meetings, consultation with the seven Colorado River Basin States (Basin States)[1] and others during the Annual Operating Plan (AOP) process, and the distribution of this document for public review constitute appropriate public involvement.

The vast majority of all the comments on the final EIS favored the concept of a beach/habitat-building flow and urged that a test be conducted in the near future. These comments indicate that the interested publics are generally well informed as to the purposes of the test and the need to include system disturbance as a process in sustaining ecosystem variability below Glen Canyon Dam.

[1] Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming.

CHAPTER II

# Description of Alternatives

This chapter presents the alternatives considered in detail, the alternatives eliminated from detailed study, and a summary comparison of the alternatives and their impacts. The No Action Alternative is dam operations under Interim Operating Criteria (Reclamation 1991) in water year 1996 (October 1995 through September 1996). The Proposed Action Alternative is operations under these same criteria but with a test, during late March and early April 1996, of the beach/habitat-building flow proposed in the Glen Canyon Dam EIS.

## NO ACTION

The Interim Operating Criteria, which are the No Action Alternative, are summarized in the table 1.

Table 1.—Summary of Interim Operating Criteria

| Minimum releases (cfs)[1] | Maximum releases (cfs) | Allowable daily fluctuations (cfs/24 hrs)[2] | Ramp rate (cfs/hr)[3] |
|---|---|---|---|
| 8,000 between 7 a.m. and 7 p.m. 5,000 at night | 20,000 | 5,000 6,000 or 8,000 | 2,500 up 1,500 down |

[1] Cubic feet per second.
[2] 5,000 cfs per 24 hours (cfs/24 hrs) for monthly release volumes of 600,000 acre-feet and less; 6,000 cfs/24 hrs for monthly release volumes between 600,000 and 800,000 acre-feet; and 8,000 cfs/24 hrs for monthly release volumes 800,000 acre-feet and greater.
[3] Cfs per hour.

These criteria were designed to reduce daily flow fluctuations well below historic levels, with the goal of protecting or enhancing downstream resources while allowing limited flexibility for power operations. Criteria such as minimum flows, maximum flows, ramp rates, and allowable daily fluctuations were established to protect downstream resources until completion of the final EIS and ROD.

Annual and monthly releases adhere to the Long-Range Operating Criteria objectives of 8.23-million acre-feet (maf) minimum annual releases and equalized storage between Lake Powell and Lake Mead. Annual releases greater than the minimum are permitted to avoid anticipated spills and equalize storage. Monthly and annual release volumes are projected for different hydrologic conditions prior to the beginning of the water year and described in the AOP (Reclamation 1995b).

Scheduled monthly release volumes are updated at least monthly during the water year. The most probable monthly release volumes scheduled for water year 1996 are presented in table 2 (Peterson, written communication 1995).

Table 2.—Comparison of most probable monthly release volumes under the No Action and Proposed Action Alternatives for water year 1996

| Month | No action release volume (acre-feet) | Proposed action release volume (acre-feet) | Release volume difference (acre-feet) |
|---|---|---|---|
| October | 899,000 | 899,000 | |
| November | 900,000 | 900,000 | |
| December | 950,000 | 950,000 | |
| January | 1,100,000 | 950,000 | -150,000 |
| February | 950,000 | 900,000 | -50,000 |
| March | 850,000 | 1,100,000 | +250,000 |
| April | 825,000 | 950,000 | +125,000 |
| May | 850,000 | 750,000 | -100,000 |
| June | 950,000 | 900,000 | -50,000 |
| July | 1,075,000 | 1,100,000 | +25,000 |
| August | 1,100,000 | 1,100,000 | |
| September | 871,000 | 821,000 | -50,000 |
| Annual total | 11,320,000 | 11,320,000 | 0 |

The actual minimum and maximum release from the dam for a given day depends on the monthly release volume, the allowable daily fluctuation, and the demand for hydroelectric power. The actual releases are usually higher than the minimum and lower than the maximum allowed. The minimum release is maintained higher during daytime hours to protect the aquatic food base from exposure. The maximum release was conservatively set to reduce sand transport in the river and to accumulate sand along the riverbed. The allowable daily fluctuation (either 5,000, 6,000, or 8,000 cfs/24 hrs) depends on the monthly release volume and was determined so that the maximum daily change in river stage would be nearly the same during all months—about 3 feet in most reaches.

The ramp rate is the rate of change in discharge, either up or down, required to meet the electrical load. The down ramp rate was set to reduce seepage based erosion of sandbars in Glen and Grand Canyons and to avoid stranding of fish. The up ramp rate was conservatively set to further reduce operation-related impacts to canyon resources, although the process under which impacts could occur was not well understood at the time interim criteria were established. Since then, scientific studies have found no cause and effect relationships between up ramp rates at the dam and impacts on canyon resources.

## PROPOSED ACTION

The proposed action is to continue releases under the Interim Operating Criteria but implement a test of the beach/habitat-building flow as a temporary deviation from these criteria. The central premise of this test flow is that:

- Periodic high flows are necessary to maintain the Colorado River's geomorphic character.

- The river's geomorphic character and associated processes influence aquatic and riparian ecology, as well as recreational use and the primitive character of the Grand Canyon experience.

The principal scientific questions to be addressed by evaluation of the test flow relate to the flow magnitude, duration, and frequency necessary for rejuvenating or rebuilding sandbars and associated backwater and terrestrial habitats in Glen and Grand Canyons that also support cultural and recreational resources.

Annual maximum daily flows greater than 80,000 cfs were common prior to construction of the dam. The beach/habitat-building test flow would be a special release of up to 45,000 cfs for a maximum duration of 7 days in March/April 1996 (see figure 2). This special high release would be preceded and followed by 4 days of low steady 8,000-cfs flows. Releases would increase from 8,000 up to 45,000 cfs at a maximum rate of 4,000 cfs/hr. Releases would decrease at variable rates simulating conditions of a natural flood:

- From the maximum discharge to 35,000 cfs, releases would decrease at a maximum rate of 1,500 cfs/hr.

- From 35,000 cfs to 20,000 cfs, releases would decrease at a maximum rate of 1,000 cfs/hr.

- From 20,000 cfs to 8,000 cfs, releases would decrease at a maximum rate of 500 cfs/hr.

The total annual release volume would be the same as under no action. However, monthly release volumes within the water year would have to be adjusted to allow for the greater release volume in March and April (see table 2). About 375,000 acre-feet of additional water would be required in March and April to conduct the test flow.

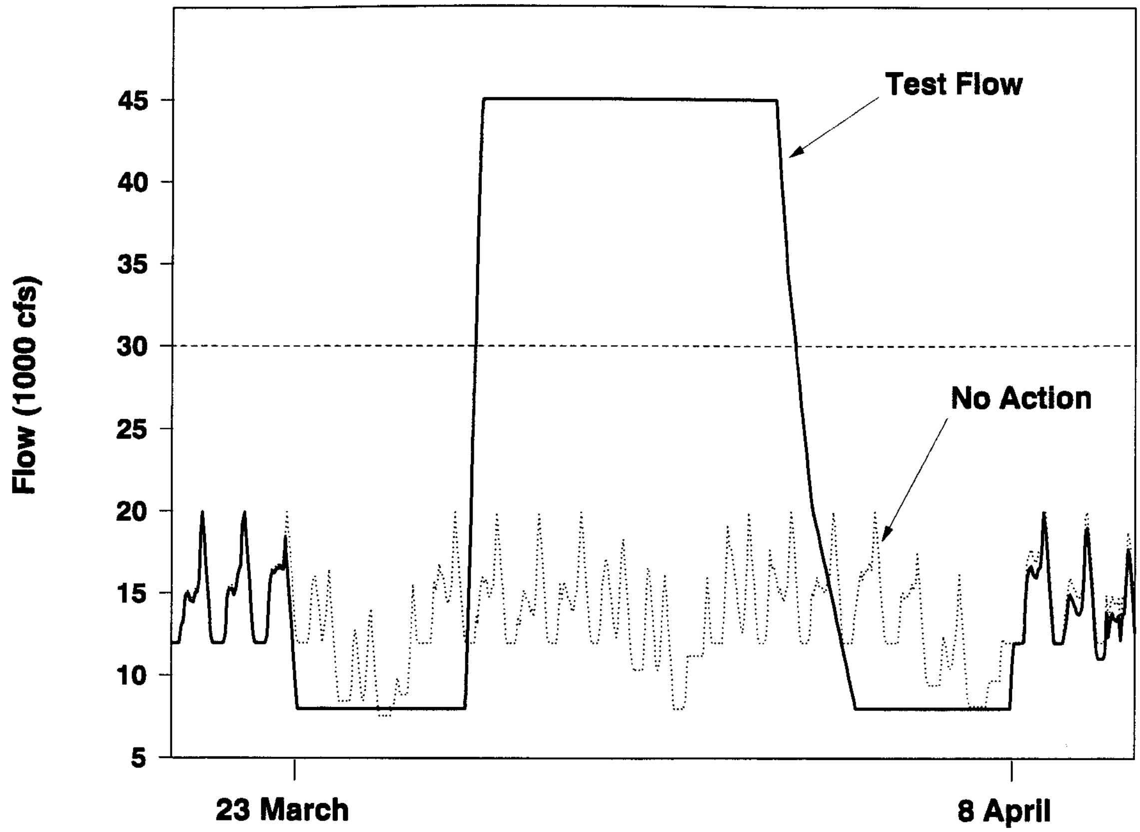


*Figure 2.—Hydrograph of beach/habitat-building test flow.*

The timing of the test flow was considered in detail. Specifically, the timeframe was selected to reduce impacts on river resources by conducting the test flow:

- Prior to native fish (especially humpback chub) spawning or larval dispersal
- After the peak of rainbow trout spawning at Lees Ferry
- After the peak concentrations of wintering bald eagle and waterfowl
- Prior to the peak release of tamarisk seeds to reduce germination
- Prior to the peak river rafting season

Final research and monitoring proposals are under development and consideration (Wegner et al., written communication 1995). These research efforts, being funded at $1.5 million, include the following processes which would be monitored before, during, and after the test flow.

- Riverflow velocity and stage elevation
- Sediment movement and deposition rates
- Fish populations, habitats, and movements
- Vegetation scour and burial
- Kanab ambersnail population and movement
- Cultural resources scour and burial
- Economic and financial effects

The activities involved with this research and monitoring in the river corridor would be led by Reclamation's Glen Canyon Environmental Studies Group and would include:

- Aerial photography
- Helicopter videography
- Land and hydrographic surveying of sediment, vegetation, and cultural resources
- Nontoxic dye tracer injection to measure river velocity
- Kanab ambersnail relocation and monitoring
- Fish shocking to monitor fish populations
- Radio tracking of up to 10 humpback chub
- Water quality and aquatic drift (plants and invertebrates) measurements

Results of the research and monitoring would be used to answer the following questions, which are based on management objectives.

Would the test flow:

- *Displace non-native fish?*
- *Rejuvenate backwater habitats for native fish?*
- *Increase height and area of existing sandbars, followed by erosion at rates that decrease with time?*
- *Reduce nearshore vegetation?*
- *Preserve and restore camping beaches?*
- *Protect cultural resources from erosion?*
- *Result in more navigable rapids?*
- *Not cause significant adverse effects on the aquatic food base, trout fishing, endangered species, cultural resources, and economics?*

Some people have suggested that a contingency plan is necessary to reduce the magnitude of or stop the test flow after it has begun. However, monitoring criteria for such a plan are difficult to establish because the affected resources would be under water and out of sight during the test flow. Some sandbars could be eroding while many others would be building. Based on the preponderance of scientific information, the likelihood of overall adverse consequences to canyon resources is minimal. The scientific value of the test flow would be lost if the flows were prematurely stopped. Therefore, the test flow would be completed once it began. This decision is supported by Grand Canyon National Park management.

## MITIGATION

Four archeological sites are proposed for data recovery (mitigation) prior to the test flow. Also, a traditional cultural property site in Granite Park would be stabilized prior to the test flow.

Any substantial loss of the trout population would be mitigated by stocking, if such losses occur. Arizona Game and Fish Department would determine any need for trout stocking. A public information program would be conducted by Reclamation and NPS to inform anglers and river rafters of the special test flow releases from the dam.

## ALTERNATIVES CONSIDERED BUT ELIMINATED FROM DETAILED ANALYSIS

Maximum releases greater than 45,000 cfs and durations longer than 7 days were considered for this test of the beach/habitat-building flow but were rejected for the following reasons:

- The test flow is a field experiment designed to test certain hypotheses related to the role that floodflows can play in resource management. A test flow of 45,000 cfs with a duration of 7 days should be of high enough magnitude and of long enough duration to conduct a meaningful experiment. Therefore, increasing the magnitude or duration of the test flow is not necessary. Also, there is a limited amount of water available to conduct the experiment. For a given amount of water, the duration of the test flow could be increased if there were a corresponding decrease in flow magnitude. However, sandbar deposition rates increase with increasing flow, and more deposition would occur with a relatively high flow of short duration compared with a lower flow of longer duration. Therefore, the proposed test flow makes more efficient use of water and is more likely to achieve measurable results than an experiment of lower magnitude and longer duration.

- Releases greater than 45,000 cfs may cause excessive sandbar erosion in narrow reaches. Sandbar deposition occurs in recirculation zones or eddies (see chapter III, SEDIMENT). However, an eddy may not exist if the riverflow is so high that the debris fan or other obstruction that created the eddy is overtopped. Sandbars in narrow reaches may be especially vulnerable to this type of erosion during very large floods. Results of this test flow are expected to provide information on the effects of larger floods.

- Since the 1983-86 high flows, a portion of the endangered Kanab ambersnail population (3.3 percent) and habitat (11 to 16 percent) is now within the river stage associated with a riverflow of 45,000 cfs. The precise impacts of the test flow on the Kanab ambersnail population are unknown, but results from the test flow can be used to assess impacts of other flow magnitudes. Test flows greater than 45,000 cfs would likely have greater impact on habitat and more risk than the proposed action.

- Releases greater than 45,000 cfs would require use of the spillways. Although the spillways were repaired after the damage that occurred during the 1983 flood, they have limited service lives. Thus, for dam safety reasons, releases through the powerplant and outlet works are preferred, because these structures have longer service lives than the spillways.

A test flow within powerplant capacity was considered but eliminated because flows of that magnitude would not be sufficient to address the research questions previously listed.

## SUMMARY COMPARISON OF ALTERNATIVES AND IMPACTS

Table 3 summarizes the impacts of the No Action and Proposed Action Alternatives on the affected environment. The impacts on each of the affected resources are described in more detail in chapter III. Since the proposed action is a test, the exact magnitude of effects is not known, and the effects presented in this EA may not be fully realized.

**Table 3.—Summary comparison of alternatives and impacts**

| Resource | No Action | Proposed Action |
|---|---|---|
| **Water** | 11.3-maf annual release. | Same as no action, with monthly release volume adjustments to schedule more water in April and March. No effect on end-of-year water storage in Lakes Powell and Mead. |
| **Sediment** | Continued slow erosion of sandbars with some accumulation of sand along riverbed and in eddies. Sand transport above Little Colorado River estimated at 640,000 tons in 1996. | One to 3 feet sand deposition on most sandbars followed by erosion over time. Net erosion on some sandbars during test flow. Sand transport above Little Colorado River estimated at 850,000 tons in 1996. |
| **Fish** | Aquatic food base continues development at 5,000-cfs reliable flow level. Backwaters used by native and non-native warmwater and coolwater fish continue to fill with sediment/ vegetation. Interactions between native and non-native fish continue; stabilized backwaters may favor non-natives. Majority of trout population spawned in river/tributaries. | Temporary reduction in *Cladophora* biomass with increased drift downstream. Backwaters re-formed. Non-native populations temporarily disrupted by high flows; interactions between native and non-native fish rapidly return to no action conditions. Some trout eggs, fry, and young lost downstream; mitigation through stocking. Adult trout may be affected for a period following test flow. |
| **Vegetation and Habitat** | Continued woody vegetation development on suitable sites down to the 20,000-cfs stage. Patches of emergent marsh plants continue to be replaced by woody plants as backwaters fill. Wildlife use riparian vegetation as habitat. Aquatic food base continues to support wintering waterfowl. | Some woody and emergent marsh vegetation lost through scouring or burial; vegetation recovery to no action levels in months/years following test flow. Some wildlife habitat lost; recovery to no action levels following test flow. No long-term effects on aquatic food base; few wintering waterfowl present during test flow. |
| **Endangered and Other Special Status Species** | All endangered and other special status species supported by habitat resources found in the canyon. southwestern river otter believed extirpated from Grand Canyon. | Habitat improvement for southwestern willow flycatcher and humpback chub. Some Kanab ambersnail and northern leopard frog habitat inundated by test flow; leopard frog population may be lost. |
| **Cultural Resources** | Continued erosion of high terraces containing archeological sites by wind and rain. | High terrace erosion rates may be reduced in short-term. Temporary restoration of natural processes generally beneficial. |
| **Recreation** | Anglers, day rafters, white-water boaters experience moderate daily flow fluctuations. | River-based recreation activities affected to some degree during test flow. Number and size of camping beaches increased. |
| **Hydropower** | Operations constrained, continued pattern of moderate hourly, daily, and seasonal flow fluctuations. | Two percent less energy generated during test flow. Little or no effect on wholesale or retail power rates. Total financial cost: $3.1 to 4.3 million; economic cost: $0.5 to 2.2 million. |
| **Air Quality** | Regional and Grand Canyon air quality very good. | Insignificant increase in emissions. |

CHAPTER III
# *Affected Environment and Environmental Consequences*

This chapter describes Colorado River resource linkages, the affected resources, and the impacts of the proposed action on them. The conditions that currently exist under interim operations establish the baseline for analysis of effects. The affected resources are water, sediment, fish, vegetation and wildlife, endangered and other special status species, cultural resources, recreation, hydropower, and air quality. The indicators used for analyzing impacts on these resources are the same as those used in the Glen Canyon Dam EIS. More detailed information on the affected resources can be found in the final EIS (USDI 1995).

Determining adverse or beneficial impacts requires value judgments. In this assessment, impacts on downstream resources consistent with natural processes are considered to be beneficial, and those that are inconsistent with natural processes are considered to be adverse. Because of the experimental nature of the proposed action, the magnitude of effects are not known. Estimates of adverse and beneficial effects presented in this EA are based on best available information but may not be fully realized.

For the purposes of the analysis presented here, it was assumed that the entire beach/habitat-building test flow period would deviate from interim operations for 17 consecutive days in March and April, with flows at 45,000 cfs for 7 of those days.

## COLORADO RIVER SYSTEM RESOURCE LINKAGES

Resources downstream from Glen Canyon Dam through Glen and Grand Canyons are inter-related or linked, since virtually all of them are associated with or dependent on water and sediment (USDI 1995). In such a linked system, changes in a single process can affect resources throughout the entire system. For example, as illustrated in figure 3, changes in operations of Glen Canyon Dam, such as the proposed test flow, would directly affect hydropower, water supply, sediment, fish, and recreation. Resources affected through the effects of operational changes on sediment include vegetation, cultural resources, fish, and recreation.

Finally, air quality, wildlife habitat, and threatened and endangered species can be affected through their linkages to other resources and the effects of water and sediment on those resources.

