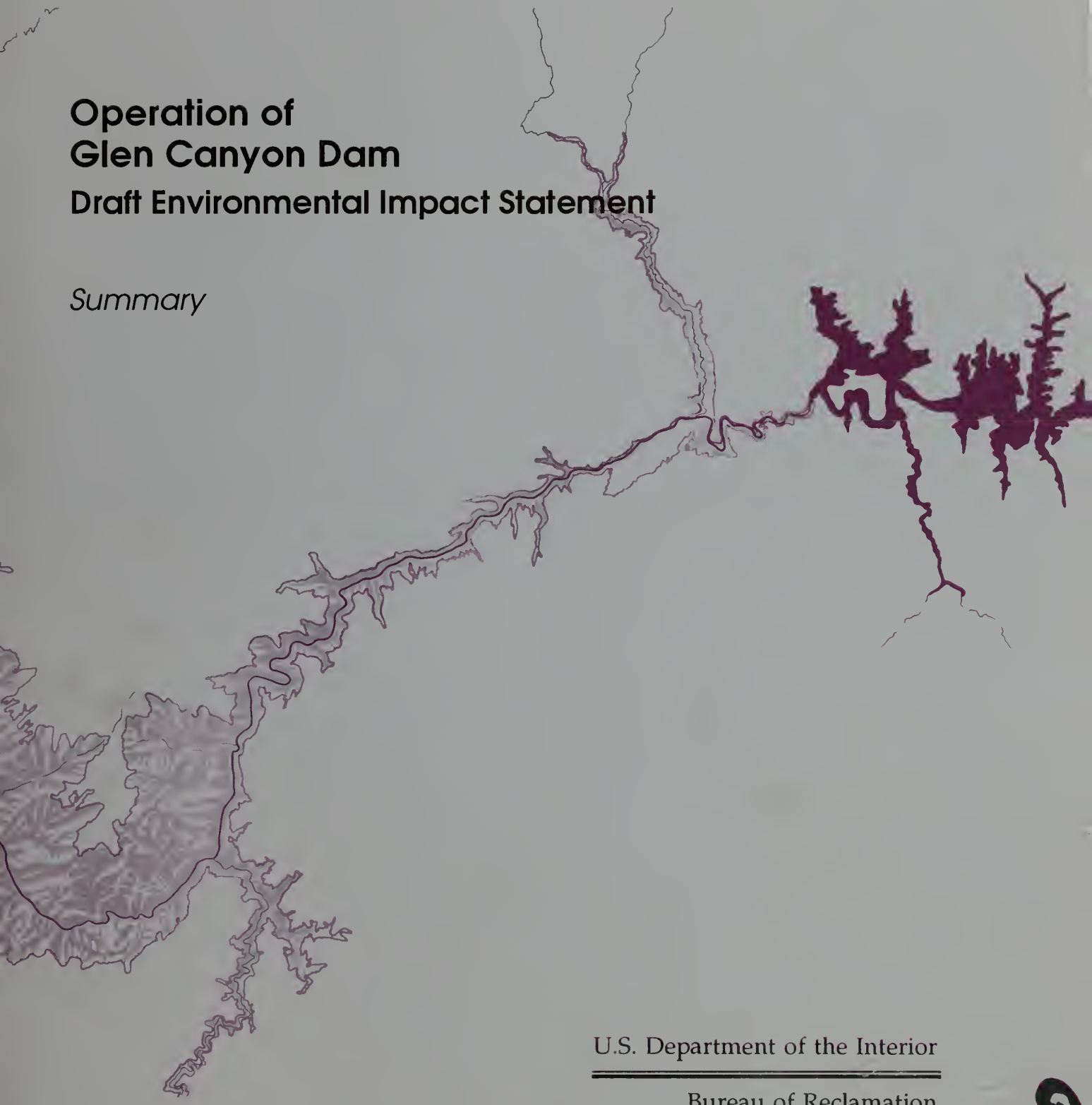
Operation of Glen Canyon Dam

Draft Environmental Impact Statement

Summary



U.S. Department of the Interior

Bureau of Reclamation

Dear Reader:

Enclosed is a summary of the *Operation of Glen Canyon Dam Draft Environmental Impact Statement*. This summary is intended for readers who desire a brief but complete overview of the contents of the draft environmental impact statement (EIS).

Nine alternatives are presented covering a full range of possible operations of Glen Canyon Dam. Two of the alternative operations evaluated, including no action, would allow unrestricted hourly fluctuations, four would provide various levels of restricted fluctuating flows; and three would provide steady flows. Additional measures are combined with the alternative operations, where appropriate, to provide additional resource protection or enhancement. The preferred alternative is the Modified Low Fluctuating Flow Alternative.

To obtain a copy of the draft EIS (with appendix) or find out where you can review a copy, please contact:

Bureau of Reclamation
Attention: Colorado River Studies Office
PO Box 11568
Salt Lake City UT 84147
Telephone: 801-524-5479

Your written comments on the draft EIS should be submitted to this same address by April 11, 1994. Comments will be evaluated and considered in the preparation of the final EIS.

Public hearings to receive oral comments will be held in California, Arizona, Utah, Colorado, and Washington, DC. Prior to these public hearings, the Bureau of Reclamation is conducting public information sessions in Washington, DC, Utah, and Arizona. The sessions were scheduled to provide the public an opportunity to learn more about the EIS by viewing a video and talking with agency representatives.

A complete list of the times and locations of the public hearings will be published in the *Federal Register*, local newspapers, and latest *Colorado River Studies Office Newsletter*. The information sessions will be announced in local newspapers and the newsletter.

Sincerely,

Roland Robison

Roland Robison, Regional Director
Upper Colorado Region
Bureau of Reclamation

The glories and the beauties of form, color, and sound unite in the
Grand Canyon—forms unrivaled even by the mountains,
colors that vie with sunsets, and sounds that span the diapason from tempest
to tinkling raindrop, from cataract to bubbling fountain. . . .
A year scarcely suffices to see it all. It has infinite variety,
and no part is ever duplicated. Its colors, though many and complex at any instant,
change with the ascending and declining sun;
lights and shadows appear and vanish with the passing clouds, and the
changing seasons mark their passage in changing colors.

JOHN WESLEY POWELL

This overview briefly describes the need, alternatives, and issues. The summary provides greater detail.

This environmental impact statement (EIS) analyzes a range of alternative Glen Canyon Dam operations designed to protect downstream resources and Native American interests in Glen and Grand Canyons, as well as to produce hydropower.

Glen Canyon Dam—the key feature of the Colorado River Storage Project—was completed by the Bureau of Reclamation in 1963 as a multipurpose facility. The purposes for which the dam was constructed are set forth in the Colorado River Storage Project Act of 1956 and include, among others: regulating the flow of the Colorado River; water storage; reclamation of arid and semiarid lands; flood control; and hydroelectric power generation, ". . . as an incident of the foregoing purposes."

The Colorado River is the main influence in the dynamic ecosystem of these canyons. Glen Canyon Dam brought about fundamental changes in the river and predam ecosystem. Sediment transport and supply has been reduced and controlled volumes of cold, clear water annually pass through Glen and Grand Canyons. Native fish that cannot tolerate these conditions have declined or disappeared from the canyon. Other species and communities that were rare or nonexistent before the dam now abound.

Alternatives

None of the alternatives considered in this EIS can return the system to predam conditions. However, this EIS considers nine alternate ways to operate the dam to reduce further adverse impacts on or to enhance the existing ecosystem. These alternatives propose changes in maximum and minimum flows, daily flow fluctuations, and rate of change in fluctuations (ramp rate). These alternatives would change the riverflows below the dam (also called discharges or releases). Releases are measured in cubic feet per second (cfs) while annual or monthly volumes are measured in acre-feet.

Other alternatives were evaluated but eliminated from detailed consideration due to various factors.

Affected Resources

By analyzing public comments, the EIS team refined and evaluated issues of concern, identifying the following resources to be evaluated: water, sediment, fish, vegetation, wildlife and habitat, endangered and other special status species, cultural resources, air quality, recreation, hydropower, and non-use value.