These linkages play a preeminent role in the resource analyses presented in this document. The proposed test flow would alter the system processes of riverflow and sediment transport patterns. Changes in these two processes would, in turn, affect

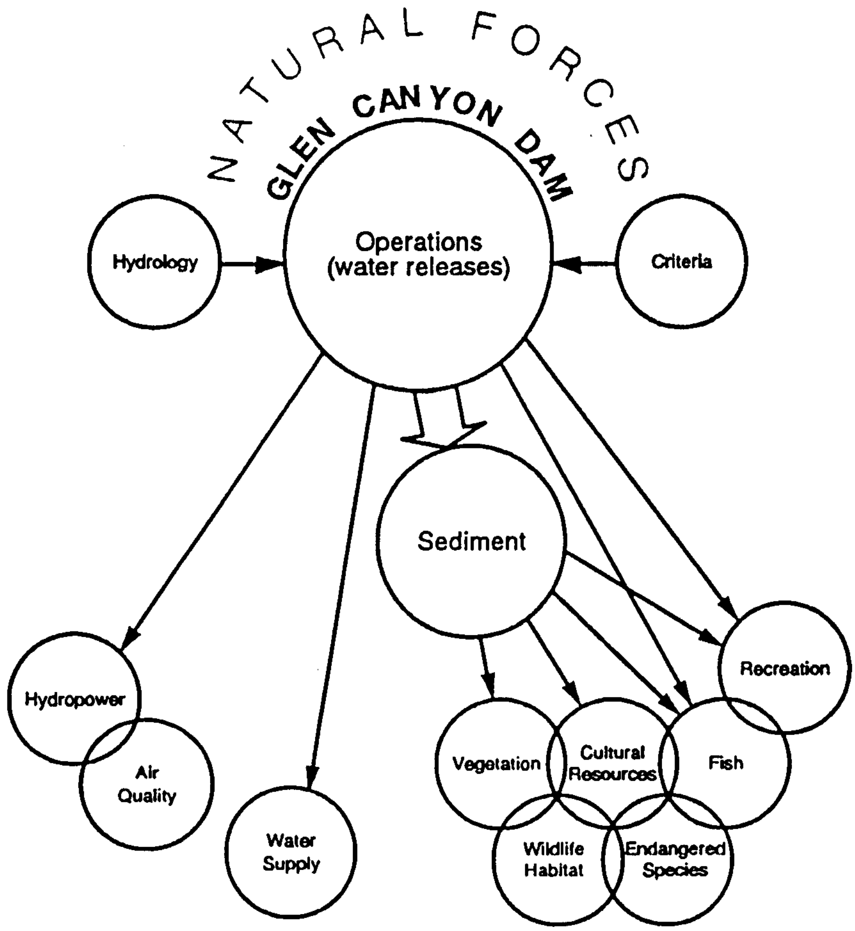


*Figure 3.—Interrelationships between Glen Canyon Dam operations and the affected resources.*

other resources. As discussed below, effects will vary in both intensity and duration. In general, without additional perturbations, resource levels would return to their no action levels after varying time spans.

The Grand Canyon ecosystem originally developed in a sediment-laden, seasonally and sometimes daily, fluctuating environment. The construction of Glen Canyon Dam altered the natural dynamics of the Colorado River. Lake Powell traps water, sediment, and associated nutrients that previously traveled down the Colorado River.

Today, the ecological resources of Glen and Grand Canyons depend on the water releases from the dam and variable sediment input from tributaries. A reduced sediment supply and regulated release of lake water now support aquatic and terrestrial systems that did not exist before Glen Canyon Dam.

## Water Volume and Pattern of Release

The major function of Glen Canyon Dam (and Lake Powell) is water conservation and storage. The dam is specifically managed to release a minimum objective of 8.23 maf of water annually to the Lower Basin. In this EA, riverflows below the dam are referred to as releases or discharge. The measure of riverflow is in cfs. Annual and monthly volumes are measured in acre-feet. To put these relationships in perspective, Glen Canyon Dam would have to release approximately 11,400 cfs, 24 hours per day, every day of the year to release 8.23 maf. The amount of water, its pattern of release, and its quality directly or indirectly affect physical, biological, cultural, and recreational resources within the river corridor.

Predam flows ranged seasonally from spring peaks sometimes greater than 100,000 cfs to winter lows of 1,000 to 3,000 cfs. During spring snowmelt periods and summer flash floods, significant daily and hourly flow fluctuations occurred. While annual variability in water volume was high, a generally consistent pattern of high spring flows followed by lower summer flows provided an important environmental cue to plants and animals in the river and along its shoreline.

The frequency of daily and hourly fluctuations has increased since the dam was completed. Within the interim operating criteria, water is released to maximize the value of generated power by providing peaking power during high-demand periods. More power is produced by releasing more water through the dam's generators. These fluctuations result in a downstream "fluctuating zone" between low and high river stages (water level associated with a given discharge) that is inundated and exposed on a daily basis.

Hydropower conserves nonrenewable fuel resources and is cleaner, more flexible, and more responsive than other forms of electrical generation. Glen Canyon Powerplant is an important component of the electrical power system of the Western United States. When possible, higher releases are scheduled in high-demand winter and summer months to generate more electricity. Glen Canyon Powerplant historically has produced about $55 million in revenue in a minimum water release (8.23-maf) year.

Glen Canyon Dam also affects downstream water temperature and clarity. Historically, the Colorado River and its larger tributaries were characterized by heavy sediment loads, variable water temperatures, large seasonal flow fluctuations, extreme turbulence, and a wide range of dissolved solids concentrations. The dam has altered these characteristics. Before the dam, river water temperature varied on a seasonal basis from highs around 80 degrees Fahrenheit (°F) to lows near freezing. Now, water released from the dam averages 46 °F and varies little year round. Very little warming occurs downstream. The dam releases clear water, and the river becomes muddy only when downstream tributaries contribute sediment.

## Sediment Transport and Its Effect on Other Resources

Sediment can be considered a basic resource, linked in some way to most of the resources within Glen and Grand Canyons. The discussions in the EA deal mainly with sand-size particles, although all sizes of sediment—from the smallest clays and silts to the largest boulders—are important system components.

Exposed and submerged sediment deposits throughout Glen and Grand Canyons are very important for cultural, recreational, and biological resources. Sediment is critical for stabilizing archeological sites and camping beaches, for developing and maintaining backwater fish habitats, for transporting nutrients, and for supporting vegetation that provides wildlife habitat.

Large annual floodflows—sometimes greater than 100,000 cfs—historically transported tremendous quantities of sediment that accumulated in high deposits and sometimes formed terraces. Wind and water eroded these deposits after the return to lower flows. Natural cycles of deposition and erosion generally prevented establishment of vegetation near the river.

Sediment supply and the river's capacity to transport sediment (especially sand and larger particles) both have been reduced. The major sources for resupplying sediment to the river below the dam are tributaries—primarily the Paria River, Little Colorado River (LCR), and Kanab Creek.

The 1983-86 floodflows transported sand stored within the river channel, eroded low elevation sandbars, and aggraded high elevation sandbars in wide reaches. In many places, vegetation that had developed since dam construction was scoured, drowned, or buried. Some archeological sites also were damaged. The high elevation sandbars eroded following the return to lower flows (as they did predam). Because floods of predam magnitude and sediment concentration can no longer occur, erosion of high terraces will continue.

The future existence of Grand Canyon sandbars depends on careful management of sand supplied from tributaries, daily water release patterns, and the long-term frequency and magnitude of flood releases from the dam. Cycles of sediment deposition and erosion are a natural process for rivers. High flows—whether daily or annual—are necessary to replenish sand deposits, but high flows occurring too frequently in the dam-altered river would lead to long-term net erosion.

## Flows, Sediment, and Downstream Resources

The Colorado River is the main influence in this dynamic ecosystem—changes in its flow ripple outward to affect both aquatic and terrestrial resources downstream. The system now contains a mixture of native and non-native plant and animal communities that began developing prior to the dam, with the introduction of non-native fish and vegetation. Dam construction and operation further modified this mixture and created the current system that is supported by postdam conditions. The river is forever changed. That change—brought about by Glen Canyon Dam—permitted this ecosystem to develop and establish itself.

***Aquatic Resources.***—The predam aquatic system supported an array of native and non-native fish. At the time of the dam closure in 1963, eight species of native and eight species of non-native fish were present in the system. By 1968, non-native fish became more abundant than natives, with trout dominating the now cold water system immediately below the dam. The reasons for extirpations or declines are undoubtedly complex, but principal known factors are competition and predation by non-native fish, habitat changes, and a fragmented ecosystem brought about by construction and operation of Glen Canyon Dam.

The biological foundation of the aquatic system in the postdam Colorado River below Glen Canyon Dam is *Cladophora glomerata*, a filamentous green alga. River conditions created by the dam make possible the abundant growth of *Cladophora*. Together, *Cladophora*, diatoms, and associated invertebrates (*Gammarus* and insects) provide an important food source for other organisms in the aquatic food chain.

The postdam conditions described above, including the *Cladophora*-diatom-*Gammarus* food chain, support a blue ribbon non-native rainbow trout fishery in the Glen Canyon reach below the dam. However, water quality changes with distance from the dam, and aquatic communities change in response. While water temperature increases only slightly downstream, sediment from tributaries accumulates, turbidity increases, and the abundance of food-chain organisms decreases. The sediment particles' abrasive action also decreases the abundance of food organisms. As their food supply decreases downstream, trout decrease in abundance and condition.

The slow-moving water in backwaters and nearshore areas provides habitat for young fish and protects them from the stress and dangers of the cold main channel. Under the proper conditions, backwaters have higher water temperatures than the main channel and provide better food conditions for young fish.

How water is released from the dam also affects aquatic resources. For example, periods of exposure to air (6 to 8 hours) can adversely affect *Cladophora* and its associated invertebrates through drying, freezing, or ultraviolet light. Fluctuating discharges may dislodge segments of *Cladophora* and temporarily increase drifting clumps of this important food-bearing resource downstream for trout and other organisms. The fluctuating zone supports fewer aquatic invertebrates than do sites that are continuously inundated. Insect larvae are uncommon in the fluctuating zone.

Bald eagles—which likely only passed through the river corridor before the dam—now stop during winter at sites along the river to feed on spawning trout and fish stranded by fluctuating flows.

Water release patterns also affect recreation. Three groups account for almost all recreational use of the Colorado River corridor: anglers, day rafters, and white-water boaters. Most trout fishing occurs in the 15-mile Glen Canyon reach below the dam.

***Terrestrial Resources.***—Riparian vegetation is defined by waterflow patterns and sediment dynamics and is an excellent example of how system processes affect linked resources. High flows transport available sediments. Some sediments are deposited and become sandbars after flows recede, while other sediments are carried out of the system to become part of Lake Mead's delta. Before the dam, annual high flows carried large sediment loads through Glen and Grand Canyons, scouring or burying any vegetation below the old high water zone (OHWZ). With the dam, flows are regulated, sediment supplies are limited, and riparian vegetation has become established in the new high water zone (NHWZ). Today, this new zone of vegetation provides over 1,000 acres of additional habitat for native and non-native wildlife.

Riparian vegetation in the NHWZ grows on sediment deposits. While high flows can rapidly and dramatically restructure sandbars and associated riparian vegetation, daily dam release patterns influence the distribution and abundance of plants on sediment deposits. Below the level of maximum flow, sediment deposits are unstable and generally unsuitable for the establishment of woody vegetation. NHWZ plants grow in the area between maximum river stage and the level where limited groundwater no longer supports growth.

Emergent marsh vegetation, such as cattails, often develops in areas with low water velocity, high concentrations of silt and clay, and a reliable water supply—typically backwaters. Marshes probably did not occur in Glen and Grand Canyons before dam construction. Even though emergent marsh vegetation now makes up less than 2 percent of the total riparian vegetation, it greatly enhances plant diversity in the river corridor. Structural diversity of the riparian plant communities and abundant invertebrates make the riparian zone—especially the NHWZ vegetation resulting from dam-regulated flows—valuable wildlife habitat.

## WATER

The indicators used to evaluate impacts on water are **streamflows, floodflows and other spills, reservoir storage, water allocation deliveries, Upper Basin yield determination**, and **water quality**.

### Affected Environment

Existing statutes, compacts, and operating criteria ("Law of the River") guide the determination of annual **streamflows**—volumes of water released from Glen Canyon Dam—to share the benefits of the Colorado River among the seven Basin States. The minimum objective annual release from Lake Powell is 8.23 maf under the current Long-Range Operating Criteria.

**Floodflows** are defined as releases in excess of the 33,200-cfs powerplant capacity. Releases in excess of 33,200 cfs cannot be used to generate power.

**Reservoir storage** in Lakes Powell and Mead depends on annual and monthly reservoir inflow and release volumes. Storage levels affect shoreline resources and lake recreation. Further, the Upper Basin States use storage in Lake Powell to meet their water delivery requirements to the Lower Basin.

**Water allocation deliveries** are the allowances of water diverted by each of the Basin States and those delivered to Mexico under the "Law of the River." **Upper Basin yield** is the USDI estimated maximum volume of water available for annual depletion by the Upper Basin States.

Glen Canyon Dam altered downstream **water quality** by changing water temperature, clarity, and nutrient flow. Water releases are cold, and very little warming occurs downstream. Lake Powell traps sediment, so the dam releases clear water, and the river becomes muddy when downstream tributaries contribute sediment.

## Environmental Consequences

Annual **streamflows** are expected to be the same under both alternatives. Monthly release volumes would differ between the No Action and Proposed Action Alternatives (see figure 4). However, there would be no impact on the distribution of

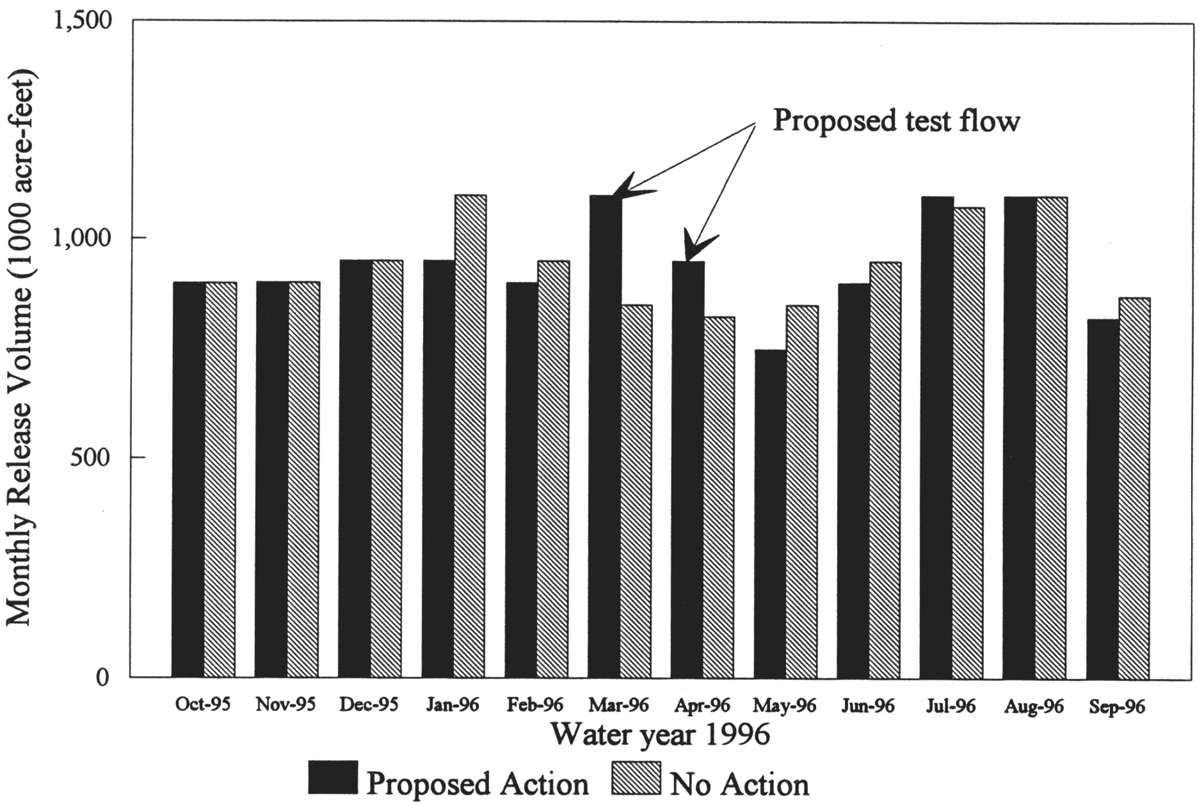


*Figure 4.—Comparison of monthly release volumes under the No Action and Proposed Action Alternatives. The greatest difference would occur in January, March, and April; no difference would occur during October through December.*

water benefits among the Basin States, because there would be no change in the annual release, and the monthly releases are re-regulated by Lake Mead and other downstream reservoirs. The differences in monthly releases volumes from Glen Canyon Dam are important in the consideration of impacts on other resources. The proposed action is not expected to substantially change the frequency of **floodflows** greater than 45,000 cfs from current conditions.

**Reservoir storage** under the Proposed Action Alternative would differ only slightly from no action from January through August 1996 and would be the same at the beginning and ending of the water year. The projected differences in Lake Powell elevation or storage between the two alternatives would be much less than the projected seasonal change under no action (about 19 feet). The greatest differences in the elevation of Lake Powell would occur at the end of February, when—under the proposed action—the lake would be 1.3 feet higher, and at the end of April, when the lake would be 1.2 feet lower than under no action (see figure 5). The effect on Lake Mead elevations would be similar. The greatest differences in Lake Mead elevations would occur at the end of February when the lake would be 1.5 feet lower and at the end of April, when the lake would be 1.3 feet higher than under no action.

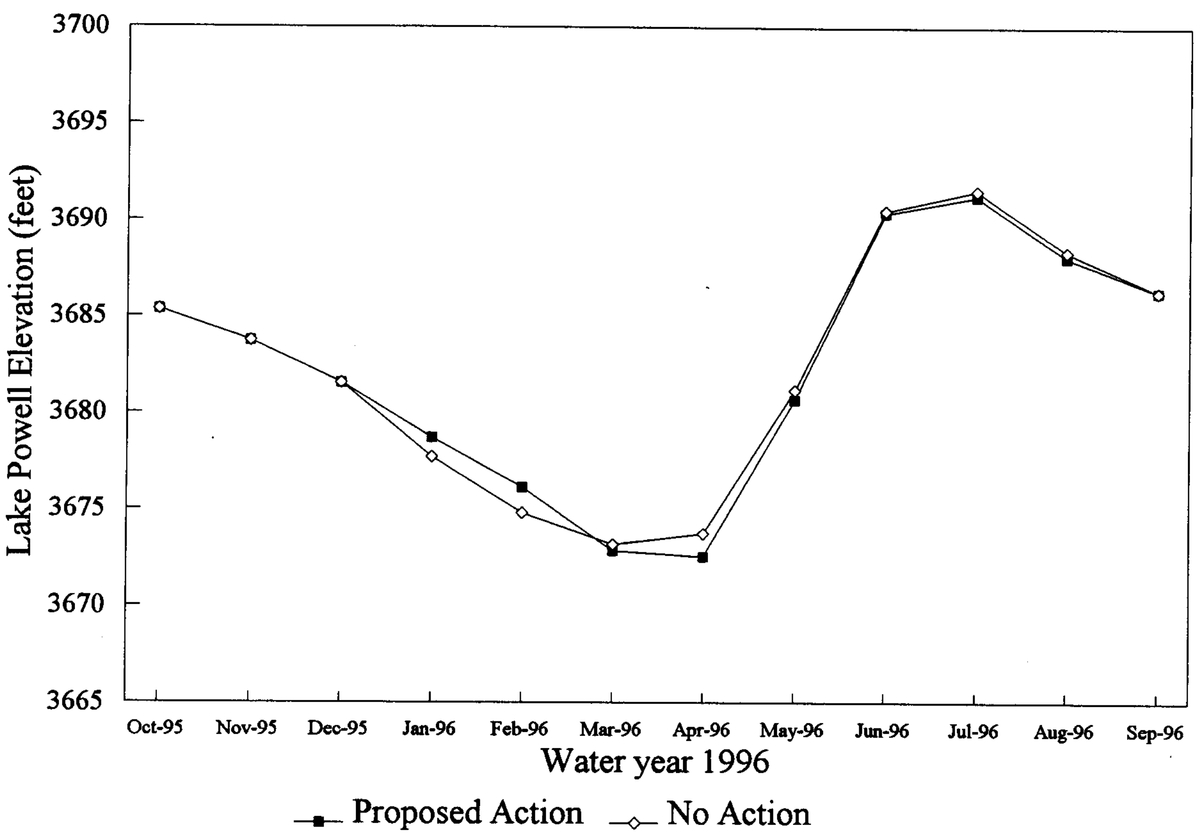


*Figure 5.—Comparison of Lake Powell elevations throughout the year and between the No Action and Proposed Action Alternatives. The difference in lake elevations between the two alternatives is greatest at the end of February and April, but only by 1.3 and 1.0 feet, respectively.*

- Since the annual release volume would not be affected, there would be no impact on **water allocation deliveries** or the **Upper Basin yield determination.**

For 7 days at the end of March and beginning of April, approximately 30,000 cfs would be released through the powerplant and about 15,000 cfs through the river outlet works. This would result in virtually no impact on downstream **water quality** because the water released through either the powerplant or outlet works is withdrawn from deep within Lake Powell where conditions are nearly constant year round. However, there would be a relatively small increase in turbidity downstream compared to periods when tributary flows are contributing sediment.