The canyon supports a complex system formed by interactions between communities of organisms and their environment, or an ecosystem. Changes in a single process can affect resources throughout the system. The EIS focuses on two processes that form linkages affected by dam operations.

- **Water release patterns** directly or indirectly affect physical, biological, cultural, recreational, and hydropower resources.
- **Sediment transport** and supply stabilizes archeological sites and camping beaches, develops and maintains backwater habitats, transports nutrients, and provides a foundation for vegetation that in turn provides wildlife habitat.

These two processes affect the complex, linked resources in the Colorado River corridor downstream from the dam. For example:

- **Aquatic resources** form a chain: river conditions created by the dam operations allow a non-native alga, *Cladophora glomerata*, to flourish. This alga, in turn, provides habitat for diatoms and for insect larvae and crustaceans that feed on diatoms. Together, these are an important food source for non-native trout, native fish, and other organisms. Habitat changes and non-native fish have created problems for native fish.
- **Terrestrial resources** are linked together, as well as to aquatic resources. Water release patterns and sediment affect riparian and emergent marsh vegetation which provide habitat for wildlife.

Environmental Consequences

This EIS evaluates the alternatives' effects on both short-term needs of the environment and long-term requirements to maintain and support the ecological elements of Grand Canyon. These evaluations use indicators for each resource to measure the effects alternatives would have on that resource.

The alternatives are variations of dam operations, ranging from unrestricted fluctuations to steady flows. The impacts often vary only slightly among alternatives. The EIS team considered the sum total of these sometimes subtle variations in recommending the preferred alternative.

Contents

Purpose of and Need for Action

The Federal action considered in this environmental impact statement (EIS) is the operation of Glen Canyon Dam, Colorado River Storage Project (CRSP), Arizona.

Purpose

On July 27, 1989, the Secretary of the Interior (Secretary) directed the Bureau of Reclamation (Reclamation) to prepare an EIS to reevaluate Glen Canyon Dam operations. The purpose of the reevaluation is to determine specific options that could be implemented to minimize—consistent with law—adverse impacts on the downstream environmental and cultural resources, as well as Native American interests in Glen and Grand Canyons.

Need

The need for this reevaluation stems from impacts to downstream resources caused by the operation of Glen Canyon Dam. Such impacts have been identified from scientific studies, resulting in significant public concern. Analysis of an array of reasonable alternatives is needed to allow the Secretary to balance and meet statutory responsibilities for protecting downstream resources and producing hydropower, and to protect affected Native American interests.

In addition, the Grand Canyon Protection Act of 1992 was enacted October 30, 1992. Section 1802 (a) of the act requires the Secretary to operate Glen Canyon Dam:

> *. . . in such a manner as to protect, mitigate adverse impacts to, and improve the values for which Grand Canyon National Park and Glen Canyon National Recreational Area were established, including, but not limited to natural and cultural resources and visitor use.*

Section 1804 (a) of the act requires the Secretary to complete an EIS on Glen Canyon Dam operations no later than October 30, 1994.

BACKGROUND

Glen Canyon Dam was completed by Reclamation in 1963 as a feature of the CRSP. The underlying project purposes are defined by section 1 of the Colorado River Storage Project Act of 1956, which authorized the Secretary to construct, operate, and maintain Glen Canyon Dam:

> *. . . for the purposes, among others, of regulating the flow of the Colorado River, storing water for beneficial consumptive use, making it possible for the States of the Upper Basin to utilize, consistently with the provisions of the Colorado River Compact, the apportionments made to and among them in the Colorado River Compact and the Upper Colorado River Basin Compact, respectively, providing for the reclamation of arid and semiarid land, for the control of floods, and for the generation of hydroelectric power, as an incident of the foregoing purposes. . .*

Since the dam was completed prior to enactment of the National Environmental Policy Act (NEPA), no EIS was filed regarding construction or operation of Glen Canyon Dam.

The "Law of the River"—a collection of Federal and State statutes, compacts, court decisions and decrees, Federal contracts, a treaty with Mexico, and formally determined long-range operating criteria—define the operation and management of the Colorado River.

The powerplant at Glen Canyon Dam has been used primarily for generating power during high demand periods (peaking power). The daily fluctuating releases associated with peaking power operations have caused concern among Federal, State, and Tribal resource management agencies; fishing and rafting interests; and environmental groups concerned about detrimental effects on downstream cultural resources, vegetation, wildlife, and other river resources.

These concerns were expressed most forcefully by the public during two Reclamation studies on possible increases in peaking power generation at Glen Canyon Dam. Although an uprate and rewind of powerplant generators was completed in 1987, Reclamation agreed not to use the increased generating capacity until completing a more comprehensive study of impacts from historic and current dam operations. Maximum releases have been limited to 31,500 cubic feet per second (cfs) instead of the potential 33,200 cfs that resulted from the uprate and rewind.

Glen Canyon Environmental Studies

In December 1982, Reclamation initiated the multiagency Glen Canyon Environmental Studies (GCES) to respond to the concerns of Federal, State, and Tribal agencies and the public. GCES Phase I was completed in 1988. In June 1988, GCES Phase II was initiated to gather additional data on specific operational elements. Agencies and individuals cooperating in the studies include Federal and State resource agencies, Indian Tribes, private consultants, universities, and river guides. CRSP power revenues funded these studies, which form the basis for the impact assessment presented in the EIS.

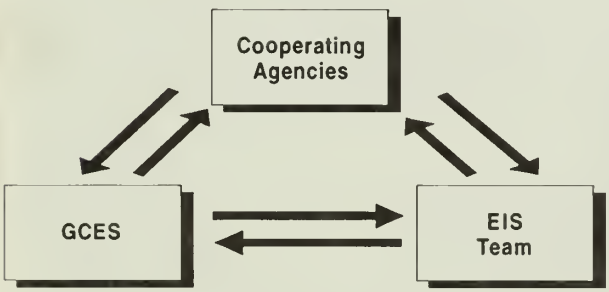
Interim Operations

To protect downstream resources until completion of this EIS and the record of decision (ROD), Reclamation began testing interim operations on August 1, 1991. The interim operating criteria and a monitoring program were implemented on November 1, 1991. Although the criteria may be modified based on new information, they will remain in effect until the EIS and ROD are completed. These interim criteria are essentially the same as those described later under the Interim Low Fluctuating Flow Alternative. The interim operating criteria:

- Restrict peak releases to 20,000 cfs
- Limit minimum releases to 5,000 cfs at night and 8,000 cfs during the day
- Limit daily fluctuations to between 5,000 and 8,000 cfs, depending on the monthly release volume
- Limit the rate of change to 2,500 cfs per hour(cfs/hr) during periods of increasing releases and 1,500 cfs per hour during periods of decreasing releases

Cooperating Agencies

The Secretary designated Reclamation as lead agency in preparing the EIS. Cooperating agencies are: Bureau of Indian Affairs (BIA), National Park Service (NPS), U.S. Fish and Wildlife Service (FWS), Western Area Power Administration (Western), Arizona Game and Fish Department (AGFD), Hopi Tribe, Hualapai Tribe, Navajo Nation, Pueblo of Zuni, San Juan Southern Paiute Tribe, and the Southern Utah Paiute Consortium.



Representatives from Reclamation, NPS, FWS, Western, U.S. Geological Survey (USGS), Hopi and Hualapai Tribes, Navajo Nation, and a private consulting firm served on the interdisciplinary EIS team charged with formulating the alternatives and assessing their impacts on the human environment.

Western may have to change the way power is marketed in the region as a result of changed operations at Glen Canyon Dam. Western currently is preparing an EIS to evaluate systemwide power marketing and allocations.

SCOPE AND SETTING

The affected area encompasses the Colorado River corridor in northern Arizona from Lake Powell through Glen and Grand Canyons to the headwaters of Lake Mead (see figure 1). The uppermost 15 miles of the river are within the Glen Canyon National Recreation Area; the remaining 278 miles of the river flow through Grand Canyon National Park. Several Indian Tribes have land resource interests in the area—Navajo Nation, Hopi Tribe, Havasupai Tribe, and Hualapai Tribe.