## SEDIMENT

The indicators used to evaluate impacts of the alternatives on sediment resources are **riverbed sand, sandbars, high terraces, debris fans and rapids,** and **lake deltas.**

### Affected Environment

Sediment particles of all sizes—from clay to boulders—are derived from the weathering of rock and are transported and deposited by water and wind. Most of the sediment that enters the river is silt and clay. Only a small percentage of this fine sediment is deposited in low velocity areas. The rest is transported directly through to Lake Mead. Sand is the most abundant sediment temporarily stored in Glen and Grand Canyons. Most sand moves through the canyon in long sequences of deposition and scour.

**Riverbed sand** and **sandbars** are the sediment resources of primary interest affected by riverflows below Glen Canyon Dam. For sandbars to exist, sufficient amounts of sand must be stored on the riverbed, and flows must be periodically large enough to move the sand and redeposit it on sandbars. The dam traps sediment, so sand supply is now limited to whatever is contributed by downstream tributaries—mainly the Paria River, LCR, and Kanab Creek—and hundreds of side canyons. The Glen Canyon reach—between the dam and the Paria River—has much less sediment than the river downstream.

The dam not only cut off the upstream sediment supply, it also greatly reduced the river's capacity to transport sediment. Even so, frequent high flows—either from floods or large daily fluctuations—can transport greater amounts of sand than are contributed by the tributaries, causing a net decrease in both the amount of stored riverbed sand and the size of sandbars. Water release patterns also modify the natural process of sandbar deposition and erosion. Rapid drops in river stage drain the groundwater stored in sandbars during higher river stages, thus accelerating sandbar erosion.

In general, sandbars are built during periods of high flow and then erode over time following the return to low flow, and in a natural system, this cycle repeats itself.

Since the Interim Operating Criteria were implemented in August 1991, sandbar erosion rates have declined, but erosion still occurs due to rain, wind, and waves—especially on higher sandbar portions above the river stage associated with a flow of 20,000 cfs. Eddy backwaters (return-current channels) exist at lower elevations and have been filling in with sediment. In January 1993, two large floods from the Little Colorado River (each lasting about 5 to 6 days) contributed about 4.6 millon tons of sand to the Colorado River and increased total flow downstream to 33,000 cfs and 26,000 cfs (Wiele, Graf, and Smith, written communication 1995). Most of this sand is deposited in the first 10 miles of river below the confluence. However, these floods resulted in sandbar deposition at locations all the way to Diamond Creek (164 miles downstream), which demonstrates the concept that occasional flood releases from Glen Canyon Dam can result in sandbar deposition. Sand that was deposited on sandbars near Diamond Creek must have come from the riverbed rather than directly from the LCR, because the sand contributed during these floods could not have traveled that far downstream before the floods ended.

High terraces, debris fans and rapids, and lake deltas are other sediment features of concern. **High terraces**—some containing archeological remains—were deposited by infrequent, very high floodflows before the dam and cannot be replenished by postdam releases. A few of these terraces may be directly exposed to erosion during floodflows, particularly in the Glen Canyon reach.

At the mouths of side canyons, **debris fans** are created and enlarged by occasional large debris flows of sediment and rock mixed with water. The largest particles—boulders—can be moved off the debris fans only by high riverflows. Since 1986, at least 25 debris flows have constricted the river channel, creating two **rapids** that have made navigation more difficult (Webb et al., written communication 1995). Debris fans also create downstream eddies where most of the camping beaches used by river runners are deposited. The return-current channels associated with the eddies become backwaters used by fish during lower flows.

Sediment transported by the Colorado River will begin to deposit upon entering either Lake Powell or Lake Mead. The location and elevation at which deposition occurs is related to the sediment particle size, riverflow, and the lake elevation. Fine sediment particles deposit in the lake farther downstream than coarser particles. Coarse sediments deposit first at the lake's upstream end, forming large **lake deltas**. High riverflows transport sediment farther into the lake than lower flows. When the lake elevation is high, sediment deposition occurs farther upstream and at higher elevations than when the lake is lower.

The growth rates of Lake Powell deltas are independent of Glen Canyon Dam operations, but delta crest elevation may vary in response to changing lake elevations, which are in turn related to water release patterns. In contrast, the growth of the Colorado River delta in Lake Mead depends on the delivery of sediment from Grand Canyon, which depends on tributary supply and the river's transport capacity over the short term. Over the long term, the average amount of sediment reaching Lake Mead would be approximately equal to 12 million tons per year—the long-term average from Grand Canyon tributaries (Andrews 1991a). The Lake Mead delta crest elevation is related to changing lake elevations which are, in turn, related to the water release pattern at Glen Canyon Dam, in combination with the release pattern at Hoover Dam.

## Environmental Consequences

***No Action.***—Under this alternative, peak flows would be relatively low throughout the year—less than 20,000 cfs—and there would be little or no potential to rebuild **sandbars**, except during a very large and rare tributary flood. Sandbars would continue to experience slow rates of erosion.

Recent investigations have determined that **riverbed sand** storage in Grand Canyon (along the riverbed and in eddies) has reached near capacity and additional sand supplied from tributaries would be mostly transported to Lake Mead over a period of months (Andrews, verbal communication 1995). Under any alternative, the river reach between the Paria River (river mile (RM) 0) and the LCR (RM 61) is the most susceptible to long-term net loss of riverbed sand. During water year 1996, the sand transport of the Colorado River above the confluence with the LCR is estimated to be 640,000 tons, which is less than the long-term average annual sand supply from the Paria River of 1.2 million tons. Annual sand transport was estimated by applying sand-discharge rating curves (Pemberton 1987) to the projected hourly releases from the dam.

In the clear-water reach upstream from the Paria River (Glen Canyon), there is relatively little riverbed sand left since construction of the dam. Net sediment erosion may continue in this reach but at a very slow rate. Long-term net changes in riverbed sand downstream from Phantom Ranch (RM 88) are expected to be negligible under no action.

**High terraces** in Glen and Grand Canyons would continue to be slowly eroded by runoff from local rainfall resulting in networks of water carved gullies (arroyos).

Riverflows would not be able to move the large boulders on existing **debris fans** and **rapids**. If the rapids are further constricted by new debris flows, the river would have very limited capability to re-widen the constrictions.

Sediment would continue to accumulate in Lake Powell and Lake Mead. **Lake delta** crest elevations would tend to vary with the lake surface elevations. During periods when Lake Mead is filling, the river channel through the delta (downstream of RM 236) would tend to be deeper, but sediment deposition would begin occurring farther upstream. During periods of lake drawdown, the river would erode a channel through the previously deposited sediments—redepositing them farther downstream in the lake—and channel depths would tend to be more shallow.

During water year 1996, both Lake Powell and Lake Mead are expected to be relatively full. Lake Mead elevations would average 12 feet higher during water year 1996 than during water year 1995. Lake elevations would increase from October through February; decrease during March, April, and May; and increase again through the end of the water year. Sediment loads entering the lake would tend to be greatest during the late summer thunderstorm season—July through October—when the lake is filling. Therefore, channel depths through the Lake Mead delta would be relatively deep during most of the year with the possible exception of May, June, and July, when lake elevations would be 4 feet lower than the peak in February. Channel depths again would decrease when the lake again begins to recede during the next drawdown cycle.

***Proposed Action.***—Under this alternative, flows and river stage would be similar to those under the No Action Alternative except during the test flow period in late March and early April, when test flows would be as much as 45,000 cfs. The test of the beach/habitat-building flow is expected to restore a remnant of the predam processes that would affect existing sediment resources in several ways:

- The river would have greater capacity to transport **riverbed sand.**
- Sediment deposited in eddies during interim operations would tend to scour, and return-current channels or backwaters would be re-formed.
- River stage would increase 5 to 11 feet more than the normal high stage associated with a flow of 20,000 cfs (see table 4). Consequently, the potential to deposit sand at higher elevations also would increase.
- Some of the sand transported from the riverbed would deposit on **sandbars** associated recirculation zones. Sandbar deposition rates in Grand Canyon and the duration of the test flow would likely limit the total deposition to about 1 to 3 feet, based on results reported by Andrews (1991b). Only minor amounts of sandbar deposition are expected in the Glen Canyon reach.
- Sand deposited at the bases of **high terraces** would tend to slow rainfall-based erosion of high terraces by creating a higher base level for runoff channel erosion. High terraces in direct contact with the river on the outside edges of riverbends are expected to erode more under high flow conditions.
- An increase in river velocity would move boulders on some **debris fans,** widen **rapids,** and decrease the drop in water surface through rapids.

Newly deposited sand would begin eroding after the return to lower flows. Erosion rates would be initially high but decrease exponentially with time. The length of time required to erode the sandbars again to their previous conditions is unknown, but would be determined by site-specific monitoring following the test flow. All of the above effects are temporary and consistent with those of a natural cycle.

The river reach between the Paria River (RM 0) and the LCR (RM 61) is the most susceptible to long-term net loss of sand. During water year 1996 with the test flow, Colorado River sand transport above the confluence with the LCR is estimated to be

Table 4.—Reach-averaged range in stage and active sandbar width under No Action and Proposed Action Alternatives

| Interim operations | | | | | | | | Beach/habitat-building test flow | |
|---|---|---|---|---|---|---|---|---|---|
| | | Daily discharge range (5,000 to 10,000 cfs at dam) | | | Annual discharge range (5,000 to 20,000 cfs at dam) | | | 45,000 cfs at dam | |
| Reach (river miles) | Local minimum flow[1] (cfs) | Range in stage above local minimum flow (feet) | Active sandbar width (feet) | Range in stage above 5,000 cfs (feet) | Range in stage above local minimum flow (feet) | Active sandbar width (feet) | Range in stage above 5,000 cfs (feet) | Range in stage above 20,000 cfs (feet) | Active sandbar width (feet) |
| -16 to 0 | 5,000 | 2 | 5 | 2 | 5 | 19 | 5 | 5 | 43 |
| 0 to 11 | 5,100 | 3 | 10 | 3 | 7 | 33 | 7 | 8 | 76 |
| 11 to 23 | 5,300 | 3 | 12 | 3 | 8 | 38 | 9 | 10 | 88 |
| 23 to 36 | 5,500 | 3 | 10 | 3 | 8 | 37 | 9 | 9 | 82 |
| 36 to 61 | 5,800 | 2 | 7 | 3 | 6 | 28 | 7 | 7 | 67 |
| 61 to 77 | 6,200 | 2 | 4 | 2 | 6 | 24 | 6 | 7 | 62 |
| 77 to 118 | 6,600 | 3 | 9 | 4 | 9 | 41 | 10 | 11 | 97 |
| 118 to 126 | 7,000 | 2 | 6 | 4 | 8 | 36 | 10 | 10 | 85 |
| 126 to 140 | 7,100 | 2 | 5 | 4 | 7 | 32 | 9 | 9 | 80 |
| 140 to 160 | 7,300 | 2 | 5 | 4 | 8 | 37 | 10 | 11 | 91 |
| 160 to 214 | 7,800 | 2 | 3 | 4 | 8 | 34 | 10 | 10 | 86 |
| 214 to 236 | 8,400 | 1 | 1 | 4 | 7 | 31 | 10 | 10 | 83 |

[1] Increase in minimum flow estimated on the basis of hydrographs of fluctuating research flows of January 29, 1991. Range of fluctuations was 5,000-14,600 cfs. Estimated inflow from streams and springs between Glen Canyon Dam and RM 225 is 1,400 cfs.

850,000 tons, which is a 33-percent increase over no action conditions. The annual sand transport is less than the long-term average annual sand supply from the Paria River (1.2 million tons).

The riverbed in the Glen Canyon reach upstream from the Paria River is armored with a layer of large cobbles. This means that, although sand may still be stored in eddies or pools, the riverbed is no longer downcutting. This reach substantially eroded after dam closure, especially during the first high releases in 1965. Erosion rates have slowed after subsequent high releases in 1980 and 1983-86. Flow releases peaked at 92,000 cfs in June 1983.

Because the Glen Canyon reach is armored from previous erosion and the proposed test flow is much lower than previous flows, additional erosion is expected to be minor. Because remaining sediment deposits in the Glen Canyon reach have withstood being subjected to floodflows in 1965, 1980, and 1983-86—as well as strong daily flow fluctuations for 25 years (prior to interim operations)—they are expected to persist after the test flow. High terraces that currently are eroding on the outside edges of riverbends are expected to experience higher rates of erosion during the test flow. The Glen Canyon reach still has some sediment supply from ungauged tributaries and likely has reached a near equilibrium condition.

No measurable impact on the Lake Powell **deltas** would result from the proposed action. This is because the test flow would cause only a slight difference in lake elevations (less than 1.3 feet) during some months—a difference much smaller than the seasonal fluctuations in lake elevation under no action.

The test flow would deliver more sediment to the Lake Mead delta in water year 1996, but the high flows would tend to scour the channel bottom through the delta and transport sediment farther into the lake. The increased sediment transport would not change the long-term sedimentation rates, which ultimately depend on tributary sediment supply. Lake Mead elevations would average 12 feet higher during water year 1996 than during water year 1995. Lake Mead elevations would increase from October through March; decrease during April, May, and June; and again increase through the end of the water year. Sediment loads would tend to be highest during the 7-day test flow (late March and early April) and during the late summer, thunderstorm season—July through October.

Channel depths through the Lake Mead delta would be relatively deep during most of the year, with the possible exception of May, June, and July, when lake elevations would be 4 feet lower than the peak in March. Channel depths would again decrease when the lake begins to recede during the next drawdown cycle. No extensive erosion of the Lake Mead delta is expected as a result of the test flow.

## FISH

Because of the dynamic interaction between resources and riverflow, changes in water release patterns are expected to affect aquatic resources. However, because of the large variety of aquatic resources and their differing water requirements, a comprehensive evaluation of the effects of the alternatives on all aquatic resources is beyond the scope of this report. Therefore, five indicators have been selected to evaluate impacts of the proposed action on fish and other aquatic resources: **aquatic food base, native fish, non-native warmwater and coolwater fish, interactions between native and non-native fish,** and **trout.**

## Affected Environment

The present aquatic ecosystem below Glen Canyon Dam is the result of complex interactions between released water, habitat, and the native and non-native organisms that inhabit it (USDI 1995). Minimum flows establish limits on productivity, and clear, cold water further defines the system. The *Cladophora*-diatom-*Gammarus*-dominated food base that supports the aquatic system is constrained by riverflow. Both native and non-native fish, as well as some terrestrial organisms, depend on this food base.

***Aquatic Food Base.***—Discharges of clear water from Glen Canyon Dam have permitted the filamentous green alga *Cladophora glomerata* to capitalize on the available nutrients released through the dam. *Cladophora* and the diatoms that live on it form the habitat for an important community of aquatic invertebrates dominated by the amphipod *Gammarus lacustris* and by chironomid and other fly larvae. *Cladophora,* along with the organisms that live on it, forms the basis of a highly productive food chain below Glen Canyon Dam (USDI 1995).

Since the inception of interim flows, the plant component of the aquatic food base has begun to change. The relative dominance of *Cladophora* in the Glen Canyon reach may be declining as other algae (e.g., *Chara* spp.) and submerged aquatic plants become established on sediment deposits from canyon wall "pour overs" (Arizona Game and Fish Department, written communication 1996). It is important to note that substrates for these plants differ. *Cladophora* grows on rock and cobble, while *Chara* and other aquatic plants grow best in sand or silt substrate. During the past year, higher minimum flows have permitted algae and other aquatic plants to become established above minimum reliable flow levels (5,000 cfs).

The prolific growth of *Cladophora,* and recently *Chara* spp. and other aquatic plants, has established the upper portion of the river below the dam as an important production area that feeds immediate downstream reaches with particulate organic matter in the form of plant debris and aquatic invertebrates in the current as drift. Much of the drift that feeds fish and other aquatic organisms is *Cladophora*—either dead from drying or scoured loose by waterflow—and invertebrates forced to move to avoid drying. Drift also settles to the bottom in eddies and backwater areas where it is fed on by organisms and recycled through the food chain.

The importance of *Cladophora* in the aquatic food base in the Lees Ferry reach, and below as drift, dictate that the relationship between flow and aquatic plants be considered in planning any management action. Drift increases with discharge.

Blinn et al. (1992) found that periods of steady flows during interim operations resulted in significantly less drift of *Cladophora* and associated invertebrates than periods of fluctuating flows. At Lees Ferry, increasing flows increased invertebrates but not algae in the drift (Leibfried and Blinn 1987). Drift densities of *Cladophora* were highest during June 1985, when high, steady flows of about 35,000 cfs were released from Glen Canyon Dam.

***Native Fish.***—The native fish of the Colorado River make up one of the most unusual assemblages of fish specially adapted to their environment found anywhere in the world. However, recent history has introduced new challenges by modifying the fish's evolutionary environment. Major dams have modified streamflow extremes, cleared and cooled the waters, converted rivers to lakes, cut off natural movement corridors, and permitted the introduction of non-native fish that compete with and/or prey upon the natives. Of the eight species of native fish, three have been extirpated from Glen and Grand Canyons, two are listed as endangered and one as a candidate species under the Endangered Species Act, and the remaining two are relatively common.

Cold water temperature is an overriding constraint for native fish in the Colorado River mainstem. Cold temperatures prevent spawning or, if spawning occurs, limit egg and larvae survival in both native and warmwater non-native fish. Because water temperature would not be altered by the proposed action, the availability of warmer, low velocity environments in the main channel—important for rearing young fish flushed from the tributaries—is the focus of this discussion.

Return-current channels (backwaters) of reattachment bars and shallow nearshore areas along the main channel are important refuges for young native fish exiting tributaries and serve as nursery areas in the mainstem. Native fish require these shallow, productive, warm refuges during the first year of life. Maddux et al. (1987) found that young-of-year humpback chub, flannelmouth suckers, bluehead suckers, and speckled dace used backwaters extensively. They found these areas to be very important on a seasonal basis, when the sun can warm the backwater above ambient river temperature. Compared to mainstem eddy habitats, backwaters offer higher zooplankton and benthic invertebrate densities (Kubley 1990; Arizona Game and Fish Department 1994), lower current velocities, and refuge from predatory fish.

Return-current channel backwaters have a tendency to fill with sediment through time. Excavation of backwaters takes place in eddies during periods of high flow (Pucherelli, written communication 1987). The exact flow magnitude necessary to maintain or restore filled backwaters is not known. Comparisons of backwater counts at near 5,000-cfs flows made during postflooding events in 1985 with backwater counts made during 5,000-cfs releases in 1991 showed nearly an 80-percent decline in the number of backwaters over the 6-year period (Weiss 1993). This decline is attributed to backwaters filling with sediment and vegetative growth. Backwaters are continuing to fill under interim operations. Natural flooding events triggered by winter flooding in the LCR in 1993 resulted in creation or restoration of some backwater habitats (McGuinn-Robbins 1994).

***Non-Native Warmwater and Coolwater Fish.***—Non-native warmwater fish such as channel catfish and carp have a long history in the Colorado River (USDI 1995). As water temperatures declined following the construction and operation of Glen Canyon Dam, both native and non-native warmwater fish populations have declined. Rainbow trout now dominate the fishery.

Non-native warmwater and coolwater fish face the same water temperature-related problems with main channel reproduction as described for native fish. Because of temperature constraints, backwaters and nearshore habitats are also believed to be important for non-native warmwater and coolwater fish survival in the main channel.

***Interactions Between Native and Non-Native Fish.***—Potential competitors with native fish include carp, fathead minnow, killifish, rainbow trout, brown trout, and red shiner and may include some omnivorous species that also prey on native fish. These competitors may share rearing habitats in backwater areas and eddies on which native fish appear to be dependent. The presence of warmwater, coolwater, and coldwater non-native species is an issue of considerable importance (USDI 1995). Predation by and competition from non-native fish on native fish are important considerations when evaluating any management action. This is especially true with the proximity of Lakes Powell and Mead and their diverse non-native fish populations. Non-native fish predators currently in the system include striped bass, channel catfish, large mouth bass, green sunfish, brown trout, walleye, and possibly others.

***Trout.***—Trout are a non-native resource found throughout Glen and Grand Canyons. Trout were originally introduced by various agencies for sport purposes (USDI 1995). Rainbow trout make up the major part of the sport fishery in the 15-mile reach below Glen Canyon Dam and the trout fishery in Grand Canyon. Brook, brown, and cutthroat trout have also been stocked in the river. Brook trout and cutthroat trout have nearly disappeared from the system.

Current practices call for stocking approximately 80,000 rainbow trout annually between Glen Canyon Dam and Lees Ferry. Natural spawning occurs where trout find suitable conditions. Evidence suggests that interim operations have increased naturally reproduced trout in the Glen Canyon population. Arizona Game and Fish Department (1993) estimated that 78 percent of the juvenile trout (smaller than about 8 inches) sampled in August 1992 were naturally reproduced. Electrofishing data from 1995 indicate a high contribution (94 percent) of naturally spawned trout (Arizona Game and Fish Department, written communication 1996).

## Environmental Consequences

***No Action.***—Effects on resources under interim flows would continue under no action conditions. The **aquatic food base** would be supported under no action conditions by minimum reliable flows of 5,000 cfs. Without high flows, return-current channels (backwaters) important to **native fish** and **non-native warmwater and coolwater fish** would continue to fill with sediment. Under no action conditions,

**interactions between native and non-native fish** would continue. **Trout** would continue to spawn in the mainstem and tributaries and would be maintained by the aquatic food base.

***Proposed Action.*—**The test flow poses some risk to the **aquatic food base**. First, algae and submerged aquatic plants have recently expanded above minimum reliable flow levels and are used by both *Gammarus* and rainbow trout. Plants and invertebrates above the 8,000-cfs stage would be subject to desiccation for 4 days before and after the special high release. However, if adverse effects result from steady releases of 8,000 cfs, they would be minimal. This assumption is based on the response of the aquatic food base to steady releases of 8,000 cfs for 3 to 4 days each Memorial Day weekend during interim operations.

Second, the high flow portion of the test flow could result in some reduction of the aquatic food base in Glen Canyon through scour of plants and invertebrates and temporarily increase downstream drift. *Chara* and submerged plants that have become established during interim flows may be lost. However, because *Cladophora* and other components of the aquatic food base survived the high flows of 1983-86, it is believed that any adverse effects would be minimal and no action conditions would return. If adverse impacts do occur, *Cladophora* may require from several months to over a year to recover (Angradi et al. 1992). *Chara* and other aquatic plants would also recover but may require more than a year to reach current levels.

The beach/habitat-building test flow in March would occur before **native fish** spawn or larva disperse from the LCR. Backwaters important to native and **non-native warmwater and coolwater fish** would be restructured by the test flow and, thereby, benefit young fish of both groups.

Most non-native fish inhabiting the aquatic ecosystem of the river corridor do not do well in existing riverine conditions. The high flows associated with the test flow may cause some temporary disruptions to non-native fish populations and, thus, affect the **interactions between native and non-native fish**. Any effect is assumed to be temporary, with rapid recovery by non-native fish populations to no action levels.

The proposed action would occur after the peak of rainbow **trout** spawning at Lees Ferry, and the spawning run in Nankoweap Creek is basically over by late March. However, some risk remains to rainbow trout from the test flow. During the test flow, some eggs, fry, and young trout would be lost downstream. These fish could be replaced through stocking. In addition, some late spawning trout may be stranded during the descending arm of the test flow, but reduced down ramp rates should minimize this loss. Direct effects to trout from the test flow would be closely monitored.

Adult trout may experience some decline in growth and body condition as a result of a reduction in the aquatic food base. Depending on the magnitude of effects to the aquatic food base, the trout population could experience reduced numbers and possible outbreaks of parasites as a response to stress. If these effects should manifest, they would not appear until after the test flow and would continue until the aquatic food base recovers to no action levels. Data obtained from post-test flow monitoring would be used to evaluate the relationships between high flows, the aquatic food base, and the trout population.

## VEGETATION AND WILDLIFE

Because of the dynamic interaction between sediment deposits, riparian vegetation, and water availability, changes in water release patterns would affect plant abundance and distribution and the animals that rely on them. Since many different plants grow in the riparian zone and have differing water requirements, a comprehensive evaluation of the effects of the alternatives on all plants in the riparian zone is beyond the scope of this report. Therefore, two plant groups were selected for detailed evaluation to serve as indicators of impacts on riparian vegetation and wildlife habitat: **woody plants** (trees and shrubs) and **emergent marsh plants** (cattails and similar aquatic plants).

The effects of dam operations on one group of wildlife using this system—wintering waterfowl—cannot be evaluated by assessing impacts to riparian vegetation. Waterfowl using the Colorado River below Glen Canyon Dam depend on the aquatic food chain associated with the abundant green alga (*Cladophora glomerata*) that has developed below the dam. Therefore, the indicator selected for detailed analysis of impacts to wintering waterfowl is the **aquatic food base** as represented by *Cladophora* and other aquatic plants.

### Affected Environment

Plant communities affected by Glen Canyon Dam releases exist in a restricted zone at the juncture between the river's edge and upland desert—the riparian zone. Water and sediment interact in this riparian zone, and vegetation occupies suitable sites from the dam downstream into Lake Mead. Water transports and deposits sediment, and the availability of water at sediment deposits supports plants that otherwise could not survive in a desert climate. Riparian vegetation also plays an important role as wildlife habitat by providing food and cover for numerous mammals, birds, reptiles and amphibians, and invertebrates. The structural diversity of the plant species found in the riparian zone provides many habitat resources in a relatively small area. The variety of animals present in the river corridor, their habitats, and how they use these habitats create a complex system that would be difficult to evaluate in detail. For this reason, riparian vegetation is used to represent wildlife resources (USDI 1995).

***Woody Plants.***—Riparian vegetation associated with the Colorado River in Glen and Grand Canyons exists in two recognizable zones: the OHWZ and NHWZ. Only the NHWZ would be affected by the proposed test flow. Since interim operations began in 1991, additional vegetation has become established, and the NHWZ now occupies suitable sites between the discharge stages of about 20,000 to 40,500 cfs. This expansion means that the pre-interim operations aggregate acreage estimate of

1,320 acres for the NHWZ (USDI 1995) has probably increased somewhat, but no current estimates are available. Common woody plants found in the NHWZ include both native and non-native species: seep-willow, arrowweed, desert broom, coyote willow, and tamarisk. Non-native tamarisk is the dominant woody plant in the NHWZ with some mesquite and other plants more common in the OHWZ becoming established in the upper, drier elevations of the NHWZ.

Riparian systems change as the water conditions that bound them change. The development of riparian vegetation in the NHWZ that began with construction of Glen Canyon Dam was interrupted by high floodflows in 1983-86. In 1983, flows in excess of 90,000 cfs removed more than 50 percent of the plants at sample sites below the 60,000-cfs stage either by scouring, drowning, or burial beneath newly deposited sediment (Stevens and Waring 1985). However, the riparian zone is a dynamic area, and Stevens and Ayers (1991) estimated that levels of riparian vegetation before interim flows were 75 percent of 1982 levels.

Different plants are affected differently by high discharges. Species with deep taproots—such as acacia, mesquite, and tamarisk—are resistant to scouring, and losses from the high flows of 1983-86 ranged from 0 to 20 percent (Stevens and Waring 1986). In contrast, high scouring losses (68 to 100 percent) were experienced by shallow-rooted clonal species such as coyote willow, arrowweed, giant reed, cattail, and bulrush. Willow, acacia, tamarisk, and arrowweed were resistant to drowning, while other species drowned: mesquite (50-percent loss), *Brickellia* spp. (62-percent loss), *Baccharis* spp. (64- to 79-percent loss), and *Aplopappus* spp. (83-percent loss). Burial by sediment transported during high flows is another concern. Species tolerant of burial include tamarisk and clonal forms such as horsetail, giant reed, willows, camelthorn, aster, and arrowweed. Burial-intolerant species include mesquite, acacia, *Baccharis* spp., *Brickellia* spp., or desert plants.

Riparian vegetation has also developed on sediment deposits at the upper end of Lake Mead below Separation Canyon. Woody vegetation has become abundant on sediment exposed by declining lake levels.

***Emergent Marsh Plants.***—Emergent marsh plants were selected as one of the indicators of riparian vegetation because their water requirements are greater than woody plants. Together with woody plants (which require drier conditions), these indicators are assumed to represent the range of riparian vegetation and wildlife habitat responses to dam operations.

Common emergent marsh plants found in or adjacent to the NHWZ include cattails, bulrushes, and giant reed. Another plant, horsetail, is not generally considered emergent marsh vegetation but is included in this category because it develops and grows under conditions similar to the other species listed. Conditions necessary for emergent marsh plant growth include a reliable water source and sediment properties found only at certain sites (USDI 1995). Patches of marsh vegetation can be found in return-current channels (backwaters), channel margins, seeps and the mouths of tributary streams, and in other isolated sites within the zone between maximum and minimum discharge stage.

Emergent marsh plants commonly occur in small patches along the river between the dam and Lake Mead. The average size of wet marshes in Grand Canyon (those supporting cattails or bulrushes) is 0.1 acre, with the largest (Cardenas Marsh) just over 1 acre in size (Stevens and Ayers 1991). Before interim flows, the aggregate acreage of emergent wet marsh plants along the Colorado River between the dam and Diamond Creek was 19 acres. Since interim flows began in 1991, some patches of wet marsh vegetation have filled with sediment, dried out, and are supporting more woody riparian plants.

Patches of emergent marsh plants are an early stage in terrestrial plant succession in this system. Without periodic disturbances such as high flows, backwaters that support emergent marsh plants fill with sediment and become suitable for woody plants, which eventually dominate the site and exclude marsh plants. Subsequent high flows redistribute sediment, re-create conditions suitable for marsh plants, and the cycle begins again. The development of patches of emergent marsh vegetation may follow a pattern similar to that identified for return-current channel backwaters (USDI 1995).

The Colorado River delta of Lake Mead also supports emergent marsh vegetation. Since the high flows of 1983-86, lake levels have generally declined in response to regional drought conditions and permitted hundreds of acres of cattails and bulrushes to develop.

***Aquatic Food Base.***—Wintering waterfowl are evaluated by analyzing effects on the aquatic food base, because it is assumed that the birds are attracted to the open water and abundant food resources available there. No specific information on feeding is available for wintering waterfowl in Glen and Grand Canyons. However, the diets of individual species are well known from other studies and indicate that foods taken from the river would range from plants through invertebrates to small fish. The variety and abundance of waterfowl using the river during winter indicate that a productive aquatic system exists below the dam. The system is supported by clear, cold releases from the dam and is based on linkages between *Cladophora*, diatoms, *Gammarus*, and larval insects (USDI 1995).

The number of waterfowl using the river corridor increases in late November, peaks in December and early January, and then decreases in February, March, and April (Stevens and Kline, written communication 1991). During peak winter concentrations in 1990-91, some 19 different species of waterfowl used the river between Lees Ferry (RM 0) and Soap Creek (RM 11) at a density of 136 ducks per mile. An average density of 18 ducks per mile occurred over the entire upper Grand Canyon (RM 0-77) during the same period. In addition, over 34 species of waterfowl have been recorded in Glen Canyon, with densities of 150 to 200 per mile (Henderson, written communication 1996).

## Environmental Consequences

***No Action.***—Under the No Action Alternative, **woody plants** would continue to occupy the NHWZ zone from the 20,000-cfs stage up to approximately the 40,500-cfs stage. Some species composition changes would occur in the upper elevations of the NHWZ as plants adapt to drier conditions under interim flow operations (USDI 1995). Some tamarisk, willow, and perhaps other plants in drier areas of the NHWZ would be replaced by mesquite and other species requiring less water. Without disturbance, woody plants would continue to increase and eventually occupy all suitable sites within the NHWZ.

Patches of **emergent marsh plants** would also change under no action conditions. Emergent marsh plants in drier sites (above 20,000-cfs stage) would be replaced by woody plants. Return-current channels (backwaters) would continue to fill with sediment, creating conditions favorable for woody plants. With continued sediment aggradation, backwaters supporting patches of emergent marsh plants would be colonized by woody plants, and the marsh plants would disappear. Without disturbance, patches of emergent marsh plants would continue to decrease in number and size.

Riparian vegetation in the upper end of Lake Mead would continue to increase as delta formation processes continue (USDI 1995). Periodically, vegetation would be inundated and lost as lake levels rise. Estimates are that Lake Mead average elevations will be 12 feet higher than in water year 1995. Inundation would be followed by lower water levels as lake storage responds to regional weather cycles. Lower lake levels would again support abundant levels of both woody and emergent marsh vegetation.

Under no action conditions, the **aquatic food base** would stabilize within the flow parameters of interim operations. The aquatic food base would be adequate for wintering waterfowl.

***Proposed Action.***—A beach/habitat-building flow would be used for restructuring sediment deposits. Incidental to sediment restructuring, it is anticipated that these flows would interrupt, disturb, and reset plant succession in the riparian community of the NHWZ in Grand Canyon. Some **woody vegetation** would be buried and lost as sand is deposited on high elevation sandbars. Patches of **emergent marsh plants** would be lost through scouring or burial as return-current channels are re-formed. Many plants would not be affected by the test flow and would play a major role in subsequent revegetation of new sediment deposits. Both woody plants and emergent marsh vegetation would develop at suitable new sites in the years following the beach/habitat-building flow. With time, the new sediment deposits would erode, vegetation would grow, and the NHWZ would return to conditions similar to no action. In the interim, before conditions return to no action, a mixture of riparian vegetation and bare sand would provide habitat diversity for both wildlife and recreationalists.

Effects of the test flow would be less pronounced in the Glen Canyon reach above the confluence of the Colorado and Paria Rivers. As discussed in the SEDIMENT section of this report, the proposed action would not result in large changes to beaches in Glen Canyon. Some sediment deposition (inches) may occur, and little scouring is anticipated. Given these assumptions, riparian vegetation and wildlife habitat in Glen Canyon would change little as a result of the test flow and would rapidly return to no action conditions.

The magnitude of change in the NHWZ in Grand Canyon resulting from the proposed action is speculative at this time. Because information is limited, a worst-case scenario was selected for evaluation of impacts to riparian vegetation within the NHWZ. The analysis of impacts to vegetation and wildlife habitat is based on the concept of change in active width of unstable sandbar as used in the final EIS (USDI 1995). It is anticipated that the test flow would inundate the NHWZ and deposit sediment over lower elevation areas currently supporting riparian vegetation.

Under the worst-case scenario, the width of unstable sandbars would temporarily increase during and after the test flow from 38 to 56 feet greater than no action conditions throughout the river reaches within Grand Canyon (table 4). While these values can be computed, such width changes actually may not occur because of the short duration of test flow and the limited amounts of sediment deposition (see SEDIMENT). Woody vegetation most likely to be affected by the test flow would be those immature plants that have developed during interim operations. Without future disturbances, riparian vegetation recovery is likely to be relatively rapid as illustrated by the estimated 75-percent level of recovery in the years following the high flows of 1983-86 (Stevens and Ayers 1991).

Riparian vegetation is used extensively by nesting birds (USDI 1995). The timing of the test flow would serve to avoid any possible effects to nesting birds. A March test would occur before neotropical migrants and waterfowl begin their nesting seasons. Since neotropical migrants nest primarily in large woody plants, no loss of nesting habitat is anticipated. Waterfowl are ground nesters, and adequate nest cover at higher elevations would remain after the test flow. The test also would occur before the peak release of non-native tamarisk seeds in late April and May. Subsequent drying of new sediment deposits following the test flow may possibly reduce the number of germinating seeds.

The beach/habitat-building test flow would add sediment to Lake Mead, transporting it farther into the lake. However, because of the short duration of the flow and the extensive area available for sediment deposition in Lake Mead, the effect on riparian vegetation would be small and difficult to measure. Any effects on vegetation would be masked by rising water levels.

A beach/habitat-building flow may increase the downstream drift of *Cladophora* and associated organisms in the **aquatic food base** used by wintering waterfowl. Because *Cladophora* has withstood much higher flows for longer duration (1983-86), no adverse impact is anticipated. However, because other algae and submerged plants use sand or silt as substrate, they may be lost (see "Aquatic Food Base" discussion under FISH).

Most wintering waterfowl would have left Glen and Grand Canyons by late March and would not be affected. However, mallard, late migrating gadwall, and American widgeon may still be common (Stevens, written communication 1995). The proposed action would have no effect on wintering waterfowl.

## ENDANGERED AND OTHER SPECIAL STATUS SPECIES

The Federal special status species evaluated in this EA include the endangered peregrine falcon, southwestern willow flycatcher, humpback chub, razorback sucker, and Kanab ambersnail. The bald eagle is threatened, and the flannelmouth sucker is a candidate (category 2) species. Arizona species of concern include the southwestern river otter, osprey, belted kingfisher, and northern leopard frog.

### Affected Environment

Individual discussions of the 11 special status species considered in this report follow.

***Peregrine Falcon.***—The Grand Canyon and surrounding areas are believed to support the largest known breeding population of peregrine falcons in the conterminous United States (Carothers and Brown 1991) and appear to be part of an increasing Colorado Plateau peregrine falcon population. Population estimates are 96 pairs at Grand Canyon National Park, with another 50 peregrine breeding areas located around Lake Powell (USDI 1995).

Peregrine falcons may be indirectly linked to river operations through the aquatic food chain. This species feeds on waterfowl, swifts, swallows, bats, and other species that derive some of their insect and other invertebrate food from the river (Reclamation 1995a). Peregrine falcons generally nest on ledges on cliff faces in Grand Canyon, and these sites are not affected by river operations. The breeding season extends from February to July in Grand Canyon.

***Southwestern Willow Flycatcher.***—This species has declined throughout its range in the Southwest. Only three sites currently are used for nesting in Grand Canyon. Proposed critical habitat in Grand Canyon has been identified along the Colorado River from RM 39 to RM 71.5. This habitat includes the main river channel and associated side channels, backwaters, pools, and marshes throughout the May-September breeding season, as well as areas within 109 yards of the edges of surface water (Reclamation 1995a).

In Grand Canyon, the southwestern willow flycatcher is a habitat generalist, occupying sites where vegetation is of average height and density (Brown and Trossett 1989). Nesting occurs in non-native tamarisk 13 to 23 feet tall with a dense foliage 0 to 13 feet from the ground (Tibbetts et al. 1994). Proximity to water is necessary and correlated with food supplies (Reclamation 1995a). Willow flycatchers in Grand Canyon forage in tamarisk stands on sandbars, around backwaters, and at the water's edge (Tibbetts et al. 1994).

***Bald Eagle.***—The Colorado River corridor through Glen and Grand Canyons is used by migrating bald eagles during the winter. Use of the river is opportunistic and currently concentrated around Nankoweap Creek (RM 52.5), where eagles exploit winter-spawning trout as food. Eagles concentrate at Nankoweap Creek in late February, with counts ranging from 6 in 1987 to 26 in 1990 (Sogge et al. 1995a). Eagles preferentially capture rainbow trout in the shallow creek rather than in the mainstem, where foraging success is lower. Eagle density is correlated with trout density in the lower reach of the creek, and trout density is correlated with water temperature in Nankoweap Creek (Reclamation 1995a).

The wintering bald eagle population has been monitored since 1988 and occurs throughout the upper half of Grand Canyon, Glen Canyon, and on both Lakes Powell and Mead. Density of bald eagles during the winter peak in late February and early March ranged from 13 to 24 eagles between Glen Canyon Dam and the LCR (RM 61.5) from 1993 to 1995 (Sogge et al. 1995a).

***Humpback Chub.***—Humpback chubs in Grand Canyon are the only successfully reproducing population of this species in the Lower Basin, with nine distinct aggregations identified: 30-Mile, LCR inflows, Lava/Chuar to Hance Rapids, Bright Angel Creek mouth, Shinumo Creek mouth, Stephens Aisle, Middle Granite Gorge, Havasu Creek mouth, and Pumpkin Spring (Valdez 1995). Some 3,000 to 3,500 adults occupy the mainstem Colorado River, with the largest subpopulation concentrated within 4.2 miles of the mouth of the LCR. Humpback chub critical habitat in Grand Canyon includes the lower 8 miles of the LCR and the Colorado River from RM 34 to RM 208.

Adult chub in the mainstem spawn in the lower 9 miles of the LCR from March through May. Adults stage in large eddies in February and March and make spawning runs up the LCR from March through May as flows decrease, warm, and clear (Valdez 1995). Young humpback chub either remain in the LCR or move into the mainstem, where mortality is believed high. Limited numbers of chubs spawned the previous year may be present in the mainstem the following spring (Reclamation 1995a).