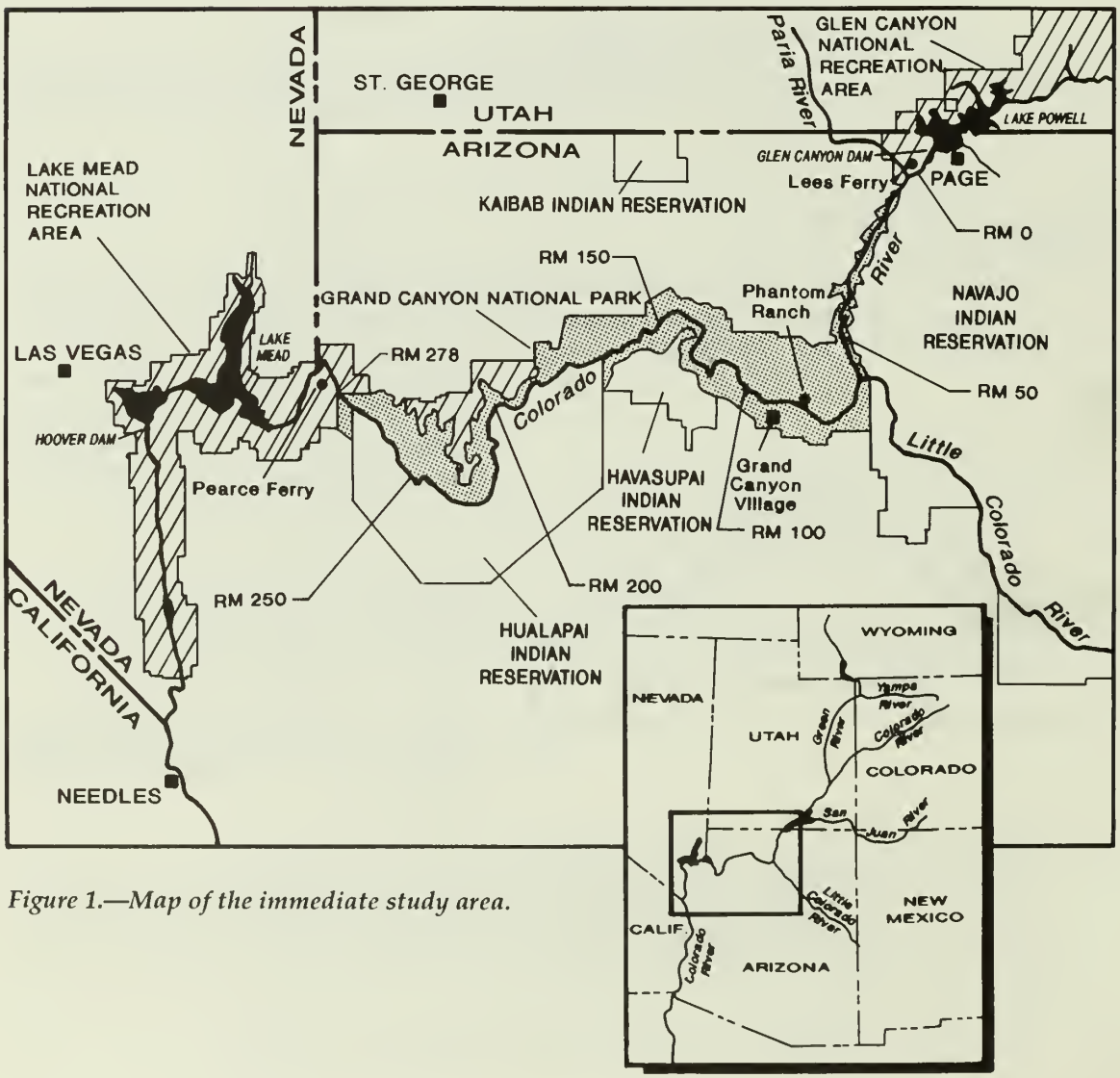


Figure 1.—Map of the immediate study area.

Some impacts occur outside of the immediate geographic area and were also evaluated. For example, power generated at Glen Canyon Dam is marketed in Wyoming, Utah, Colorado, Arizona, Nevada, and New Mexico.

Glen Canyon Dam stores and releases water from Lake Powell, which has an active capacity of almost 25 million acre-feet (maf). Water can be released from the dam through the powerplant, the outlet works, or spillways (figure 2). Although the combined release capacity of the facilities is 256,000 cfs, the maximum combined release from Glen Canyon Dam is not expected to exceed a probable maximum flood of 180,000 cfs.

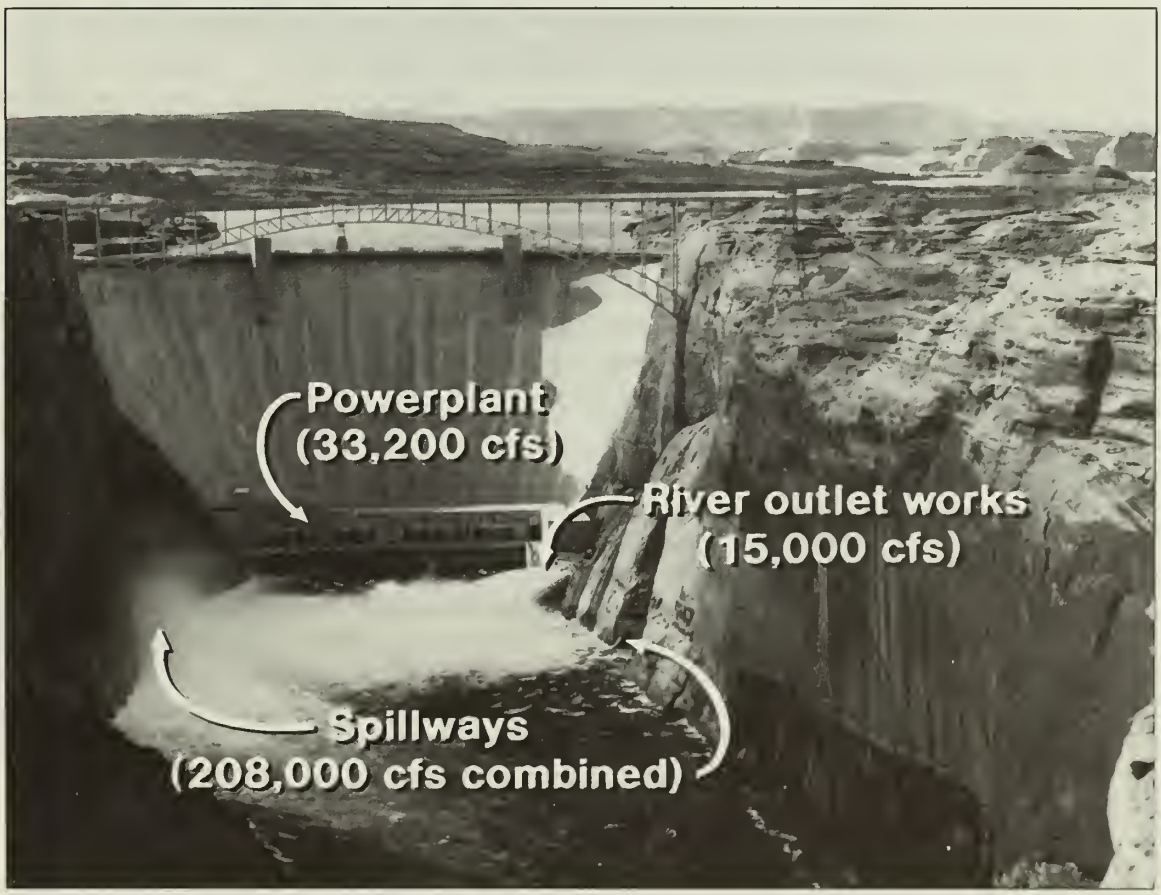


Figure 2.—Photograph of Glen Canyon Dam and Powerplant showing water release capacities of the powerplant, outlet works, and spillways.

PUBLIC INVOLVEMENT

This EIS has received broad interest from water and power users, environmental and conservation groups, Federal and State agencies, Indian Tribes, and private citizens across the country. Information has been disseminated through public meetings and periodic newsletters to about 20,000 people. In addition, interest groups have been invited to observe and participate in the cooperating agency meetings.

The ongoing Glen Canyon Dam EIS scoping process was initiated in early 1990 to receive public comment on and determine the appropriate scope of the EIS. Every effort was made to notify all potentially interested parties about the scoping process and opportunities to provide comment. Reclamation increased opportunities for public participation through public meetings, news releases, mailings, and legal notices, as well as contacts with media, organizations, and individuals.

The *Federal Register* notice of environmental scoping meetings was published on February 23, 1990, with a corresponding news release announcing the opening of the scoping process. The scoping comment period initially established for March 12 through April 16, 1990, was extended to May 4, 1990, in response to public comment. Public meetings were held in Salt Lake City, Denver, Phoenix, Flagstaff, Los Angeles, San Francisco, and Washington, DC. More than 17,000 comments were received during the scoping period, reflecting national attention and intense interest in the EIS.

Issues of Concern

As a result of the analysis of the oral and written scoping comments, the following were determined to be resources or issues of public concern: beaches, endangered species, ecosystem, fish, power costs, power production, sediment, water conservation, rafting/boating, air quality, the Grand Canyon wilderness, and a category designated as "other" for remaining concerns. Comments regarding interests and values were categorized as: expressions about the Grand Canyon, economics, nonquantifiable values, nature versus human use, and the complexity of Glen Canyon Dam issues.

The EIS team consolidated and refined the public issues of concern, identifying the resources and their significant issues to be analyzed in detail. These resources are: water, sediment, fish, vegetation, wildlife and habitat, endangered and other special status species, cultural resources, air quality, recreation, hydropower, and non-use value.

Description of Alternatives

The nine alternatives considered in detail are described below, beginning with the No Action Alternative (historical operations) to provide a baseline for comparison. Figure 3 summarizes the alternatives and their descriptions.

UNRESTRICTED FLUCTUATING FLOWS	
No Action	Maintain fluctuating releases and provide a baseline for impact comparison.
Maximum Powerplant Capacity	Permit use of full powerplant capacity.
RESTRICTED FLUCTUATING FLOWS	
High	Slightly reduce daily fluctuations from historic no action levels.
Moderate	Moderately reduce daily fluctuations from historic no action levels; includes habitat maintenance flows.
Modified Low (*Preferred Alternative*)	Substantially reduce daily fluctuations from historic no action levels; includes habitat maintenance flows and endangered fish research.
Interim Low	Substantially reduce daily fluctuations from historic no action levels; same as interim operations.
STEADY FLOWS	
Existing Monthly Volume	Provide steady flows that use historic monthly release strategies.
Seasonally Adjusted	Provide steady flows on a seasonal or monthly basis; includes habitat maintenance flows.
Year-Round	Provide steady flows throughout the year.

Figure 3.—Glen Canyon Dam EIS alternatives.

The eight action alternatives were designed to provide a broad spectrum of options. One alternative would allow unlimited fluctuations in flow to maximize power production, four would impose varying restrictions on fluctuations, and three others would provide steady flows on a monthly, seasonal, or annual basis. The names of the alternatives reflect the operational regimes that they represent. In addition, the restricted fluctuating flow and steady flow alternatives include common elements, which are discussed next.

COMMON ELEMENTS

The elements common to all restricted fluctuating flow and steady flow alternatives were designed to provide additional resource protection or enhancement. Impact analyses took these common elements into account.

Adaptive Management

Many uncertainties exist regarding downstream impacts of water releases from Glen Canyon Dam. The concept of adaptive management is based on the need for operational flexibility to respond to future monitoring and research findings and variable biological and physical conditions.

The objective of the Adaptive Management Program would be to develop modifications to dam operations and exercise other authorities under existing law—as appropriate—to protect, mitigate adverse impacts to, and improve the values for which the Glen Canyon National Recreation Area and Grand Canyon National Park were established. Long-term monitoring and research are essential to adaptive management and would measure how well the selected alternative meets resource management objectives and provide additional understanding of resource responses to dam operations.

The Adaptive Management Program, under the direction of the Secretary of the Interior, would include an Adaptive Management Work Group (AMWG), a technical work group, and an independent scientific review panel.

Adaptive Management Work Group

The AMWG would be comprised of representatives from at least each of the EIS cooperating agencies, Basin States, contractors for the purchase of Federal power, recreation industry and users, and environmental organizations.

The work group could function as either a single, large forum (anyone can participate) or a two-tiered forum (a large group, with a small group

comprised of one representative from each interest to facilitate the process). Either structure may require formal chartering as a Federal Advisory Committee. In any event, all AMWG meetings would be open to public participation.

The AMWG would:

- Develop proposals for modifying operating criteria, for research under the long-term monitoring program, and for other mitigation actions, as appropriate
- Facilitate technical coordination and input from interested parties

Technical Work Group

This work group would be comprised of technical representatives from Federal, State, and Tribal governments. This work group would conduct and coordinate monitoring, research, and inventory programs and maintain the scientific information data base.

Independent Scientific Review Panel

The review panel would be comprised of scientific experts not otherwise participating in the long-term monitoring and research studies. Responsibilities of this review panel would include reviewing scientific study plans, resource reports, and scientific logic and protocols.

Consultation would be maintained with appropriate agencies of the Department of the Interior, including the FWS, NPS, and Reclamation; the Secretary of Energy; Governors of Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming; Indian Tribes; and the general public, including representatives of academic and scientific communities, environmental organizations, the recreation industry, and purchasers of Federal power produced at Glen Canyon Dam.

Further development of the adaptive management process would occur between the draft and final EIS.

Monitoring and Protecting Cultural Resources

The existence and operation of Glen Canyon Dam has had an effect on the historic properties within the Colorado River corridor of Glen and Grand Canyons. These properties include prehistoric and historic archeological sites, along with Native American traditional cultural places and sacred sites. Impacts are likely to occur to some of these historic properties regardless of the EIS alternative chosen for implementation.

National Historic Preservation Act guidelines instruct Federal agencies to develop measures to avoid or minimize loss of historic properties resulting

from their actions. Due to potential impacts of any dam operation, Federal agency compliance with sections 110 and 106 of the National Historic Preservation Act will be required.

Given the potential impacts from the existence and operation of Glen Canyon Dam, Reclamation and NPS have complied with documentation requirements in established regulations (36 CFR 800). The Advisory Council on Historic Preservation, Arizona State Historic Preservation Officer, Reclamation, NPS, and Indian Tribes completed a programmatic agreement which ensures that both Reclamation's and NPS's responsibilities are satisfied. Administration, implementation, and refinement of the program design are detailed in the programmatic agreement and accompanying monitoring and historic preservation plans to be completed by October 1994.

The programmatic agreement and accompanying plans will direct long-term monitoring, which includes continuing consultation, identification, inspection, analysis, evaluation, and remedial protection actions as necessary to preserve the historic properties within Glen and Grand Canyons. Remedial actions would be performed on an as-needed basis as the result of knowledge gained through monitoring. NPS would be the lead agency in any required NEPA compliance. The ongoing consultation process should minimize the influence of Glen Canyon Dam operations on cultural resources.

Flood Frequency Reduction Measures

Although infrequent floodflows may be considered beneficial to downstream resources, frequent or unscheduled floods may be damaging. Under this common element, the frequency of unscheduled floodflows greater than 45,000 cfs would be reduced to no more than 1 year in 100 years as a long-term average. This would allow for the management of the habitat maintenance flows and beach/habitat-building flows described later in this section. Floodflow frequency of once in 100 years is considered rare enough for resource needs, while not imposing unreasonable requirements on Lake Powell water storage.

Two separate methods of reducing flood frequency have been identified. These methods focus on reserving additional storage space for flood control.

1. Increase the capacity of Lake Powell 0.75 maf by raising the height of the four spillway gates 4.5 feet to elevation 3704.5 feet (currently, each gate is 40 feet wide and 52.2 feet high). This additional capacity would be nonviolable flood control space and would be used only in years when existing flood protection measures were insufficient. Construction of this project would cost about $3 million. No permits under the Clean Water Act or Rivers and Harbors Act would be required.