Limited humpback chub breeding occurs among other subpopulations in the mainstem. Valdez (1995) documented limited spawning success at 30-Mile Spring in upper Marble Canyon, and young chubs have been recorded at Kanab Creek. However, such sightings are insignificant when compared to the reproductive success of chubs spawning in the LCR.

Young humpback chub use return-current channel backwaters (Maddux et al. 1987). Backwater habitat area has declined under interim operations (McGuinn-Robbins 1995) as a result of sediment aggradation.

***Razorback Sucker.***—The razorback sucker is extremely rare in Grand Canyon, with 10 observations occurring between 1981 and 1990 (Reclamation 1995a). All individuals were old, and no reproduction is known to have occurred. Critical habitat for the razorback sucker in Grand Canyon includes the Colorado River from the confluence with the Paria River (RM 0) to and including Lake Mead.

In other systems, razorback suckers spawn earlier than other Colorado River native fish. In Lake Mohave, where the largest population of suckers occurs, razorback suckers spawn from November into May (Reclamation 1995a). In Upper Basin riverine situations, razorback suckers begin spawning on the rising spring hydrograph (April through May) and spawn through spring runoff.

***Flannelmouth Sucker.***—The flannelmouth sucker is a candidate for listing under the Endangered Species Act, but this fish is relatively abundant and reproduces in several tributaries in Grand Canyon. The species is found in the Paria River and LCR; Shinumo, Bright Angel, Kanab, and Havasu Creeks; as well as in various locations in the mainstem (USDI 1995).

Because of their dependence on tributary spawning, tributary access as estimated by dam discharge is a critical consideration for flannelmouth suckers.

***Kanab Ambersnail.***—The snails occurring in Grand Canyon are one of only two known populations of Kanab ambersnails. Demographic analyses based on size class distribution indicate that the Kanab ambersnail is an "annual" species, with much of the population maturing and reproducing in July and August, and most snails over-wintering as small size classes (Stevens et al. 1995).

Kanab ambersnail habitat includes vegetation supported by a spring in the canyon wall. The primary vegetation used by Kanab ambersnails is crimson monkey-flower and non-native watercress. The total area of primary vegetation/habitat was 0.22 acre in June 1995 (Stevens et al. 1995).

***Southwestern River Otter.***—The southwestern river otter is an Arizona species of concern. While never numerous, this subspecies of otter occurred historically in Grand Canyon. Although suitable habitat appears to be present in Grand Canyon, no reliable sightings have occurred since the mid-1980's (Reclamation 1995a). This species is assumed extirpated from Grand Canyon.

***Osprey.***—Ospreys are a State of Arizona candidate threatened species that migrates through the river corridor between Lake Powell and Lake Mead (USDI 1995). Ospreys are most numerous along the Colorado River in Grand Canyon during fall migration and are relatively rare during March and April (Reclamation 1995a). Ospreys feed on fish that they generally catch from the mainstem river.

***Belted Kingfisher.***—The belted kingfisher is a State of Arizona candidate threatened species that migrates through Grand Canyon between Lake Powell and Lake Mead (Reclamation 1995a). It is most common in Grand Canyon during spring migration.

This species uses the river and its tributaries for feeding and nests in suitable banks. Suitable nest sites are probably very rare in Grand Canyon, and this species has not historically nested there (Stevens et al. in press).

***Northern Leopard Frog.***—The northern leopard frog is a State candidate for threatened species in Arizona. This frog is rare in the river corridor, with only two known individuals recorded below Lees Ferry (Stevens, written communication 1995). A population is currently located in Glen Canyon and in 1993 consisted of 80 to 100 transformed frogs, a large number of individuals less than 1 year old, and tadpoles (Drost and Sogge 1995). This population is genetically similar to Lake Powell populations of northern leopard frogs (Stevens, written communication 1995). The origin of the Glen Canyon population is unknown but may have been natural or received assistance from man (e.g., bait anglers).

The Glen Canyon population is associated with a spring, a perched pool, and rivulets exiting the pool. Dense emergent vegetation consisting of giant reed, cattail, bulrush, and sedge is associated with the site. Most of the existing frog habitat in Glen Canyon lies below the 45,000-cfs stage.

## Environmental Consequences

Several special status species would not be affected by either alternative. These species are briefly discussed here and are not treated further in this analysis.

The **southwestern river otter** is believed to be extirpated from Grand Canyon.

Wintering waterfowl are abundant in the upper river reaches below Glen Canyon Dam and would continue to provide seasonal food for **peregrine falcons** under no action conditions. Although most waterfowl would have departed by the late March test flow, other food would be abundant. Reclamation has determined in its biological assessment of the experimental test flow that the proposed action would have no effect on peregrine falcons (Reclamation 1995a).

There were 18 **bald eagles** at Nankoweap Creek in 1995 (Sogge et al. 1995a). Numbers of eagles would continue to fluctuate with conditions in Nankoweap Creek under both no action and the proposed action conditions. Rainbow trout would have concluded their spawning run into Nankoweap Creek by late March, and wintering and migrant bald eagles generally would have left the area. Any eagles present during the test flow could forage in the river. Reclamation has concluded in its biological assessment that the proposed test flow would have no effect on bald eagles wintering in Grand Canyon (Reclamation 1995a).

Because of the migratory nature of use of Grand Canyon by **ospreys** and **belted kingfishers**, there would be no effect from the proposed action on these species. Numbers of osprey are low during spring, while sightings of belted kingfishers are most common in spring (Stevens et al. in press). Increased flow may temporarily benefit fish-eating birds by ponding additional water in tributary mouths and providing increased fishing opportunities.

The **razorback suckers** occurring 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 test flow and would suffer no adverse effects. There is no indication that young razorback suckers occur in Grand Canyon. Reclamation has determined in its biological assessment that the test flow would have no effect on razorback suckers in Grand Canyon (Reclamation 1995a).

The proposed action would not change channel temperatures, so the primary consideration for **flannelmouth suckers** is tributary access. Tributary access would improve during the test flow. Therefore, the test flow would not adversely affect flannelmouth suckers.

***No Action.***—Impacts on four special status species are evaluated below.

*Southwestern Willow Flycatcher.*—In 1995, five southwestern willow flycatchers were located: three nonbreeding males and one pair that fledged a single young (Sogge et al. 1995b). Cardenas Marsh, a site regularly used by southwestern willow flycatchers in the past, was not used in 1995.

The conditions under which the southwestern willow flycatcher experiences limited reproductive success in Grand Canyon would continue under the No Action Alternative. Cardenas Marsh is experiencing increased sediment aggradation under interim flows, with vegetation changing from emergent marsh plants to woody plants. While riparian areas used by nesting southwestern willow flycatchers have stabilized in size, sediment deposition in low-lying emergent marsh vegetation—where the birds forage—would continue. Without periodic disturbance to re-form sites supporting emergent marsh vegetation, these sites would fill with sediment and be replaced by woody riparian vegetation.

*Humpback Chub.*—Under no action conditions, humpback chub would continue to spawn in the LCR and perhaps at limited additional sites in the mainstem. However, the habitat quality of backwaters—assumed important for native fish recruitment— would continue to decline as they fill with sediment. Without disturbance, backwaters used by young native fish would eventually be lost through sediment aggradation and plant succession as they become suitable for and support woody riparian vegetation.

*Kanab Ambersnail.*—Extensive surveys have been conducted on the Kanab ambersnail population and its habitat since it was discovered that both habitat and snails had expanded down to the 20,000-cfs stage in response to interim flows. Land surveys in 1995 revealed rapid changes in vegetation cover over the growing season, with 5.9 to 9.3 percent of the primary habitat (crimson monkey-flower and water-cress) occurring below the 33,000-cfs stage, and 11.1 to 16.1 percent occurring below the 45,000-cfs stage (Stevens et al. 1995). The Kanab ambersnail population appears to change in abundance and distribution on a seasonal basis. The total estimated Grand Canyon population rose from 18,500 snails in March to as many as 104,000 in September 1995 as reproduction took place (Stevens et al. 1995). The proportion of the total estimated snail population occurring below the 33,000-cfs stage rose from 1.0 percent in March to 7.3 percent in September. The proportion of the population occurring below the 45,000-cfs stage was 3.3 percent in March, 11.4 percent in June, and 16.4 percent in September 1995.

*Northern Leopard Frog.*—The Glen Canyon population of this species would likely persist under no action conditions. In addition, other nearby sites may be colonized by frogs from this population, as has probably happened in the past (Stevens, written communication 1995). To date, these colonizing groups have been small (one to three frogs) and have not become established at other sites.

***Proposed Action.***—The test flow would affect the following four species.

*Southwestern Willow Flycatcher.*—The proposed action would not directly affect nest sites or individual southwestern willow flycatchers. The tamarisk trees currently used for nesting primarily lie at or above the 45,000-cfs stage and survived the high flows of 1983-86 (Reclamation 1995a). Nests are located 9 to 21 feet above the ground, further removing them from direct impact. In addition, breeding male southwestern willow flycatchers do not establish territories until May and would not be present on the site at the time of the test flow.

Patches of emergent marsh vegetation and other low-lying areas on bar faces (within proposed critical habitat) used by southwestern willow flycatchers for foraging are likely to be affected by restructuring of sediment deposits during the test flow. Marshes were not seriously scoured by a 45,000-cfs flow in 1980 (Stevens and Ayers 1991). Therefore, Reclamation has determined in its biological assessment that the test flow may affect the southwestern willow flycatcher but is not likely to adversely impact the species (Reclamation 1995a), and no mitigation measures are recommended. Without restructuring flows, sites supporting emergent marsh vegetation would be colonized by woody riparian vegetation, which may reduce habitat quality for the southwestern willow flycatcher.

FWS is interested in obtaining additional information on southwestern willow flycatcher habitat as a result of the test flow. FWS has identified reasonable and prudent measures in order to minimize impacts of the test flow on species habitat and to identify an allowable incidental take for habitat impacts. These measures include:

- Concluding the 45,000-cfs portion of the test on or prior to April 4
- Identifying understory characteristics at historic nest sites and initiating post-fledging studies
- Identifying relationships between flow velocity and stage and nest site habitat to determine incidental take

- Continuing survey/monitoring studies in 1996

- Continuing formal consultation after the test flow to include test results

FWS believes the implementation of these measures would reduce adverse effects on the species habitat to an acceptable level.

*Humpback Chub.*—The proposed action would be timed to limit potential adverse impacts to humpback chub, especially 1995-spawned fish. Most young chubs hatched in 1995 would still be in the LCR; a limited number of young chubs may be in the mainstem. In addition, the proposed action would occur before any significant movement of adult spawning chubs into the LCR. Adult chubs have survived flow events of much higher magnitude. Finally, the Glen Canyon Dam final EIS identified consideration of the previous year's production of humpback chub as a criterion for implementing a beach/habitat-building flow. The 1995 production of humpback chub was not strong (Reclamation 1995a).

The proposed action may affect humpback chubs in several ways. First, a high flow (relative to dam operations) in March may serve as a spawning cue for adults entering the LCR. Second, the test flow is expected to result in additional drift, which may provide additional food for staging adults. Third, young chubs in the mainstem may be lost during the test flow. Finally, the test flow would re-form backwaters and make them available for use by chubs later in 1996 and possibly beyond. For these reasons, Reclamation has determined in its biological assessment that the experimental test flow may affect humpback chubs but would not adversely affect the population or its habitat (Reclamation 1995a).

*Kanab Ambersnail.*—Because the Kanab ambersnail habitat has expanded toward the river under interim operations, flows above 20,000 cfs would cause some incidental take of individuals of the population. In their biological opinion on the preferred alternative in the *Operation of Glen Canyon Dam Final Environmental Impact Statement*, FWS indicated that such operations (including a beach/habitat-building flow) would not jeopardize the continued existence of the Kanab ambersnail. The opinion clearly states that allowable incidental take would be exceeded if 10 percent of the occupied habitat in Grand Canyon is inundated by flows. A test flow of 45,000 cfs would inundate about 11 to 16 percent of identified habitat (Reclamation 1995a).

Assuming long-term residence by Kanab ambersnails at the currently occupied site in Grand Canyon, this population has survived and recovered from numerous similar and higher flows of longer duration during predam conditions, plus six postdam flows in excess of 45,000 cfs (1965, 1980, 1983-86) (Reclamation 1995a). Short-term reduction in habitat area (by scouring) does not appear to adversely affect the long-term viability of this Kanab ambersnail population.

Reclamation believes that affected habitat would re-establish on the site based on an estimated 40-percent increase in area of habitat since completion of the dam and the introduction of non-native watercress (Reclamation 1995a).

Because of new information obtained since release of the Glen Canyon Dam Final EIS, Reclamation has reinitiated consultation and is currently working with FWS to finalize a plan to study the ambersnail population before, during, and after the test flow. This study would likely include:

- Assessing ambersnail population density
- Marking ambersnails occurring below the 45,000-cfs stage and moving about 90 percent of these to habitat above the 45,000-cfs stage
- Assessing survivorship and movement of the marked animals after the test
- Removing 100 snails for genetic study

Reclamation and FWS believe that the above activities would reduce the incidental take to acceptable levels.

*Northern Leopard Frog.*—The proposed action would affect the Glen Canyon population of northern leopard frogs. The magnitude of effects would depend on weather conditions and the population's previous experience with high flows. If adult frogs are active, they may be able to move to higher elevations. If the weather is cold and adults are inactive, they would be lost downstream. If eggs and/or tadpoles are present, they would be lost as high flows carry them downstream.

The population's history at the Glen Canyon site may also affect how it responds to the proposed action. If the population occupied Glen Canyon before high flows of 1983-86, it is likely the population would be reduced but quickly recover to no action levels. However, if the population has not experienced high flow conditions, it may be lost during the proposed action. The site currently occupied would be surveyed following the test, and a determination of population status made. If frogs are present, no further actions would occur. However, if the population is absent after the test, Reclamation would work with Glen Canyon National Recreation Area staff to evaluate management measures and goals, including the possibility of reintroducing frogs at the site.

As discussed in the SEDIMENT section of this EA, the proposed action would not result in large changes to beaches in Glen Canyon. Some sediment deposition (inches) may occur, and little scouring is anticipated. Given these assumptions, habitat conditions at the site now occupied by northern leopard frogs would change very little. Therefore, under the worst-case scenario, if the population were lost during the test flow, suitable habitat would remain if reintroduction were considered a viable management action.

## CULTURAL RESOURCES

The indicators used to evaluate impacts on cultural resources include **archeological sites** (both prehistoric and historic) and **Native American traditional cultural properties and resources.**

### Affected Environment

The affected area includes a 255-mile section of the Colorado River corridor within Glen and Grand Canyons and lands adjacent to the Havasupai and Hualapai Reservations, Lake Mead National Recreation Area, and within and adjacent to the Navajo Nation. The sites and properties relate to cultural traditions dating from approximately 2500 B.C. to the present. Indian tribes that have ancestral claims to the Grand Canyon and that continue to use the area today include the Havasupai, Hopi, Hualapai, Navajo, Southern Paiute, and Zuni.

A total of 475 prehistoric and historic sites have been located within the river corridor. Of these, 323 sites have been determined eligible for inclusion on the *National Register of Historic Places* (National Register). Anglo-American historic use of the area is represented by 71 sites dated between 1869 and 1940. One such resource, the Charles H. Spencer Steamboat, is listed on the National Register.

According to the Monitoring and Remedial Action Plan in attachment 5 of the final EIS, a total of 336 sites comprise the number of properties that either are impacted or potentially impacted by the existence of the dam (USDI 1995). Within this group of 336 sites, 263 sites exist on sediment deposits subject to erosion. Fewer than 37 of these sites lie above the LCR confluence and within the river stage associated with a flow of 45,000 cfs.

While archeological data provide some information about traditional uses of the area, each of the six tribes mentioned above has its own account of its history and relationships with other tribes and Grand Canyon. The Colorado River, the larger landscape in which it occurs, and the resources it supports are all considered sacred by Native Americans. Within this landscape, specific places—including shrines, burial locations, archeological sites, and plant and mineral collection areas—are considered important by each tribe. The locations of these traditional cultural properties are closely held secrets, and it is often with reluctance that tribes reveal specific sites. Although some resources may be linked to specific locations, some are place independent or encompass numerous locations. Values placed by Native Americans on the land in general—as well as on specific sites, locations, and natural resources—represent traditions that are centuries old.

The total number of Native American traditional cultural places potentially affected by the flow is confidential to each tribal signatory to the Programmatic Agreement on Cultural Resources.

Given the potential impacts of Glen Canyon Dam operations, Reclamation and NPS complied with National Historic Preservation Act documentation requirements. The Advisory Council on Historic Preservation, Arizona State Historic Preservation Officer, Reclamation, NPS, and Indian tribes completed the programmatic agreement, ensuring that Reclamation's and NPS's responsibilities under the act are satisfied. The agreement and accompanying plans dictate long-term monitoring that includes continuing consultation, identification, inspection, analysis, evaluation, and remedial protection actions to preserve historic properties within Glen and Grand Canyons.

## Environmental Consequences

Glen Canyon Dam changed the pattern of sediment deposition, erosion, and flooding through Glen and Grand Canyons. As a result, general loss of river-deposited high terraces has occurred. **Archeological sites** once protected by sandbars and terraces have become increasingly exposed to erosion by wind, rainfall, and riverflows. Neither alternative considered in this EA would alter postdam sediment input. Therefore, it is expected that impacts on archeological sites related to the existence—rather than operation—of the dam would continue regardless of alternative flow patterns. However, sandbar deposition from the test of the beach/habitat-building flow could protect the base of high terraces and temporarily slow their rate of erosion. Thus, it is anticipated that the effect of the proposed action on archeological sites would be generally beneficial. General sandbar deposition expected during the test flow also would benefit many of the **Native American traditional cultural properties and resources** (especially plant and animal species) that depend on sandbars and high terraces along the river.

A few archeological sites within the corridor below Glen Canyon Dam have the potential to be adversely affected by the test flow because of their unique locations. General sandbar deposition is expected to occur during the test flow where eddies exist (see SEDIMENT). However, in some locations, eddies would no longer exist under the higher test flow conditions, and net sediment erosion would likely occur. In consultation with the programmatic agreement signatories, Reclamation and NPS would identify those sites that may be adversely affected by the flow. Prior to the test flow, mitigation in the form of data recovery would be conducted on the portions of those sites that are likely to be damaged.

Effects of the proposed action would be monitored throughout the length of the river corridor by NPS and the tribes during regularly scheduled monitoring trips after the test flow. Dives before and after the test flow would monitor the effects of the flow on the Charles H. Spencer Steamboat.

The actions that would be taken to mitigate adverse effects of the test flow on cultural resources lie within the scope of the programmatic agreement, which addresses normal operations of Glen Canyon Dam as defined in the final EIS. Hence, these actions would satisfy National Historic Preservation Act responsibilities of Reclamation and NPS for considering the effect of the test flow on cultural resources.

## RECREATION

The indicators used to evaluate impacts on recreation resources include **fishing, day rafting, white-water boating, lake activities and facilities, economic value** of recreation, and **regional economic activity**.

### Affected Environment

**Fishing** in Glen Canyon occurs mostly from boats, but some anglers wade in the area around Lees Ferry. Rapid increases in river stage may place these wading anglers at risk.

Only flows above 33,200 cfs affect the quality of **day rafting**. During these rare floodflows, use of dam outlet works and/or spillways prevents launching from the site below the dam. Day rafters must motor upstream from Lees Ferry and then float back down to the starting point, which reduces the trip quality for many users.

The wilderness characteristics of **white-water boating** trips are influenced by fluctuating river stages and by the conditions of beaches, vegetation, and other features of the riparian zone. Many river users believe that daily fluctuations detract from a trip's wilderness character (Shelby, Brown, and Baumgartner 1992).

White-water trip safety depends both on flow levels and on the timing and variation in river stage. Very low flows may make some rapids impassable, and very high flows may create additional risks of capsizing.

Useable camping beach area above the high water line is limited in narrow reaches of the canyon. In the short term, high flows and large fluctuations in river stage limit usable beaches by completely inundating some and reducing the usable area of others. Low flows result in more available and usable beaches. In the long term, vegetative overgrowth and beach erosion would reduce usable beach area.