2. Change releases to provide a minimum of 1 maf of space from January 1 through June. This additional space would be nonviolable flood control space and would be used only in years when existing floodflow protection measures are insufficient. Existing practices target Lake Powell to reserve 500,000 acre-feet of reservoir space on July 1 (until the runoff peak has passed).

By implementing either flood protection measure, additional reserved reservoir space would be available each month from January 1 through July 1 to store any additional unforecasted inflow.

Beach/Habitat-Building Flows

Sandbars above the normal peak river stage would continue to erode, unwatered vegetation may die, and backwater habitat within normal stage would tend to fill with sediment under any EIS alternative. To alleviate this, beach/habitat-building flows have been incorporated in all restricted fluctuating and steady flow alternatives.

Beach/habitat-building flows would be scheduled high releases of short duration designed to rebuild high elevation sandbars, provide water for vegetation, deposit nutrients, restore backwater channels, and provide some of the dynamics of a natural system. A frequency of 1 in 5 years (when the reservoir is low) was assumed for analyzing the environmental consequences. These flows would be avoided during high reservoir conditions because of the increased risk of unscheduled flows greater than powerplant capacity.

Magnitudes would be at least 10,000 cfs greater than the allowable peak discharge in a minimum release year for a given alternative but not greater than 45,000 cfs. Releases would be increased and decreased at no more than 4,000 cfs per hour. A single test of a beach/habitat-building flow would be conducted prior to long-term implementation of this element to test the predictions made about its impacts. This test would have a discharge of about 45,000 cfs and would not set a precedent for future releases. Scheduled flows exceeding powerplant capacity (33,200 cfs) may require legislation to implement.

Beach/habitat-building flows could be scheduled in the spring (to coincide with the peak in the natural hydrologic cycle) or in late summer when, due to local thunderstorms, tributaries are expected to supply large quantities of sediment and nutrients. Initially, these flows would be scheduled in spring for a duration of 1 to 2 weeks. Additional water—shifted from the other 11 months—would be scheduled in the spring to support this flow.

Beach/habitat-building flows would be recommended by the Adaptive Management Program and scheduled as part of the Annual Operating

Plan. Such flows would be recommended during years when sufficient quantities of sediment are available, but not following a year in which a large population of young humpback chub is produced.

New Population of Humpback Chub

The Grand Canyon population of humpback chub (an endangered species) uses habitats in both the Colorado River mainstem and the Little Colorado River (LCR). The only known successful spawning habitat for that population is in the LCR, and individuals move between the mainstem and LCR.

Since the only known humpback chub population in the Lower Colorado River Basin depends on the LCR for survival, a catastrophic event or a series of chronic incidents that would reduce the viability of this spawning habitat could cause the loss of this population. Conditions in the mainstem (principally water temperatures) are not conducive to humpback chub spawning or survival of eggs and young. Therefore, at least one more population in one or more of the tributaries below Glen Canyon Dam should be established.

In consultation with FWS, NPS, AGFD, and other land management entities such as the Havasupai Tribe, Reclamation would make every effort—through funding, facilitating, and technical support—to ensure that a new population of humpback chub is established in one or more of the tributaries within Grand Canyon.

Further Study of Selective Withdrawal

Water released from Glen Canyon Dam to produce hydroelectricity is withdrawn from the cold depths of Lake Powell at an elevation of 3470 feet—230 feet below the water surface when the reservoir is full (3700 feet). The river water temperature at Lees Ferry, 16 miles downstream, is nearly constant year-round and averages about 46 degrees Fahrenheit (°F).

Only a few species of aquatic organisms thrive under these conditions, but those few species are abundant. However, many native species cannot reproduce in these constant, cold temperature conditions.

Except for draining the reservoir, no operational method could prevent the continued release of cold water. Multilevel intake structures (a means of selective withdrawal) could be built at Glen Canyon Dam to provide seasonal variation in water temperature. A structure would be attached to each of the eight existing 15-foot-diameter penstocks to withdraw warmer water from upper levels of the reservoir.

Preliminary studies indicated that multilevel intake structures on each of the eight existing penstocks could increase the downstream river temperature 5 to 18 °F above present conditions (river temperatures between 54 and 69 °F from May to October). This temperature increase is still 7 to 16 °F cooler than predam conditions during the summer months and is the warmest possible temperature (not necessarily the optimum temperature) for native fish or other resources. Withdrawal levels could be seasonally adjusted to meet ecological objectives, although this would involve complex factors.

Increasing the temperature of river water may create problems for species currently inhabiting the Colorado River below Glen Canyon Dam. The cold river temperatures may act as a barrier to the upstream migration of non-native predatory fish such as striped bass from Lake Mead. Higher water temperatures may encourage the upstream migration of predatory fish, further endangering humpback chub and other native fish through increased predation or competition.

The cost of installing multilevel intake structures at Glen Canyon Dam has been estimated at $60 million. This estimate is based on actual costs for similar structures at Flaming Gorge Dam.

Many questions will need to be answered before a decision can be made on selective withdrawal. Additional research and analysis could determine whether a selective withdrawal structure would enhance endangered species and other native fish populations in the Colorado River. FWS, in consultation with AGFD, would be responsible for recommending to Reclamation whether or not multilevel intake structures should be built at Glen Canyon Dam. Upon FWS recommendation, Reclamation would seek congressional authorization and funding. Reclamation also would be responsible for design, NEPA compliance, permits, construction, operation, and maintenance.

Emergency Exception Criteria

Normal operations described under any alternative would be altered temporarily to respond to emergencies. These changes in operations would be of short duration (usually less than 4 hours) and would be the result of emergencies at the dam, downstream, or within the inter-connected electrical system. Examples of system emergencies include:

- Insufficient generating capacity
- Transmission system: overload, voltage control, and frequency
- System restoration
- Humanitarian situations (search and rescue)

UNRESTRICTED FLUCTUATING FLOWS

The two unrestricted fluctuating flow alternatives would allow flows to vary, as necessary, for power generation purposes.

No Action Alternative

Minimum releases (cfs)	Maximum releases (cfs)	Allowable daily fluctuations (cfs/24 hrs)	Ramp rate (cfs/hr)
1,000 Labor Day to Easter 3,000 Easter to Labor Day	31,500	30,500 Labor Day to Easter 28,500 Easter to Labor Day	Unrestricted

The No Action Alternative (historic operations) is presented first to provide an understanding of baseline conditions and operations at Glen Canyon Dam. This alternative provides the basis for impact comparison.

Within the overall CRSP purpose, the objective of the No Action Alternative is to produce the greatest amount of firm capacity and energy practicable while adhering to the releases required under the "Law of the River." Under no action, Glen Canyon Dam operations would be the same as they were from 1963—when the dam was placed in operation—until the research flows began in June 1990. This alternative would continue operations established under the *Criteria for Coordinated Long-Range Operation of Colorado River Reservoirs* (Long-Range Operating Criteria) including daily fluctuating releases. The maximum allowable discharge during fluctuations is 31,500 cfs. Releases fluctuate when the dam is being operated to follow power system load changes, to produce peaking power, to regulate the power system, or to respond to power system emergencies.

Annual Release Volume

Annual release volume is based on inflow and remaining space in Lake Powell and Lake Mead. Annual release volumes vary greatly, but all adhere to the Long-Range Operating Criteria objectives of an 8.23-maf minimum annual release and equalized storage between the two reservoirs. Annual releases greater than the minimum are permitted to avoid anticipated spills and to equalize storage.

From 1966 to 1989, annual releases ranged from 8.23 maf to 20.4 maf (1984). The minimum release has occurred in about half the years since the dam was closed in 1963.

Monthly Release Volume

Under the No Action Alternative, the volume of water released from Lake Powell each month depends on forecasted inflow, existing storage levels, monthly storage targets, and annual release requirements. Demands for electrical energy, fish and wildlife needs, and recreation needs also are considered and accommodated as long as the risk of spilling and storage equalization between Lakes Powell and Mead are not affected. Power demand is highest during winter and summer months, and recreation needs are highest during the summer. Therefore, higher volume releases are scheduled during these months whenever possible to benefit these uses.

Spills are excess annual releases that cannot be used for project purposes; they usually are the result of inflow forecast changes. Floodflows—the spills of principal concern—are releases greater than the designed powerplant capacity that are discharged through the river outlet works and spillways.

Each month during the inflow forecast season (January to July), the volume of water to be released for the rest of the year is recomputed based on updated streamflow forecast information. Scheduled releases for the remaining months are adjusted to avoid anticipated spills and maintain conservation storage in accordance with the Long-Range Operating Criteria.

Under high storage conditions, fall and early winter releases are designed to meet the January 1 storage target (22.6 maf). Under lower storage conditions, releases are scheduled at a minimum of about 550,000 acre-feet per month. January through July releases are scheduled to create space in the reservoir so that the forecasted runoff will not produce spills but will fill the reservoir in July. July through September releases are used to meet the minimum annual release requirement and to reach the January 1 target of 22.6 maf.

Floodflow Avoidance

Methods for providing protection against flood releases under the No Action Alternative are:

1. Storage in Lake Powell is not allowed to exceed 22.6 maf as of January 1 of each year (before the forecast season) in preparation for storing and regulating spring runoff.

2. On the first of each month from January to June, a protection factor is added to the forecasted inflow so that more water is assumed to be coming into the reservoir than indicated by the forecast.

3. Throughout the streamflow forecast season (January 1 to July 1), operations are planned as though Lake Powell has 500,000 acre-feet less capacity than it actually has. This provides a storage buffer to further protect against unforecasted inflow.

Hourly Operations

Hourly releases are set to reach monthly release volumes, to maintain established minimum flow rates, and to follow energy demand. Emergency conditions—such as search and rescue operations, generating equipment failures, or power system emergencies—may cause extreme departures from normal operations. Except for search and rescue operations, these departures are short lived (less than 4 hours) and their effects on water releases can be adjusted in a short time (less than 4 hours).

Hourly power operations are most flexible during months with moderate release volumes. The need to maintain minimum flows in months with low release volumes limits flexibility to accommodate changing hourly power demands. If the reservoir is nearly full and inflow is extremely high, monthly releases are scheduled at or near maximum capacity most of the time, leaving little flexibility for hourly releases to change in response to power demand.

Releases fluctuate when the generating units are being operated to follow changes in power system load, to produce peaking power, to regulate the power system, or to respond to power system emergencies. During a minimum release year, the greater the daily release volume the greater the daily fluctuation. To the extent possible within higher priority operating constraints, the following guidelines are used in producing hydroelectric power:

- Maximize water releases during the peak energy demand periods, generally Monday through Saturday between 7 a.m. and 11 p.m.
- Maximize water releases during peak energy demand months and minimize during low demand months
- Minimize and, to the extent possible, eliminate powerplant bypasses

Minimum Flow. Minimum flows are restricted to no less than 1,000 cfs from Labor Day until Easter and 3,000 cfs from Easter until Labor Day (the recreation season). Also during the recreation season, weekday releases must average no less than 8,000 cfs from 8 a.m. to midnight. The minimum flow for any given hour typically depends on the monthly release volume and the magnitude and predictability of electrical load across and within the hour. In some cases, dispatcher experience may be a factor. Occasionally, power system emergencies prevent meeting the minimum release objectives.

Maximum Flow. Maximum flows are determined by powerplant capacity, the power demand at the time of release, and the amount of water required and/or available for release in a given month. As much as 33,200 cfs can be discharged through the powerplant if the reservoir is at the appropriate elevation. Flows greater than 33,200 cfs are discharged

through the outlet works first and then through the spillways. Peak discharges under normal no action operations do not exceed 31,500 cfs. Releases greater than 31,500 cfs are steady on a daily basis.

Range of Fluctuating Flows. The range of daily fluctuations under the No Action Alternative is only restricted to between the minimum and maximum flows.

Ramp Rate. The ramp rate is the rate of change in discharge to meet the electrical load by achieving either higher or lower releases. North American Electric Reliability Council operating criteria require Western to meet scheduled load changes by ramping up or down beginning at 10 minutes before the hour and ending at 10 minutes after the hour. Any ramping to meet scheduled load changes occurs during that same 20-minute period. The principal times of change are in the morning, when releases are increased to respond to the peak daytime demand, and at night, when releases are decreased as the electrical demand diminishes. A computerized automatic generation control (AGC) system controls the rate of release and generation on an instantaneous basis.

Under historical operations, scheduled ramping typically has resulted in large river stage changes. However, the continuous small changes in discharge caused by AGC rarely affect river stage by more than a foot.

Under the No Action Alternative, the only restriction on ramp rates is the physical capability of the generators. The 1-hour up ramp rates have been less than 4,000 cfs per hour about 32 percent of the time and greater than 8,000 cfs about 11 percent of the time. The down ramp rates have been less than 4,000 cfs about 29 percent of the time and greater than 8,000 cfs about 7 percent of the time.

Maximum Powerplant Capacity Alternative

Minimum releases (cfs)	Maximum releases (cfs)	Allowable daily fluctuations (cfs/24 hrs)	Ramp rate (cfs/hr)
1,000 Labor Day to Easter 3,000 Easter to Labor Day	33,200	32,200 Labor Day to Easter 30,200 Easter to Labor Day	Unrestricted

This alternative was developed to allow use of the maximum powerplant discharge capacity that resulted from the previously discussed 1987 uprate and rewind. Operations under the Maximum Powerplant Capacity

Alternative would be the same as under the No Action Alternative except that use of the full powerplant capacity (estimated flows of 33,200 cfs) would be allowed. Monthly and annual operations, including flood control, would be identical to those described under no action. Releases in excess of 31,500 cfs would be possible only when Lake Powell's elevation is greater than 3641 feet. This additional capacity would be used when power demand is high—typically 4 hours or less.

Daily and Hourly Operations

Minimum releases would be at least 3,000 cfs from Easter to Labor Day and 1,000 cfs for the remainder of the year. The range in daily release fluctuations and ramp rates would be unrestricted.

RESTRICTED FLUCTUATING FLOWS

The restricted fluctuating flow alternatives were designed to provide a range of downstream resource protection measures, while offering varying amounts of flexibility for power operations. All four alternatives—high, moderate, modified low, and interim low fluctuating flows—restrict daily fluctuations at Glen Canyon Dam as compared to the No Action and Maximum Powerplant Capacity Alternatives. Each alternative also specifies ramp rate restrictions and minimum release requirements.

Within the constraints of the alternatives, maximum water releases would be scheduled to coincide with times of peak electrical demand. If additional energy must be purchased to meet daily demand, attempts would be made to schedule low hourly releases at night to allow those purchases during the more economical hours of the day.

Scheduled annual and monthly release volumes would be determined using essentially the same considerations described under the No Action Alternative. Beach/habitat-building flows would modify monthly release volumes when Lake Powell is drawn down.

Habitat maintenance flows—short-term high releases during the spring—are included in the Moderate and Modified Low Fluctuating Flow Alternatives to transport and deposit sand for maintaining camping beaches and fish and wildlife habitat. These maintenance flows were not included in the other restricted fluctuating flow alternatives for the following reasons. With habitat maintenance flows, the High Fluctuating Flow Alternative would, over the long term, move more sand than supplied by tributaries and would result in net erosion. Maintenance flows were not included in the Interim Low Fluctuating Flow Alternative in order to preserve the current interim flow operations for which nearly 2 years of data have been collected.

High Fluctuating Flow Alternative

Minimum releases (cfs)	Maximum releases (cfs)	Allowable daily fluctuations (cfs/24 hrs)	Ramp rate (cfs/hr)
3,000 5,000 8,000 depending on monthly volume, firm load, and market conditions	31,500	15,000 to 22,000 depending on monthly release volume	Unrestricted up 5,000 or 4,000 down

The High Fluctuating Flow Alternative was developed to slightly reduce fluctuating flows, with the goal of protecting or enhancing downstream resources while allowing flexibility for power operations. Releases would be tied to hydrology and power system demand. This alternative would have the same annual and monthly operation plan as described under the No Action Alternative but would include additional restrictions on daily and hourly operations. Parameters such as minimum flows, down ramp rates, and allowable daily fluctuations were designed to provide some resource protection, but without substantial impacts to hydropower. Although daily fluctuation limits would be constant within a month, the minimum and maximum flows might be different each day.