**Lake activities and facilities** at Lakes Powell and Mead, particularly related to powerboating and powerboat access, can be negatively impacted by low lake levels and large changes in lake level during the peak recreation season. Navigation through the Lake Mead delta can be especially difficult during periods when lake levels are drawing down.

Net **economic value,** a measure of the value over and above the costs of participating in a recreation activity, 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.

**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.

## Environmental Consequences

***No Action.***—If angler use is similar to that in 1991, approximately 2,500 **fishing** trips (20 percent of annual angling use) would occur during March and April. Under no action, upramping and downramping operations are restricted to 2,500 cfs and 1,500 cfs, respectively. These slow changes in river stage pose relatively little risk to wading anglers.

If the pattern of **day rafting** use is similar to that in 1991, approximately 2,300 day use rafting trips (7 percent of total annual day rafting use) would occur during March and April. Flows likely would remain under 20,000 cfs under no action. Day use rafting trips would launch from below the dam during 1996, and there would be no effect on trip quality.

If private and commercial **white-water boating** use is similar to that in 1991, approximately 400 individuals would take private trips and 370 individuals would take commercial trips during March and April. This represents 13 percent and 3 percent of the total annual private and commercial trips, respectively. Useable beach area would be limited in some narrow reaches of the canyon. Vegetative encroachment and net beach erosion would continue.

Under no action, riverflows would vary annually between 5,000 and 20,000 cfs; daily change in flow would be no greater than 8,000 cfs. The wilderness characteristics of a white-water boating trip would be relatively high. Minimum flows of 5,000 cfs or greater would not impede passage down the river. The range of flows expected under no action are routinely experienced by river runners.

Navigation through the Lake Mead delta is expected to be easier during 1996 than in 1995 due to higher lake elevations (see SEDIMENT discussion earlier in this chapter). As shown in figure 5, the elevation of Lake Powell is expected to vary by about 19 feet during water year 1996, which is typical and would not affect **lake activities and facilities.**

The net **economic value** of recreation in Grand Canyon was estimated for a number of different types of water years in the Glen Canyon Dam EIS (USDI 1995). Unfortunately, none of the water years analyzed was an 11.3-maf year. However, a reasonable estimate can be obtained by interpolation. Linearly, interpolating between water year 1987 (13.43 maf) and water year 1989 (8.23 maf) yields $11.6 million in 1991 dollars. Updating this figure to 1995 dollars using the relevant Consumer Price Index (1.114), the net economic value of recreation under no action would be approximately $12.9 million (1995 nominal dollars).

The **regional economic activity** that results from nonresident anglers, white-water boaters, and day rafters who visit the region has been estimated (USDI 1995) at approximately $25.7 million (1995 nominal dollars). As discussed in Douglas and Harpman (1995), recreational use in the region comprised of Coconino and Mojave Counties supports approxi-mately 585 jobs. Of this total, there are 21 licensed fishing guides (Gunn 1996b).

***Proposed Action.***—The increased water velocity during the test flow would make boat handling and wading more difficult. Advance publicity, onsite warnings provided by management agencies, and the obvious nature of the test flows would allow anglers to make personal assessments of danger during this period. Judging by the 1991 use pattern, the number of anglers affected by the test flow would be relatively small—3 percent of the annual use over the 8-day high flow period, if uniformly distributed. During the remainder of the year, **fishing** safety would be unchanged.

Fishing quality, as measured by the number of fish caught, may be affected by the proposed action. The nature, timing, and extent of this impact, if any, remain the subject of considerable speculation. During the 4 days of low steady flows preceding and following the test high release, angling may be quite good (Maddux et al. 1987). During the upramping portion of the test flow, increased water velocities would dislodge aquatic plants, insects, and other aquatic life from the substrate. The increased drift of these food sources downstream may stimulate trout feeding and may improve angling success for a short time. During the high release, high water velocities, increased stream width, and turbid conditions would make angling difficult. It is likely that angler success would be reduced during this period. As a result, at least one company has canceled all guided fishing trips during this period (Gunn 1996a).

The test flow is likely to cause downstream displacement of larval and juvenile trout. Should this displacement be substantial, a large portion of the year class could be lost. All other factors being the same, the future population of catchable-size trout would be affected. The extent to which this downstream displacement may affect the future trout population in the Glen Canyon reach is unknown but will be the subject of research during water year 1996. This downstream displacement can be mitigated by replacing the naturally spawned young-of-year fish with stocked fingerlings.

The test flow also may have delayed impacts on the adult trout population. If the test flow were to cause a decrease in the abundance and distribution of the food sources preferred by trout, a parallel decline in the condition and health of adult trout could occur. The likelihood of this occurring is believed to be low and the effects temporary; however, some risk is involved.

During the test flow, releases would exceed 33,200 cfs, and the outlet works would be used, which would preclude launching **day rafting** trips from the base of the dam. Day use rafting trips could still be launched from Lees Ferry and boats moved upstream under power. However, the current concessionaire plans to suspend all trips during the 8 days in which the outlet works are in use (Crane 1996). Assuming that day rafting use is uniformly distributed in March and April, relatively few individuals (less than 1 percent of the annual total) would make day use rafting trips during this period. During the remainder of the year, day use rafting operations would not be affected.

During the test flow, increased river stage would reduce the size of camping beaches, and some camping beaches may be completely inundated. River runners would need to use caution in selecting their campsites. During the test flow, it is expected that sand would deposit on most beaches. Some eroded beaches would be re-formed, and some camping beaches would increase in area while others would decrease in area. Some riparian vegetation may be scoured from sediment deposits. Other vegetation would be buried under new sediment deposits. On the whole, usable beach area is expected to increase. The duration of this effect is unknown but is expected to range from months to years.

Compared to no action, the safety of **white-water boating** would decrease somewhat during the test flow. Water velocities would be much higher, and the size and strength of some waves would greatly increase. At other locations, increases in river stage would "wash out" some rapids and make white-water boating safer. During the remainder of the year, river safety would be unchanged.

Judging by 1991 use data, few commercial white-water boaters would be on the river during the test flow; therefore, there would be little impact on commercial boaters. Some private white-water boating trips are scheduled to be on the river during the test flow. Thus far, NPS has not received any requests to change launch dates for these individuals (Cherry, verbal communication 1995).

Wilderness values are expected to improve over no action conditions. During the test flow, the river would more closely approximate predam spring conditions. Following the test flow, reformation of sediment deposits is expected to improve the natural characteristics of the riparian system.

Similar to the No Action Alternative, navigation through the Lake Mead delta is expected to be easier in 1996 than in 1995.

The total variation in the elevation of Lake Powell during the year would be the same under both alternatives. Compared to no action, the elevation of Lake Powell is expected to be 1.3 feet higher in February and 1.2 feet lower in April (see figure 5). **Lake activities and facilities** are not expected to be affected by these minor differences in lake level.

No net change in white-water boating use or significant change in trip value is expected to result from the proposed action. Therefore, net **economic value** is expected to be identical to no action or approximately $12.9 million (1995 nominal dollars) during 1996.

An adverse effect on **regional economic activity** could result from changes in recreation visitation. Based on 1991 nonresident recreation use, the assumptions that anglers and day rafting would not take place during the 8 days of high flows and that these recreators do not visit at any other time of the year, approximately 328 (1 percent of annual) fewer day rafting trips and 308 (3 percent of annual) fewer fishing trips could result. Applying the 1991 per trip expenditures (USDI 1995) to this change in visitation and using the appropriate Consumer Price Index (1.114) indicates that lost recreational expenditures could approximate $100,000 (1995 nominal dollars).

However, an offsetting increase in **regional economic activity** is likely to result from the research activities associated with the test flow. As described elsewhere in this document, research expenditures would be approximately $1.5 million. A substantial portion of this sum would be spent in the region by locally based researchers, institutions, and contractors. In addition, members of the press, Government officials, and other researchers are expected to stay in the area during the test flow. The net effect of the test flow on **regional economic activity** is likely to be positive. However, temporary adverse effects on fishing guide and day use rafting guide income are likely.

## HYDROPOWER

The indicators used to evaluate impacts of the alternatives on hydropower are **power operations** and **economic and financial costs.**

### Affected Environment

Glen Canyon Dam and Powerplant are part of the Colorado River Storage Project (CRSP), one of the Federal projects from which Western Area Power Administration (Western) markets power. Glen Canyon Dam generates approximately 75 percent of the total CRSP power.

The total annual amount of energy produced by the dam is based on actual water conditions. Western's Salt Lake City Area Integrated Project (SLCA/IP) annually markets more than 4 billion kilowatthours (kWh) from Glen Canyon Powerplant to 198 entities principally in the six-State area shown in figure 6.

Hydropower plants such as Glen Canyon can generate electricity without causing air pollution or using nonrenewable fuels. Also, they are able to rapidly change generation levels to satisfy changes in the demand for electricity. This capability is termed "load following."

Power is most valuable when it's most in demand—during the day when people are awake and industry and businesses are operating. Water from Glen Canyon Dam is used for load following as much as possible, particularly during this onpeak period of the day. For purposes of this analysis, the onpeak period is defined as the hours from 7:00 a.m. to 11:00 p.m.

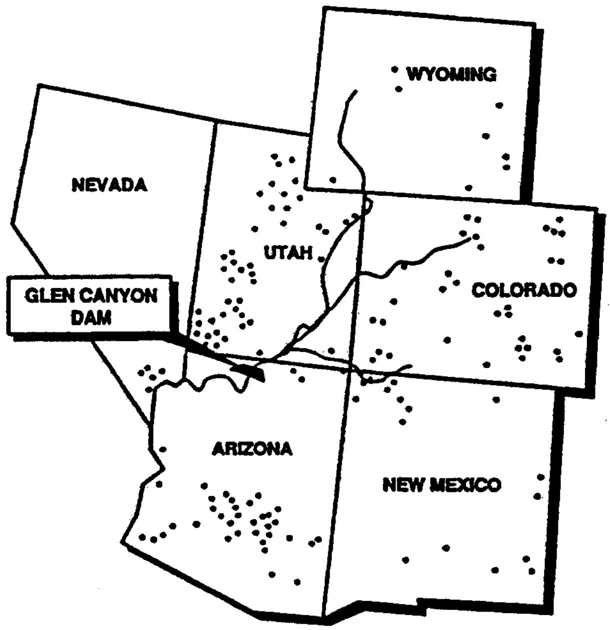


*Figure 6.—Power from Glen Canyon Dam is sold over a six-State area.*

There are approximately 5.6 million end use retail consumers (residential, agricultural, commercial, and industrial) in the six-State area where power from Glen Canyon Powerplant is sold. Approximately 3.9 million (70 percent) of these end users do not receive power from the dam. Nearly 1.3 million (23 percent of the total) end users are served by large systems that have their own generation capability and rely on Federal power for a relatively small proportion of their energy needs. The remaining 0.4 million (7 percent of the total) end users are served by small systems that rely heavily on Federal power to supply their needs.

Retail power rates paid by end use consumers are affected to varying degrees by Western's wholesale rate. The extent of this effect, if any, depends on the proportion of Federal hydropower used by the customer's utility to meet their power needs, the wholesale rate, and the cost of replacement power.

Western's ratesetting procedure differs from that of a profit-making utility. Western charges are based on a rate which is designed to ensure that revenues are sufficient to repay all costs assigned to the CRSP power function within a prescribed period. These costs include annual power operation and maintenance costs, certain environment-related costs, power facilities construction costs, and irrigation project costs allocated to the power function.

## Environmental Consequences

***No Action.***—Monthly release volumes were planned at the beginning of the water year during the AOP process (Reclamation 1995b). Most probable monthly release volumes under no action are listed in table 2; hourly operations are restricted under interim flows as described in table 1.

This power analysis is similar in approach to previous analyses undertaken by Western (Western 1993a, 1993b, 1993c). The assumptions made about load curves and prices differ from these previous efforts. In this analysis, an aggregate hourly load curve was assumed to represent system demand during water year 1996. This aggregate load curve was constructed from 1994 hourly load data reported by Salt River Project, Platte River Power Authority, Colorado Springs Utilities, and Deseret Generation and Transmission. This publicly available data was obtained from information provided to the Federal Energy Regulatory Commission on form 714. The 1994 load data was escalated by 2 percent per annum to account for load growth, adjusted for the number of days and the pattern of weekdays and weekends in 1996. End-of-month reservoir elevations corresponding to most probable monthly release volumes were obtained from the Colorado River Simulation System model (Reclamation 1988). Using these inputs, hourly **power operations** for all 12 months under no action were simulated using a variant of the peak-shaving model (Environmental Defense Fund 1988).

Using this methodology, a no action hourly pattern of generation for water year 1996 was estimated. A summary of monthly generation for the No Action and Proposed Action Alternatives is shown in table 5.

Table 5.—Monthly energy generated in water year 1996 at Glen Canyon Dam by alternative under most probable release scenario

| Month | No Action (MWh)[1] | Proposed Action (MWh) | Difference (MWh) |
|---|---|---|---|
| October | 432,765 | 432,765 | 0 |
| November | 431,910 | 431,910 | 0 |
| December | 454,150 | 454,150 | 0 |
| January | 522,096 | 451,734 | -70,362 |
| February | 448,481 | 425,980 | -22,501 |
| March | 403,398 | 456,094 | 52,696 |
| April | 406,257 | 427,691 | 21,434 |
| May | 406,043 | 357,947 | -48,096 |
| June | 461,574 | 437,203 | -24,371 |
| July | 523,346 | 535,234 | 11,888 |
| August | 532,429 | 532,131 | -298 |
| September | 419,972 | 395,871 | -24,101 |
| Total | 5,442,421 | 5,338,710 | -103,711 |

[1] Megawatthours.

Impacts on the power system presented in this EA are based on an evaluation of the difference between no action and the proposed action. Consequently, **financial and economic** estimates are unavailable for no action.

The retail rates paid by approximately 30 percent of the end users in the region are affected by Western's SLCA/IP wholesale rate. The no action rate, established on December 1, 1994, is 20.17 mills per kWh (mills/kWh). Using the revised small system retail spreadsheets developed for the Glen Canyon Dam EIS (Power Resources Committee 1993) and inserting this SLCA/IP rate yields a no action weighted average small system retail rate of 69.60 mills/kWh.

***Proposed Action.***—Monthly release volumes under the proposed action are listed in table 2. Hourly operations would be constrained under no action operations as described in table 1.

Several features of the proposed action impact **power operations** at Glen Canyon Dam. These can be categorized into two periods: impacts during the months the test flow occurs and impacts during the other months in the water year.

The impacts during the test flow period are:

1. During the 4 days of steady flows preceding the high release, on average, less power is generated than needed to supply firm load (see figure 2).

2. During the high release, the outlet works would be used to release flows in excess of 30,000 cfs, bypassing the powerplant. Water released through the outlet works is considered "spilled" and is unavailable to produce electricity at Glen Canyon Dam. In figure 2, all releases above the 30,000-cfs line are considered spilled.

3. During the high release, more power would be generated than needed to supply system firm load.

4. During the 4 days of steady flows following the high release, on average, less power is generated than needed to supply firm load (see figure 2).

Impacts on the power system also would occur during the other months in water year 1996. These impacts would occur because water volumes would be shifted from the months of January, February, May, June, and September to March and April for the test flow. From a power perspective, the resulting pattern of monthly release volumes is less desirable. For example, under the proposed action, there is less water available in January—a peak power demand month—than there is under no action.

Both economic and financial impacts are expected to result from the proposed action. Economic impacts are the dollar value of real resources committed by the United

States as a result of the test flow, including the additional use of fuels such as gas and coal. Due to the short duration of the test flow, no new capital investments are expected, and none were considered in this analysis.

The **economic** analysis illustrates the estimated cost to the Nation of implementing the proposed action. Explicitly omitted from this, and all economic analyses, is consideration of investments made prior to the period of analysis. These expenditures are considered sunk or fixed costs. This concept is relevant to the short-term analysis presented here because the price of replacement power may contain both a fixed and a variable cost component. The fixed cost component of replacement power is a prorated sunk cost. This component of the cost of purchased power was excluded from the economic analysis through the use of spot market prices which reflect only the variable cost of generation.

In the economic analysis, spot market prices were used to value both purchases and sales. The prices used are 1998 hourly mean weekday prices deflated to 1996 dollars using the forecast producer price index for electricity (0.8613). The spot market prices in attachment C were estimated using Argonne National Laboratory's spot market network model (VanKuiken et al. 1994), which was used for Western's Power Marketing EIS (Western 1994).

The **financial** analysis provides an estimate of the monetary cost to Western resulting from the proposed action and does not account for those utilities beneficially affected. Financial impacts include both real resource (economic) costs and sunk costs. For the purposes of this analysis, replacement power purchases were assumed to be made at existing contract prices, and spot market prices were used to value sales. The prices for purchased power used in the financial analysis are found in the column labeled "RMG Contract Price" in attachment C. These prices are reflective of Western's replacement power costs.

Hourly operations under the proposed action were simulated using the same methods described for no action for 10 months of water year 1996. With the exception of the test flow period in March and April, the hourly pattern of flow and generation was simulated using the peak shaving model. During the test flow period, the hourly pattern of releases described under the proposed action was used.

Although the generators at Glen Canyon Powerplant have a combined capacity of 1,356 megawatts (MW), there are concerns about running them continuously at 100-percent output for 7 days. For this reason, generation during the test flow was assumed to be limited to about 1,166 MW (30,000 cfs, based on projected reservoir elevations). This operational constraint was incorporated in the March and April pattern of hourly generation.

As shown in table 5, approximately 103,711 MWh (2 percent) less energy would be generated under the proposed action. The difference between the two alternatives reflects the approximately 217,000 acre-feet of water that would be spilled during the test flow.

Using the pattern of hourly generation simulated under no action and the proposed action, the difference in hourly generation was calculated for each hour in a most probable release water year 1996. The hour-by-hour economic and financial cost of this difference was then evaluated using the prices shown in attachment C. If generation during a particular hour under the proposed action exceeded generation under no action, the appropriate sales price for that hour was applied to the difference. If generation for a particular hour under the proposed action was less than that under no action, the appropriate purchase price for that hour was applied to the difference. A summary of the estimated economic and financial cost for each month is shown in table 6.

As shown in table 6, there are no differences in cost during the months of October, November, December, and August. Compared to no action, additional economic and financial costs are incurred during the months of January, February, May, June, and September. These costs result from unfavorable shifts in monthly release volumes that would be necessary to accommodate the test flow. Economic and financial benefits would occur during the months of March, April, and July. During March and April, generation levels under the proposed action greatly exceed those under no action. The resulting economic and financial benefits during March and April result from additional spot market sales during these months. The benefits realized during July result from a favorable shifting of water volume to this peak demand month.

Table 6.—Monthly financial and economic cost of the proposed action under most probable release scenario

| Month | Financial cost ($) | Economic cost ($) |
|---|---|---|
| October | 0.0 | 0.0 |
| November | 0.0 | 0.0 |
| December | 0.0 | 0.0 |
| January | 1,571,000 | 1,271,000 |
| February | 510,000 | 402,000 |
| March | (1,080,000) | (1,102,000) |
| April | (286,000) | (392,000) |
| May | 1,189,000 | 867,000 |
| June | 545,000 | 559,000 |
| July | (237,000) | (237,000) |
| August | 0.0 | 0.0 |
| September | 534,000 | 480,000 |
| Total | 2,746,000 | 1,848,000 |

The proposed action would result in net economic and financial power costs of $1.848 million and $2.746 million, respectively, during a most probable release water year 1996. The difference between the economic and financial costs represents a net transfer of $898,000 from Western to the suppliers of the replacement power.

The economic and financial costs shown in table 6 are based on the most probable pattern of releases (table 2). However, actual releases may be less than or greater than the forecast. Since the economic and financial cost of the test flow is dependent on the amount and pattern of water released during the year, the analysis described previously was repeated for the forecast minimum probable release scenario (9.03 maf) and the forecast maximum probable release scenario (16.4 maf). The estimated economic costs across the range of anticipated hydrologies are shown in table 7. The estimated financial costs across the range of anticipated hydrologies are shown in table 8.