Daily and Hourly Operations

Minimum flows would be 3,000, 5,000, or 8,000 cfs depending on monthly release volume, firm load, and power market conditions. The maximum flow during hourly fluctuating releases would be limited to 31,500 cfs. When high inflow volumes and storage conditions require releases greater than 31,500 cfs, such releases would be steady on a daily basis.

The limit on daily fluctuations often would be more restrictive than the minimum and maximum flow rates. Fluctuations would be limited to 15,000 to 22,000 cfs over any 24-hour period, depending on the monthly release volume.

The ramp rate would follow the power load for increasing flows without restriction, but decreasing flows would be limited to 5,000 cfs per hour (winter and summer) or 4,000 cfs per hour (spring and fall).

Moderate Fluctuating Flow Alternative

Minimum releases (cfs)	Maximum releases (cfs)	Allowable daily fluctuations (cfs/24 hrs)	Ramp rate (cfs/hr)
5,000	31,500	±45% of mean flow for the month not to exceed ±6,000	4,000 up 2,500 down

The Moderate Fluctuating Flow Alternative was developed to reduce daily flow fluctuations below no action levels and to provide special high steady releases of short duration, with the goal of protecting or enhancing downstream resources while allowing intermediate flexibility for power operations. This alternative would have the same annual and essentially the same monthly operating plan as described under no action (except for the addition of habitat maintenance flows), but would restrict daily and hourly operations more than the No Action, Maximum Powerplant Capacity, or High Fluctuating Flow Alternatives. Parameters such as minimum flows, ramp rates, and allowable daily fluctuations were designed to provide resource protection through consistent release patterns throughout each month.

Daily and Hourly Operations

Minimum flows for a given month would vary depending on the monthly release volume but would be no less than 5,000 cfs. The maximum rate of release for a given month also would vary depending on the monthly release volume but would be no greater than 31,500 cfs under normal operations. When high inflow volumes and storage conditions require releases greater than 31,500 cfs, such releases would be steady on a daily basis. Because of restrictions on daily fluctuations and ramp rates, maximum flows during a minimum release year would normally not exceed 22,300 cfs. The ramp rate would be limited to 4,000 cfs per hour for increasing flows and 2,500 cfs per hour for decreasing flows.

Allowable daily fluctuations as well as minimum and maximum flows would be determined based on the mean releases for the month. The allowable fluctuation would be plus or minus 45 percent of the mean daily flow, not to exceed plus or minus 6,000 cfs.

Habitat Maintenance Flows

Habitat maintenance flows are included in this alternative to re-form backwaters and maintain sandbars, which are important for camping beaches and wildlife habitat. Habitat maintenance flows are high, steady releases within powerplant capacity (33,200 cfs) for 1 to 2 weeks in spring.

The exact month would be determined under the Adaptive Management Program and the Annual Operating Plan. A more complete description of habitat maintenance flows can be found under the Modified Low Fluctuating Flow Alternative that follows.

Modified Low Fluctuating Flow Alternative (*Preferred Alternative*)

Minimum releases (cfs)	Maximum releases (cfs)	Allowable daily fluctuations (cfs/24 hrs)	Ramp rate (cfs/hr)
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

The Modified Low Fluctuating Flow Alternative was developed to reduce daily flow fluctuations well below no action levels and to provide special high steady releases of short duration, with the goal of protecting or enhancing downstream resources while allowing limited flexibility for power operations. This alternative would have the same annual and essentially the same monthly operating plan as described under the No Action Alternative but would restrict daily and hourly operations more than any of the previously described fluctuating flow alternatives.

This alternative is essentially the same as the Interim Operating Criteria implemented on November 1, 1991, except for the addition of habitat maintenance flows, endangered fish research, and the common elements. Also, the method of reducing flood frequency is specified for this alternative. Flood frequency reduction would be accomplished by raising the height of the spillway gates (see "Common Elements").

Additional information on the effects of dam operations has been gathered since the Interim Operating Criteria were developed. Some of this preferred alternative's parameters could change slightly in the final EIS based on possible adjustment to the interim operations, new information, or public comments.

Daily and Hourly Operations

Minimum flows would be no less than 8,000 cfs between 7 a.m. and 7 p.m. and 5,000 cfs at night. The maximum rate of release would be limited to 20,000 cfs during fluctuating hourly releases. Any releases greater than 20,000 cfs (other than for emergencies) would be steady on a daily basis

and would be made in response to high inflow and storage conditions. Ramp rates would be limited to 2,500 cfs per hour for increasing flows and 1,500 cfs per hour for decreasing flows.

The limit on daily fluctuations often would be more restrictive than the minimum and maximum flow rates. Fluctuations would be limited during any 24-hour period, depending on monthly release volumes.

Habitat Maintenance Flows

Maximum releases under the Modified Low Fluctuating Flow Alternative normally would not exceed 20,000 cfs during a minimum release year. Without higher flows:

- Portions of sandbars above the normal peak stage could not be rebuilt.
- Sediment would accumulate at low elevations, including backwaters.
- Camping beaches and return-current channels would likely become overgrown with vegetation.

Once low elevation sandbars became vegetated, large flows (perhaps greater than 45,000 cfs) would be required to remove vegetation and re-form backwaters. Although an occasional floodflow (greater than 33,200 cfs) may rebuild high elevation beaches and re-form backwaters, frequent floodflows would likely transport more sand than could be supplied by the tributaries—resulting in long-term sandbar erosion. Therefore, habitat maintenance flows are included in this alternative to re-form backwaters and maintain sandbars, which are important for camping beaches and wildlife habitat.

Habitat maintenance flows are high, steady releases within powerplant capacity for 1 to 2 weeks in the spring. The exact month would be determined under the Adaptive Management Program and the Annual Operating Plan. March was assummed for evaluating impacts for the following reasons:

- Backwater channels could be re-formed prior to the humpback chub spawning period.
- More sediment is likely to be supplied by tributary flow in March than later in the spring.
- March is prior to the peak recreation use season.

Habitat maintenance flows would not be scheduled when the projected storage in Lake Powell on January 1 is greater than 19 maf. Annual release volumes under such conditions are typically greater than the minimum annual release volume (8.23 maf), and such flows already may be near or exceed powerplant capacity.

Although habitat maintenance flows are defined as steady, minor fluctuations of up to plus or minus 1,000 cfs would be permitted to regulate voltage within the power grid. Maintenance flows would begin by increasing flows at a rate no greater than 2,500 cfs per hour and would conclude by decreasing flows back to the normal operating range at a rate no greater than 1,500 cfs per hour. The limit on daily change in flow would not apply during these transitions.

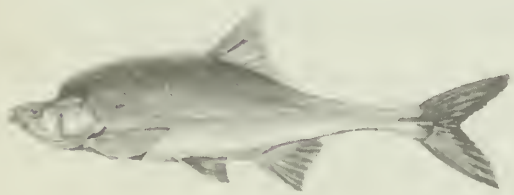
Habitat maintenance flows differ from beach/habitat-building flows because they would be within powerplant capacity and would occur nearly every year when the reservoir is low. Habitat maintenance flows would not occur in years when a beach/habitat-building flow is scheduled. Neither of these special releases would be scheduled in a year when there is concern for a sensitive resource—such as sediment or an endangered species.

Increasing the flow to 30,000 cfs for 10 days would result in the release of an additional 412,000 acre-feet of water in March, which would require adjusting the release volumes in the other months. This scheduling adjustment would be determined during the Annual Operating Plan preparation and may vary from year to year.

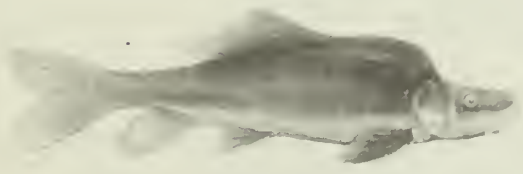
Endangered Fish Research

Further studies of the linkages between endangered fish, their habitat, and Colorado River flows are a part of this alternative. Endangered fish research flows would be between 8,000 and 20,000 cfs with a steady pattern and monthly release volumes during the spring and summer months similar to the Seasonally Adjusted Steady Flow Alternative.