Table 7.—Economic cost of lost power under the proposed action by anticipated hydrology

| Hydrology scenario | Annual release volume (maf) | Economic value of power ($) |
|---|---|---|
| Maximum probable | 16.40 | 525,000 |
| Most probable | 11.32 | 1,848,000 |
| Minimum probable | 9.03 | 2,231,000 |

Table 8.—Financial cost and potential rate impacts under the proposed action by anticipated hydrology

| Hydrology scenario | Financial cost of power ($) | Financial cost of research ($) | Total financial cost ($) | Potential SLCA/IP wholesale rate[1] ($/MWh) | Potential small system retail rate[1] ($/MWh) |
|---|---|---|---|---|---|
| Maximum probable | 1,628,000 | 1,500,000 | 3,128,000 | 20.12 | 69.61 |
| Most probable | 2,746,000 | 1,500,000 | 4,246,000 | 20.12 | 69.61 |
| Minimum probable | 2,786,000 | 1,500,000 | 4,286,000 | 20.12 | 69.61 |

[1] The rate effects shown here assume that Western will bear the financial cost of the test flow. This may or may not occur. See text for discussion on reimbursability.

As shown in table 7, the economic costs of the proposed action range from $525,000 to $2,231,000 with an expected economic cost of $1,848,000. These costs represent the value of the additional fossil fuels burned to make electricity during the water year.

The costs of research are not included in table 7 because these costs represent an income transfer from one group (power users) to another group (researchers). This transfer would have no net effect on the economy of the United States.

As shown in table 8, the total financial cost of the proposed action includes both the cost of replacing power lost during the water year 1996 and the cost of research (described in chapter II). Across the range of anticipated hydrology, these costs range from $3,128,000 to $4,286,000 with an expected cost of $4,246,000. To place this in perspective, approximately $147 million in revenues are expected in water year 1996 from CRSP power sales. This expected cost represents a 3-percent decline in power revenues.

Ordinarily, these costs would impact the wholesale rate. Section 1807 of the Grand Canyon Protection Act provides that all costs of the Glen Canyon Dam EIS, including supporting studies and long-term monitoring, shall be nonreimbursable except during the years 1993-97. In those years, the Secretary of the Interior must total the budget impact of all titles in the act and determine whether the receipts exceed all annual costs, including the EIS, studies, and monitoring. However, should the Secretary determine that the net offsetting receipts for fiscal year 1996 have increased, the costs would be considered a nonreimbursable expense. As such, these funds would be treated as having been repaid and returned to the general fund. Under this condition, the proposed action would have no impact on the SLCA/IP firm power rate.

If the Secretary determines that a reduction in net offsetting receipts has occurred in fiscal year 1996, the total financial costs would be considered reimbursable. As shown in table 8, such a determination could result in an SLCA/IP power rate increase of 0.05 mills/kWh (0.2-percent increase) for all anticipated hydrologies compared to no action (Moulton, written communication 1996).

If the SLCA/IP wholesale rate increases, there could be a small impact on the retail rates of end users in the region. Using the spreadsheet for interim operations and inserting the range of SLCA/IP rates yields a weighted average small system retail rate of 69.61 mills/kWh (0.01-percent increase).

A final Secretarial determination has not yet been made. If the additional purchased power costs are determined to be nonreimbursable, there would be no change in Western's wholesale rate, and the proposed action would have no effect on the retail rates of end users.

## AIR QUALITY

### Affected Environment

Glen Canyon Dam is one component of an interconnected utility system. Air quality in Grand Canyon and the surrounding region is affected by emissions of particulates, carbon compounds, sulphur dioxides ($SO_2$), and nitrous oxides ($NO_x$) from powerplants and other emission sources. It also is affected by weather, wind, and other environmental factors.

Powerplant emissions result when fossil fuel is burned to provide electric power. Annual powerplant emissions in the region rise and fall with the availability of water to generate hydropower. For example, during an 8.23-maf year when the reservoir is full, approximately 4.0 million MWh of hydropower is generated at Glen Canyon Dam. During an 11.3-maf year such as 1996, approximately 5.5 million MWh of hydropower is generated at Glen Canyon Dam. There is a difference of 1.5 million MWh or 38 percent between these 2 years.

Differences in the amount of energy generated at Glen Canyon Dam lead to changes in generation levels at other interconnected powerplants. This results in differential emission levels in the six-State marketing area.

## Environmental Consequences

***No Action.***—Grand Canyon enjoys some of the cleanest air in the lower 48 States, resulting in a visual range that sometimes exceeds 240 miles. However, haze—consisting of air pollution brought into the Grand Canyon area from urban and industrial areas in the surrounding region—results in a summertime average visibility of only 100 miles.

Regional air quality is comparatively good by national standards. Locally significant degradation of air quality does result from the operation of some fossil-fueled powerplants.

***Proposed Action.***—The proposed action would result in both positive and negative air quality impacts during the water year.

Less hydropower would be produced during the months of January, February, May, June, and September than under the No Action Alternative. This would require increased levels of generation at other powerplants in the region. A least-cost mix of hydro, coal, and gas plants would be used to replace the hydropower that would otherwise have been generated. As a result, there would be an increase in the emission of $SO_2$ and $NO_x$ in these months. More hydropower would be produced during the months of March, April, and July. During these months, other hydro, coal, and gas plants would generate less electric power. As a result, there would be a decrease in the emission of $SO_2$ and $NO_x$ during these months.

Compared to no action, 103,737 MWh or 2 percent less hydropower would be produced during the water year, resulting in a net increase in $SO_2$ and $NO_x$ emissions from interconnected powerplants in the region. However, compared to the annual variation in emissions due to water availability, this increase is not likely to be significant.

## CUMULATIVE IMPACTS

Cumulative impacts on the environment result from incremental impacts of the action when added to other past, present, and reasonably foreseeable future actions, regardless of what agency (Federal or non-Federal) or person undertakes such actions. Since there are no other anticipated actions on the Colorado River between Lakes Powell and Mead, there are no cumulative impacts in the immediate area.

Physical and biological resources are closely linked in the ecosystem below Glen Canyon Dam. The impacts based on these linkages have been analyzed in the sections on those resources in this chapter.

### Power

Because there is more water available in water year 1996, 38 percent more electrical energy will be produced this year than was produced in any of water years 1988 through 1995. Consequently, less energy would be produced by burning fossil fuel to produce power. Only 2 percent less power would be produced at Glen Canyon Dam under the proposed action. This difference is very small when compared to the increase in electrical generation relative to any of those previous water years. Power rates are not expected to change as a result of the proposed action.

### Air Quality

Relative to recent water years, air quality in water year 1996 would be improved under either alternative because more hydropower would be generated at Glen Canyon Dam and less at thermal plants in the region, resulting in a net decrease in emissions. The proposed action would result in more emissions than no action. However, compared to the typical monthly variation in emissions resulting from differential levels of hydropower generation, the difference would be negligible.

## UNAVOIDABLE ADVERSE IMPACTS

Some unavoidable adverse impacts likely would occur to trout, Kanab ambersnails, and northern leopard frogs. These impacts are described earlier in this chapter. Also, bypassing the powerplant with approximately 15,000 cfs of water for 7 days would cause an unavoidable loss of power generation. This is discussed in detail in the HYDROPOWER section of this chapter.

## IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

Under the proposed action, some archeological and cultural sites possibly could be damaged or lost. If this occurs, these sites can never be reconstructed. Although data recovery would provide mitigation, such impacts would be irreversible.

Some endangered Kanab ambersnails could be inundated or displaced downstream under the proposed action. However, no significant impact on the population is anticipated. Also, a small population of leopard frogs in Glen Canyon would be inundated or displaced downstream. There is a good chance that this population would be lost. These issues are discussed in detail under ENDANGERED AND OTHER SPECIAL STATUS SPECIES.

During the test flow, 217,000 acre-feet of water would be spilled. This amount of water could generate approximately 104,000 MWh of electricity. Under the proposed action, the opportunity to generate this power at Glen Canyon Dam would be irretrievably lost.

## INDIAN TRUST ASSETS

Reclamation policy is to protect American Indian Trust Assets from adverse impacts resulting from its programs and activities when possible. Indian Trust Assets are property interests held in trust by the United States for the benefit of Indian tribes or individuals. Although there is no concise legal definition of Indian Trust Assets, courts have traditionally interpreted them as being tied to property. Lands, minerals, and water rights are common examples of trust assets.

No adverse impacts to Indian Trust Assets are anticipated from the proposed action.

The possibility exists for discovery of items identified in the Native American Graves Protection and Repatriation Act of 1990. Potential impacts to human remains and objects are addressed in the Programmatic Agreement on Cultural Resources and accompanying monitoring and remedial action plan in the final EIS (USDI 1995).

The Hualapai Tribe has asserted that there are Indian Trust Assets within its reservation boundary and that these are affected by dam operations. The claimed resources include land, recreation, fish, vegetation, wildlife, and cultural resources. Reclamation does not agree that trust assets are affected because, in Reclamation's opinion, dam operations do not affect reservation lands. Reclamation has concluded that the proposed action would have beneficial impacts on those resources of concern to the Hualapai Tribe. An analysis of the impacts on these resources is presented under CULTURAL RESOURCES earlier in this chapter.

## ENVIRONMENTAL JUSTICE IMPLICATIONS

The proposed action does not involve facility construction, population relocation, health hazards, hazardous waste, property takings, or substantial economic impacts. Neither of the alternatives analyzed in this EA has an adverse human health or environmental effect on minority and low income populations as defined by environmental justice policies and directives (see CULTURAL RESOURCES and INDIAN TRUST ASSETS earlier in this chapter).

## INTERNATIONAL IMPACTS

The annual amount of water released from Glen Canyon Dam and ultimately delivered downstream under the proposed action is identical to that released under no action. There will be no impact on either the quality or quantity of water specified for delivery under the Mexican Water Treaty of 1944.

Compared to no action, additional fossil fuels would be used to produce electricity under the proposed alternative. The bulk of this replacement power would be generated by coal and gas plants that use fuels of domestic origin. A small possibility exists that some electrical power could be produced by powerplants which burn oil, and some of this oil could be imported. If so, the amount of imported oil used as a result of the proposed action would be insignificant.

CHAPTER IV
# *Consultation and Coordination*

This chapter summarizes public involvement and coordination with State and Federal agencies, tribal governments, and private organizations that occurred during planning and preparation of this environmental assessment. It also includes the distribution list for this document.

## PUBLIC INVOLVEMENT

Beach/habitat-building flows were discussed throughout the Glen Canyon Dam EIS process, which began in 1990 at numerous Cooperating Agency and interested party meetings.

The public process to develop the one-time test of the beach/habitat-building flow in water year 1996 began in June 1995 and has involved numerous Government agencies (both State and Federal), Native American tribes, and private organizations. These participants are identified in the distribution list at the end of this chapter.

The process of developing and implementing the test flow was presented to the Transition Work Group on June 21, 1995. It was further discussed at work group meetings on August 30 and November 30, 1995. During these meetings, participants were given the opportunity to present data and voice opinions about the test flow. These meetings—along with this document's distribution for review and comment—constitute appropriate public involvement.

The Colorado River Basin States have been kept apprised of the progress pertaining to the test flow. The involved States were sent all information on the Transition Work Group meetings and participated in the meetings described above.

Reclamation received 16 letters containing about 350 specific comments on the draft EA/FONSI. Most comments requested clarifications or editorial changes. All comments were read and considered by the preparers of this document, and text changes were made where deemed appropriate.

## CONSULTATION

In compliance with the Grand Canyon Protection Act, a Transition Work Group meeting on November 30, 1995, was specifically identified as consultation to deviate from interim operations.

Formal consultation with the Basin States on the 1996 Annual Operating Plan was accomplished at a meeting of the Colorado River Management Work Group in Las Vegas, Nevada, on July 18, 1995. The Basin States' representatives did not object to the test flow as described in the EA, providing an agreement could be reached on long-term operating procedures for implementing future beach/habitat-building flows. Agreement was reached and was included in the AOP for water year 1996, which was signed by the Secretary on December 15, 1995 (Reclamation 1995b). It states, in part:

> *This approach would attempt to accomplish the objectives of the Beach/Habitat Building Flow recommendation of the Glen Canyon Dam EIS utilizing reservoir releases in excess of powerplant capacity required for dam safety purposes during high reservoir conditions at Glen Canyon Dam. Such releases would be consistent with the 1956 Colorado River Storage Project Act, the 1968 Colorado River Basin Project Act and the 1992 Grand Canyon Protection Act.*

The Secretary's commitment to operate Glen Canyon Dam pursuant to this agreement is stated in his letter to the Colorado Basin States Governors transmitting the 1996 AOP:

> *It is my intention that Glen Canyon Dam will be operated on a long term basis in conformance with the proposal described in the 1996 AOP regarding Beach/Habitat Building Flows.*

## Fish and Wildlife Coordination

Consultation with the U.S. Fish and Wildlife Service and the Arizona Game and Fish Department was conducted throughout the process, and they were included in the formulation of the test flow plans. Both agencies were represented on the EIS team, Cooperating Agencies, and the Transition Work Group. The Fish and Wildlife Coordination Act report dated June 28, 1994, and the biological opinion dated December 21, 1994—written in connection with the EIS—both strongly supported beach/habitat-building flows. FWS issued a no jeopardy biological opinion on the test flow on February 16, 1996.

## Cultural Resources

Reclamation and NPS have complied with National Historic Preservation Act documentation requirements by entering into a programmatic agreement on cultural resources regarding Glen Canyon Dam operations with the Advisory Council on Historic Preservation, Arizona State Historic Preservation Officer, and Indian tribes. The programmatic agreement and accompanying plans dictate long-term monitoring that includes continuing consultation, identification, inspection, analysis, evaluation, and remedial protection actions to preserve historic properties within Glen and Grand Canyons. This agreement forms the framework for consultation on the effects of particular dam operations, such as the test flow, on cultural resources.

In consultation with NPS and the tribes, Reclamation has identified archeological sites and traditional cultural properties that are likely to be adversely affected by the test flow. Adverse effects of the test flow on the few sites that may suffer damage will be mitigated by data recovery prior to the flow. A proposal outlining data recovery, planned prior to the test flow, would be reviewed by all signatories before this work is undertaken.

The remainder of proposed cultural resources activities is geared toward gathering data about the effects of the flow on cultural sites within the river corridor. Dives by NPS personnel are planned before and after the test flow to gauge effects on the Charles H. Spencer Steamboat. Native American groups were afforded the opportunity to submit plans for monitoring the test flow effects on traditional cultural properties. Reclamation will integrate tribal and NPS recommendations for monitoring; recommendations will be reviewed by all programmatic agreement signatories prior to the test flow.

## EXECUTIVE ORDERS

Executive Order 11988 requires Federal agency avoidance of long- and short-term adverse impacts to flood plains; and Executive Order 11990 requires minimization of the destruction, loss, or degradation of wetlands and preservation and enhancement of the natural and beneficial values of wetlands. The proposed action is part of the research necessary to determine the best management practices for the ecological health and well-being of the flood plains and wetlands of Glen and Grand Canyons. The public review required by both Executive Orders has been achieved through the EIS, public scoping, Transition Work Group, and AOP processes.

## DISTRIBUTION LIST

### Federal Agencies

Department of the Army
- Corps of Engineers, Dallas, Texas; Salt Lake City, Utah; Phoenix, Arizona

Department of Energy
- Western Area Power Administration, Sacramento, California; Golden and Loveland, Colorado; Salt Lake City, Utah; Phoenix, Arizona

Department of the Interior
- Bureau of Indian Affairs; Hopi Agency, Keams Canyon, Arizona; Truxton Canon Agency, Valentine, Arizona; Navajo Area Office, Gallup, New Mexico; Southern Paiute Field Station, St. George, Utah
- U.S. Fish and Wildlife Service, Phoenix, Arizona; Flagstaff, Arizona; Pinetop, Arizona
- U.S. Geological Survey, Tucson and Flagstaff, Arizona; Boulder, Colorado; Menlo Park, California
- National Biological Service, Fort Collins, Colorado

Department of the Interior (continued)
- National Park Service, Washington, DC; Fort Collins, Colorado; Flagstaff, Arizona; Grand Canyon National Park, Grand Canyon, Arizona; Lake Mead National Recreation Area, Boulder City, Nevada; Glen Canyon National Recreation Area, Page, Arizona; Canyonlands National Park, Moab, Utah
- Office of Environmental Policy and Compliance, Washington, DC
- Office of the Field Solicitor, Phoenix, Arizona

Department of Justice, Denver, Colorado

Environmental Protection Agency, Region VIII, Denver, Colorado; Region IX, San Francisco, California

U.S. General Accounting Office, Washington, DC; Denver, Colorado

## State and Local Agencies

Arizona State Government, Phoenix
- Governor
- Commerce Department
- Environmental Quality, Department of
- Game and Fish Department
- State Historic Preservation Officer
- Parks Recreation Council
- Water Resources, Department of

California State Government, Sacramento
- Governor
- Colorado River Board of California, Glendale

Colorado State Government, Denver
- Governor
- Colorado Water Conservation Board

Nevada State Government, Carson City
- Governor

New Mexico State Government, Santa Fe
- Governor
- Interstate Stream Commission

Utah State Government, Salt Lake City
- Governor
- Water Resources, Division of

Wyoming State Government, Cheyenne
- Governor
- State Engineer

## Indian Tribes

Havasupai Tribe, Supai, Arizona
Hopi Tribe, Kykotsmovi, Arizona
Hualapai Tribe, Peach Springs, Arizona
Navajo Nation, Window Rock, Arizona
Paiute Tribe of Utah, Cedar City, Utah
San Juan Southern Paiute Tribe, Tuba City, Arizona
Southern Paiute Consortium, Pipe Springs, Arizona
Zuni Pueblo, Zuni, New Mexico

## Schools

Arizona State University, Tempe, Arizona
Northern Arizona University, Flagstaff, Arizona
Utah State University, Logan, Utah

## Interested Organizations

American Fisheries Society, Bethesda, Maryland; Olympia, Washington; McCall, Idaho; Albuquerque, New Mexico
America Outdoors, Flagstaff, Arizona
American Rivers, Washington, DC
Applied Technology Associates, Inc., Flagstaff, Arizona
Argonne National Laboratory, Lakewood, Colorado; Argonne, Illinois
Arizona Municipal Power Users Association, Phoenix, Arizona
Arizona Nature Conservancy, Tucson, Arizona
Arizona Power Authority, Phoenix, Arizona
Arizona Power Pooling Association, Phoenix and Mesa, Arizona
Arizona River Runners, Phoenix, Arizona
Arizona Wildlife Federation, Mesa, Arizona
Audubon Society, Coordinating Counsel of Utah, Clearfield, Utah; Maricopa, Phoenix, Arizona; Napa-Sonoma, Napa, California; Northern Arizona, Flagstaff and Sedona, Arizona; Prescott, Prescott, Arizona; Yosemite Area Chapter, Mariposa, California
Bio/West, Inc., Logan, Utah
Bountiful City Light and Power Department, Bountiful, Utah
Canyoneers, Inc., Flagstaff, Arizona
Colorado River Resource Coalition, Salt Lake City, Utah; Desert Hot Springs, California
Colorado River Energy Distributors Association, Salt Lake City, Utah; Phoenix, Arizona
Dixie Escalante Rural Electric Association, St. George and Beryl, Utah
Desert Flycasters, Chandler, Arizona
Eco-Plan Associates, Mesa, Arizona

Environmental Defense Fund, Inc., New York, New York; Oakland, California; Boulder, Colorado; Austin, Texas
Friends of the Colorado River, Flagstaff, Arizona
Friends of the River, Inc. (and Foundation), San Francisco and Sacramento, California
Grand Canyon River Guides Association, Flagstaff, Arizona
Grand Canyon Trust, St. George, Utah
High Country River Rafters, Golden, Colorado
Intermountain Consumer Power Association, Sandy, Utah
Los Angeles Department of Water and Power, Los Angeles, California
Maricopa Water District, Waddell, Arizona
Murray City Power, Murray, Utah
Natural Resources Defense Council, Inc., New York, New York; San Francisco, California
Sierra Club Southwest Office, Phoenix, Arizona
SWCA, Inc., Flagstaff, Arizona
Tri-State Generation and Transmission Association, Inc., Denver, Colorado
Trout Unlimited, Vienna, Virginia; Rocky Mountain Region, Wheat Ridge, Colorado; West Coast Region, Fairfax, California; Arizona Council, Flagstaff, Glendale, and Phoenix, Arizona
Upper Colorado River Commission, Salt Lake City, Utah
Wilderness Society, The, Bethesda, Maryland

## Interested Individuals

Clifford Barrett, Salt Lake City, Utah
Mike Brown, New Castle, Utah
Kenton Grua, Flagstaff, Arizona
Kay Johnson, Murray, Utah
Christie O'Day, Tempe, Arizona
David Onstad, Phoenix, Arizona
Gail Peters, Phoenix, Arizona

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| Gordon S. Lind | Environmental Protection Specialist | NEPA compliance |
| Timothy J. Randle | Hydraulic Engineer | Water, sediment |
| Mary I. Voita | Technical Writer-Editor | Technical writing, editing |

# Bibliography


Andrews, E.D. 1991a. Sediment transport in the Colorado River Basin, in *Colorado River Ecology and Dam Management*, Proceedings of a Symposium, May 24-25, 1990, Santa Fe, New Mexico. National Academy Press, Washington, DC, pp. 54-74.

______. 1991b. Deposition rate of sand in lateral separation zones, Colorado River (abstract), in *AGU 1991 Fall Meeting Program and Abstracts*. American Geophysical Union EOS Transactions, supplement to vol. 72, no. 44, p. 218.

______. November 1995. Verbal communication. U.S. Geological Survey.

Angradi, T.R., R.W. Clarkson, D.A. Kinsolving, D.M. Kubly, and S.A. Morgensen. 1992. Glen Canyon Dam and the Colorado River: responses of the aquatic biota to dam operations, Glen Canyon Environmental Studies Technical Report. Arizona Game and Fish Department, Phoenix, Arizona.

Arizona Game and Fish Department. 1993. *Glen Canyon Environmental Studies Phase II 1992 Annual Report*. Prepared for Bureau of Reclamation, Glen Canyon Environmental Studies. Arizona Game and Fish Department, Phoenix, Arizona.

______. 1994. *Glen Canyon Environmental Studies Phase II 1993 Annual Report*. Prepared for Bureau of Reclamation, Glen Canyon Environmental Studies. Arizona Game and Fish Department, Phoenix, Arizona.

Blinn, D.W., L.E. Stevens, and J.P. Shannon. 1992. The effects of Glen Canyon Dam on the aquatic foodbase in the Colorado River corridor in Grand Canyon, Arizona, Glen Canyon Environmental Studies Technical Report. Northern Arizona University, Flagstaff, Arizona.

Brown, B.T., and M.W. Trossett. 1989. Nesting habitat relationships of riparian birds along the Colorado River in Grand Canyon, Arizona. *Southwestern Naturalist* vol. 34, no. 2, pp. 20-270.

Bureau of Reclamation. 1988. Colorado River Simulation System User's Manual. Bureau of Reclamation, Denver, Colorado.

______. 1991. *Glen Canyon Dam Interim Operating Criteria Finding of No Significant Impact and Environmental Assessment*. Bureau of Reclamation, Salt Lake City, Utah.

______. 1995a. Biological assessment of a one time test of beach/habitat-building flow from Glen Canyon Dam: spring 1996. Bureau of Reclamation, Salt Lake City, Utah.

______. 1995b. Annual Operating Plan for Colorado River Reservoirs 1996. Bureau of Reclamation, Lower Colorado Region, Boulder City, Nevada.

Carothers, S.W., and B.T. Brown. 1991. *The Colorado River Through Grand Canyon: Natural History and Human Change.* University of Arizona Press, Tucson, Arizona.

Cherry, S. December 5, 1995. Verbal communication. National Park Service, Grand Canyon, Arizona.

Crane, Dean A. February 9, 1996. Verbal communication. ARAMARK DBA Wilderness River Adventures, Page, Arizona.

Douglas, Aaron J., and D.A. Harpman. July 1995. Estimating recreation employment effects with IMPLAN for the Glen Canyon Dam region. *Journal of Environmental Management*, vol. 44, no. 3, pp. 233-247.

Environmental Defense Fund. 1988. *Elfin User's Manual.* Environmental Defense Fund, Oakland, California.

Gunn, Terry. January 25, 1996a. Verbal communication. Lees Ferry Anglers, Marble Canyon, Arizona.

______. February 9, 1996b. Written communication. Lees Ferry Anglers, Marble Canyon, Arizona.

Henderson, N. February 2, 1996. Written communication. National Park Service, Page, Arizona

Kubly, D.M. 1990. The endangered humpback chub (*Gila cypha*) in Arizona: a review of past studies and suggestions for future research (draft report). Prepared by Arizona Game and Fish Department for Bureau of Reclamation, Salt Lake City, Utah.

Leibfried, W.C., and D.W. Blinn. 1987. The effects of steady versus fluctuating flows on aquatic macroinvertebrates in the Colorado River below Glen Canyon Dam, Arizona, Glen Canyon Environmental Studies Technical Report. Bureau of Reclamation, Salt Lake City, Utah.

Maddux, H.R., D.M. Kubly, J.C. DeVos, Jr., W.R. Persons, R. Staedicke, and R.L. Wright. 1987. Effects of varied flow regimes on aquatic resources of Glen and Grand Canyons, Glen Canyon Environmental Studies Technical Report. Arizona Game and Fish Department, Phoenix, Arizona.

McGuinn-Robbins, D.K. 1994. Comparison of the number and area of backwaters associated with the Colorado River in Glen and Grand Canyons, Arizona. Arizona Game and Fish Department, Phoenix, Arizona.

Minckley, W.L. 1991. Native fishes of the Grand Canyon region: an obituary? in *Colorado River Ecology and Dam Management*, Proceedings of a Symposium, May 24-25, 1990, Santa Fe, New Mexico. National Academy Press, Washington, DC, pp. 124-177.

Moulton, R. February 14, 1996. Written communication. Western Area Power Administration, Salt Lake City, Utah.

Patten, et al. October 1994. Written communication. Arizona State University, Tempe, Arizona.

Pemberton, E.L. 1987. Sediment data collection and analysis for five stations on the Colorado River from Lees Ferry to Diamond Creek, Glen Canyon Environmental Studies Technical Report. Bureau of Reclamation, Salt Lake City, Utah.

Peterson, R. November 1995. Written communication. Bureau of Reclamation, Salt Lake City, Utah.

Power Resources Committee. 1993. Power system impacts of potential changes in Glen Canyon powerplant operations, Glen Canyon Environmental Studies Technical Report. Stone and Webster Management Consultants, Inc., Denver, Colorado.

Pucherelli, M.J. 1987. Written communication. Bureau of Reclamation, Denver, Colorado.

Shelby, Bo, T.C. Brown, and R. Baumgartner. July 1992. Effects of streamflows on river trips on the Colorado River in Grand Canyon, Arizona. *Rivers*, vol. 3, no. 3, pp. 191-201.

Sogge, M.K., C. Van Riper III, T.J. Tibbitts, and T. May. 1995a. Monitoring winter bald eagle concentrations in the Grand Canyon: 1993-1995. National Biological Service Colorado Plateau Research Station, Northern Arizona University, Flagstaff, Arizona.

Sogge, M.K., T.J. Tibbitts, C. Van Riper III, and T. May. 1995b. Status of the southwestern willow flycatcher along the Colorado River in Grand Canyon National Park summary report. National Biological Service Colorado Plateau Research Station, Northern Arizona University, Flagstaff, Arizona.

Stevens, L.E. 1995. Written communication. Bureau of Reclamation, Flagstaff, Arizona.

______. January 1996. Verbal communication. Bureau of Reclamation, Flagstaff, Arizona.

Stevens, L.E., and T.J. Ayers. 1991. The impacts of Glen Canyon Dam on riparian vegetation and soil stability in the Colorado River corridor, Grand Canyon, Arizona: 1991 draft annual report. National Park Service Cooperative Studies Unit, Northern Arizona University, Flagstaff, Arizona.

Stevens, L.E., and N. Kline. 1991. Written communication. National Park Service, Flagstaff, Arizona.

Stevens, L.E., F.R. Protiva, D.M. Kubly, V.J. Meretsky, and J. Petterson. 1995. The ecology of Kanab ambersnail (Succineidae: *Oxyloma haydeni kanabensis* Pilsbry, 1948) at Vaseys Paradise, Grand Canyon, Arizona (draft final report), Glen Canyon Environmental Studies Report. Bureau of Reclamation, Flagstaff, Arizona.

Stevens, L.E., and G.L. Waring. 1985. Effects of post-dam flooding on riparian substrates, vegetation, and invertebrate populations in the Colorado River corridor in Grand Canyon, Arizona, Glen Canyon Environmental Studies Technical Report. Bureau of Reclamation, Salt Lake City, Utah.

Stevens, L.E., K.A. Buch, B.T. Brown, and N. Kline. In press. Dam and Geomorphic Influences on Colorado River Waterbird Distribution, Grand Canyon, Arizona in *Regulated Rivers: Research and Management.*

Tibbitts, T.J., M.K. Sogge, and S.J. Sferra. 1994. A survey protocol for the south-western willow flycatcher (*Empidonax traillii extimus*). U.S. Department of the Interior, National Park Service. Technical Report NPS/NAUCPRS/ NRTR-94/04. Colorado Plateau Research Station, Northern Arizona University, Flagstaff, Arizona.

U.S. Department of the Interior. 1995. *Operation of Glen Canyon Dam Final Environmental Impact Statement.* Bureau of Reclamation, Salt Lake City, Utah.

Valdez, R. 1995. Life history and ecology of the humpback chub (*Gila cypha*) in the Colorado River, Grand Canyon, Arizona (draft final report). Bureau of Reclamation, Logan, Utah.

Vankuiken, J.C. et al. November 1994. *APEX User's Guide (Argonne Production, Expansion, and Exchange Model for Electrical Systems).* Argonne National Laboratory, Argonne, Illinois.

Webb, R.H., T.S. Melis, and P.G. Griffiths. 1995. Written communication. U.S. Geological Survey, Tucson, Arizona.

Wegner, D.L., L.E. Stevens, and T.S. Melis. December 1995. Written communication. Glen Canyon Environmental Studies Group, Flagstaff, Arizona.

Weiss, J. 1993. The relationship between flow and backwater fish habitat of the Colorado River in Grand Canyon (draft report), Glen Canyon Environmental Studies Technical Report. Bureau of Reclamation, Flagstaff, Arizona.

Western Area Power Administration. 1993a. Financial assessment high discharge experimental flow Glen Canyon Dam Qmax = 33,200. Western Area Power Administration, Salt Lake City, Utah.

______. 1993b. Financial assessment high discharge experimental flow Glen Canyon Dam Qmax = 45,000. Western Area Power Administration, Salt Lake City, Utah.

______. 1993c. Financial assessment high discharge experimental flow Glen Canyon Dam Qmax = 45,000 (revised). Western Area Power Administration, Salt Lake City, Utah.

______. February 1994. *Salt Lake City Area Integrated Projects Electric Power Marketing Draft Environmental Impact Statement*. Western Area Power Administration, Salt Lake City, Utah.

Wiele, S.M., J.B. Graf, and J.D. Smith. 1995. Sand deposition in the Colorado River in Grand Canyon from floods in the Little Colorado River (draft). Prepared by U.S. Geological Survey in cooperation with Bureau of Reclamation. Boulder, Colorado.

# *Attachments*

Attachment A

# *Environmental Commitments*

The following environmental commitments would be honored under the proposed action described in this document.

1. Reclamation would fund and administer the monitoring and research activities connected with the test flow. Monitoring and research results would provide the opportunity to quantify how sediment, fish, vegetation, cultural, recreation, and hydropower resources are affected by a flow of the proposed magnitude and duration and allow for better understanding of natural processes (physical and biological) and resource linkages. This increased knowledge would enable better management of these downstream resources.

2. Reclamation would fund Kanab ambersnail relocation and monitoring and southwestern willow flycatcher research and monitoring.

3. Data recovery would be conducted at four archeological sites prior to the test flow as mitigation for potential impacts. A traditional cultural property site in Granite Park would be stabilized prior to the test flow.

4. A public information program would be conducted to inform anglers and river rafters of the special test flow releases from the dam.

Attachment B

# Glen Canyon Environmental Studies Controlled Flood Research Programs

**Research Titles**

**February 13, 1996**
**Transition Work Group Presentation**

## A. PHYSICAL SYSTEM COMPONENTS

"Main channel streamflow, sediment transport, and sediment storage - collection of critical data"
Researchers: Graf and Smith

"Reworking of aggraded debris fans by experimental flood"
Researchers: Webb, Melis, and Griffiths

"Main channel streamflow, sediment transport, and sand storage - development of predictive methods"
Researchers: Smith, Wiele, Topping, Graf, and Griffin

"Deposition rate and topographic evolution of sand bars in lateral separation eddies during high flows"
Researchers: Andrews, Cacchione, Nelson, Schmidt, and Rubin

"A proposal to evaluate the effects of the 1996 controlled high flow release from Glen Canyon Dam on Colorado River sand bars in the Grand Canyon"
Researchers: Parnell, Dexter, Kaplinkski, and Hazel

"Effects of a beach/habitat building flow on campsites in the Grand Canyon"
Researcher: Kearsley

"The effects of flood flows (45,000 cfs) in the Colorado River on observed and reported boating accidents in Grand Canyon"
Researchers: Weber and Jalbert

## B. AQUATIC SYSTEM COMPONENTS

### B-1 Fisheries

"A proposal to determine effects of a controlled flood on the aquatic ecosystem of the Colorado River downstream from Glen Canyon Dam"
Researchers: Ayers, Hoffnagle, Valdez, Liebried, McIvor, and Henderson

**B-2 Endangered Species**

"A draft proposal to access, mitigate and monitor the impacts of an experimental high flow from Glen Canyon Dam on the endangered Kanab Ambersnail at Vasey's Paradise, Grand Canyon"
Researchers: Stevens, Kubly, Petterson, Protiva, and Meretsky

## C. TROPHIC LINKAGES

**C-1 Drift Studies**

"Proposal to study the effects of the 1996 spring flood maintenance flows from Glen Canyon Dam on the aquatic food base in the Colorado River through Grand Canyon, Arizona"
Researchers: Blinn and Shannon

**C-2 Chemistry and Thermal Structure of Lake Powell and Glen Canyon Tailwater**

"The effects the flood on the vertical thermal and chemical structure in Lake Powell and an estimate of the flood effect on primary productivity in the Colorado River: Glen Canyon Dam to Lee's Ferry"
Researchers: Marzolf, Hart, and Stephens

## D. TERRESTRIAL SYSTEM COMPONENTS

**D-1 Vegetation**

"Effects of the 1996 beach building flow on riparian vegetation in the Colorado River corridor in Glen and Grand Canyons"
Researchers: Kearsley and Ayers

"Effects of the 1996 experimental flood on riparian vegetation in lower Grand Canyon"
Researchers: Christiansen, Kearsley, Phillips, Riley, Abeita, Matuck, and Lake Mead staff

**D-2 Backwater Rejuvenation Studies**

"A proposal to evaluate backwater rejuvenation along the Colorado River in Grand Canyon, Arizona"
Researchers: Stevens, Huffnagle, Parnell, Melis, Schmidt, Stanitski-Martin, Springer

## E. CULTURAL RESOURCE COMPONENT

"Evaluation and mitigation efforts for cultural resources surrounding the 1996 spike flow experiment"
Researchers: Yeatts, Balsom, Downum, Austin, Stoffle, Hunga, Jackson, and Burchett

## F. COORDINATION AND LOGISTICS

**Logistics -**
**Coordination (USGS) -**
**Helicopters -**
**GIS -**
  **Thermal imagery -**
  **GIS integration -**
**Glen Canyon National Recreation Area**

Attachment C

# Prices Used in Power Impact Analysis

(Units—$/MWhr)

| Hour | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | June | July | Aug | Sep | RMG Con-tract |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 17.17 | 20.28 | 18.63 | 16.48 | 16.81 | 19.90 | 17.57 | 15.56 | 16.93 | 17.90 | 17.79 | 16.08 | 16.00 |
| 2 | 16.42 | 20.28 | 17.89 | 16.45 | 16.45 | 19.77 | 17.49 | 15.38 | 16.35 | 17.22 | 17.70 | 15.49 | 16.00 |
| 3 | 16.28 | 19.58 | 17.46 | 16.45 | 16.44 | 19.64 | 17.18 | 15.00 | 15.83 | 17.10 | 17.49 | 15.21 | 16.00 |
| 4 | 16.28 | 19.94 | 17.90 | 16.48 | 16.48 | 19.68 | 17.36 | 14.82 | 15.64 | 16.95 | 17.47 | 15.20 | 16.00 |
| 5 | 16.73 | 20.28 | 18.56 | 17.20 | 17.00 | 20.02 | 17.75 | 15.46 | 16.13 | 17.16 | 17.47 | 15.74 | 16.00 |
| 6 | 18.98 | 20.61 | 19.90 | 18.38 | 18.31 | 21.45 | 17.85 | 15.87 | 16.36 | 17.76 | 17.73 | 16.91 | 16.00 |
| 7 | 18.86 | 20.92 | 19.61 | 20.26 | 19.70 | 20.90 | 18.05 | 15.66 | 16.47 | 17.83 | 17.34 | 17.01 | 16.00 |
| 8 | 19.24 | 21.25 | 20.21 | 22.82 | 20.52 | 21.15 | 18.37 | 16.67 | 17.68 | 19.52 | 17.90 | 18.02 | 24.75 |
| 9 | 19.60 | 21.31 | 20.91 | 21.24 | 19.64 | 21.47 | 19.31 | 17.69 | 20.79 | 22.68 | 20.79 | 19.48 | 24.75 |
| 10 | 19.36 | 21.31 | 20.96 | 20.08 | 18.40 | 22.92 | 19.06 | 17.74 | 24.07 | 25.86 | 23.20 | 19.72 | 24.75 |
| 11 | 21.18 | 21.07 | 19.68 | 20.07 | 17.75 | 22.59 | 19.85 | 18.00 | 25.75 | 25.89 | 25.93 | 20.30 | 24.75 |
| 12 | 21.68 | 21.07 | 19.38 | 18.17 | 17.41 | 21.76 | 19.53 | 18.14 | 26.49 | 25.89 | 26.35 | 21.85 | 24.75 |
| 13 | 22.67 | 20.67 | 18.58 | 17.50 | 17.30 | 21.05 | 19.51 | 18.17 | 26.75 | 25.89 | 26.35 | 23.42 | 24.75 |
| 14 | 23.04 | 20.06 | 18.22 | 16.82 | 17.09 | 20.40 | 19.51 | 18.72 | 26.56 | 25.89 | 26.92 | 21.25 | 24.75 |
| 15 | 23.32 | 19.35 | 17.74 | 16.34 | 16.69 | 20.34 | 19.97 | 19.16 | 27.38 | 25.89 | 26.85 | 23.90 | 24.75 |
| 16 | 23.32 | 19.55 | 17.74 | 16.15 | 16.57 | 20.27 | 19.96 | 19.25 | 27.10 | 25.89 | 25.12 | 23.82 | 24.75 |
| 17 | 23.16 | 20.60 | 19.40 | 17.06 | 16.97 | 20.44 | 20.05 | 18.99 | 26.55 | 25.89 | 24.40 | 23.83 | 24.75 |
| 18 | 23.28 | 21.11 | 20.67 | 20.38 | 17.79 | 21.63 | 19.96 | 18.41 | 25.89 | 25.89 | 23.76 | 23.77 | 24.75 |
| 19 | 24.39 | 21.50 | 21.50 | 20.38 | 19.20 | 23.72 | 19.75 | 17.94 | 25.89 | 25.89 | 23.79 | 22.87 | 24.75 |
| 20 | 24.14 | 21.31 | 21.36 | 20.37 | 19.20 | 24.72 | 20.24 | 17.85 | 26.40 | 25.89 | 24.09 | 22.48 | 24.75 |
| 21 | 22.40 | 21.19 | 21.03 | 19.83 | 18.34 | 23.28 | 19.52 | 17.86 | 25.76 | 25.89 | 23.45 | 20.35 | 24.75 |
| 22 | 20.48 | 21.07 | 20.29 | 17.70 | 18.33 | 20.60 | 19.36 | 17.48 | 25.20 | 25.89 | 23.45 | 19.70 | 24.75 |
| 23 | 19.95 | 21.07 | 20.34 | 18.72 | 18.59 | 21.82 | 18.44 | 16.51 | 23.15 | 22.94 | 21.51 | 19.02 | 24.75 |
| 24 | 18.94 | 20.39 | 19.51 | 16.90 | 17.64 | 20.15 | 17.55 | 15.70 | 18.70 | 21.34 | 19.48 | 17.49 | 16.00 |