Research may require as many as 5 low-release years (annual release at or near 8.23 maf). Since low water release years are expected to occur about half the time, it is uncertain how many total years it would take to complete the studies. However, it is likely that research flows could be completed within 10 years. Upon completion of the research flows and analysis of the data, Reclamation would implement any necessary changes in operating criteria to comply with the Endangered Species Act.



Humpback Chub



Razorback Sucker

Interim Low Fluctuating Flow Alternative

Minimum releases (cfs)	Maximum releases (cfs)	Allowable daily fluctuations (cfs/24 hrs)	Ramp rate (cfs/hr)
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

The Interim Low Fluctuating Flow Alternative was developed to reduce daily flow fluctuations to well below no action levels, with the goal of protecting or enhancing downstream resources while allowing limited flexibility for power operations. This alternative would have the same annual and monthly operating plan as the No Action Alternative but would restrict daily and hourly operations as much as or more than any alternative allowing fluctuating flows. This alternative is the same as the Interim Operating Criteria implemented on November 1, 1991 (except for the addition of the common elements). Parameters such as minimum flows, maximum flows, ramp rates, and allowable daily fluctuations were designed to protect downstream resources until completion of the final EIS and ROD.

Daily and Hourly Operations

Minimum flows would be no less than 8,000 cfs between 7 a.m. and 7 p.m. and 5,000 cfs at night. The maximum rate of release would be limited to 20,000 cfs during fluctuating hourly releases. Any releases greater than 20,000 cfs (other than for emergencies) would be steady on a daily basis and would be made in response to high inflow and storage conditions. Ramp rates would be limited to 2,500 cfs per hour for increasing flows and 1,500 cfs per hour for decreasing flows. The limit on daily fluctuations often would be more restrictive than the minimum and maximum flow rates. Fluctuations would be limited during any 24-hour period, depending on monthly release volumes.

STEADY FLOWS

The steady flow alternatives were designed to provide a range of downstream resource protection measures by minimizing daily release fluctuations. Flows would be steady on either a monthly, seasonal, or year-round basis. The monthly distribution of release volumes would differ, but daily and hourly operating criteria would be the same for all steady flow alternatives. Flows would be the same each day within the

month or season (except during flood control operations). The scheduled annual release volume would be determined in accordance with the Long-Range Operating Criteria.

Monthly or seasonal release volumes would be based on the month-to-month pattern specified for the alternative. Although the goal would be to maintain steady (uniform) water releases for selected durations, the ability to maintain a steady flow from one period to the next would depend on the accuracy of streamflow forecasts and the space available in Lake Powell.

Minimum or maximum flow rates would be determined by the monthly water volume to be released. The goal would be to hold flows steady to within plus or minus 1,000 cfs per day and adjust them between months in response to forecast changes. Ramp rates within this flow range would not be restricted because river stage fluctuations would be within a few inches. The maximum change in releases between months would be 2,000 cfs per day.

Daily variations of plus or minus 1,000 cfs per day (approximately 42 megawatts) would allow some minor flexibility in dam operations, primarily for electrical system regulation. AGC would cause minor fluctuations as the powerplant's computerized regulation system made adjustments every 2 to 6 seconds. Resulting changes in river stage would not be noticeable downstream. Flow fluctuations of this magnitude were measured during steady research flows, and the corresponding river stage fluctuations were small.

Water releases in excess of powerplant capacity would flow through the outlet works and/or spillways during high water years or, as necessary, during beach/habitat-building flows.

The habitat maintenance flows included in the Seasonally Adjusted Steady Flow Alternative were not included in the other steady flow alternatives. Such flows would be contrary to the concepts for which these steady flow alternatives were developed; i.e., to keep flows steady under the Year-Round Steady Flow Alternative and to retain the pattern of historic monthly releases under the Existing Monthly Volume Steady Flow Alternative.

Existing Monthly Volume Steady Flow Alternative

Minimum releases (cfs)	Maximum releases (cfs)	Allowable daily fluctuations (cfs/24 hrs)	Ramp rate (cfs/day)
8,000 Oct-Nov 8,500 Dec 11,000 Jan-Mar 12,500 Apr 18,000 May-Jun 12,500 Jul 9,000 Aug-Sep	18,000	±1,000	2,000 between months

The Existing Monthly Volume Steady Flow Alternative was developed to provide steady flow on a monthly basis while continuing to maintain flexible monthly release volumes to avoid spills and maintain conservation storage. Steady flows were included each month with the goal of protecting or enhancing downstream resources, especially the aquatic ecosystem that exists downstream from the dam.

This alternative would have the same annual and monthly operating plan as the No Action Alternative, but releases would be steady within months. Also, beach/habitat-building flows would modify monthly release volumes when Lake Powell is drawn down.

Minimum Flow

Both minimum and maximum flows would be within plus or minus 1,000 cfs of the mean monthly release. Based on analysis of historical releases, minimum flows would rarely be below 8,000 cfs (476,000-acre-foot monthly volume).

Monthly Release Volume

The scheduled monthly release volumes would be the same as the monthly volumes under the No Action Alternative. Based on the period 1963-89, February has the lowest monthly median release volume (556,000 acre-feet—equivalent to 10,000 cfs), and August has the highest monthly median release volume (903,000 acre-feet—equivalent to 14,700 cfs).

Seasonally Adjusted Steady Flow Alternative

Minimum releases (cfs)	Maximum releases (cfs)	Allowable daily fluctuations (cfs/24 hrs)	Ramp rate (cfs/day)
8,000	Monthly volumes prorated	±1,000	2,000 between months

The Seasonally Adjusted Steady Flow Alternative was developed to enhance the aquatic ecosystem by releasing water at a constant rate within defined seasons and by using habitat maintenance flows. Seasonal variations in minimum flows and habitat maintenance flows were designed with the goal of protecting and enhancing native fish. Monthly release patterns would differ from the No Action Alternative as explained in more detail below.

This alternative would provide steady flows on a 1- to 3-month basis, providing seasonal variations throughout the year to meet downstream resource needs. The highest releases would occur in May and June, with relatively low releases from August through December.

Minimum Flow

The minimum monthly constant release for each season is shown above. These minimum release requirements would be relaxed to avoid spills during high storage or inaccurate forecast situations.

Monthly Release Volume

Releases within each month would be steady and would have to equal or exceed the monthly minimums. Any additional water in excess of the minimum annual release volume would be distributed equally among the 12 months, subject to an 18,000-cfs maximum. This 18,000-cfs maximum would be exceeded when the annual release is more than 13.14 maf. If forecasts changed, the volume of water to be released during the remainder of the year would be recomputed monthly based on updated forecasts, and the constant rate of release would be adjusted accordingly.

Habitat Maintenance Flows. Habitat maintenance flows are included in this alternative to re-form backwaters and maintain sandbars, which are important for camping beaches and wildlife habitat. Habitat maintenance flows are high, steady releases within powerplant capacity (33,200 cfs) for 1 to 2 weeks in the spring. The exact month would be determined under the Adaptive Management Program and the Annual Operating Plan. Habitat maintenance flows are described in more detail under the Modified Low Fluctuating Flow Alternative.

Year-Round Steady Flow Alternative

Minimum releases (cfs)	Maximum releases (cfs)	Allowable daily fluctuations (cfs/24 hrs)	Ramp rate (cfs/day)
Yearly volume prorated	Yearly volume prorated	±1,000	2,500 up

The Year-Round Steady Flow Alternative was developed to eliminate fluctuating flows, both daily and seasonal. Year-round steady flows were designed with the goal of protecting or enhancing downstream resources by providing the greatest amounts of river-stored sediment and biomass possible in the postdam environment.

Minimum Flow

Minimum flows would be determined from the mean monthly release but would correspond generally to the minimum annual release volume of 8.23 million acre-feet, which is about 11,400 cfs. The minimum release requirement would be relaxed to avoid spills during high storage or inaccurate forecast situations.

Monthly Release Volume

The monthly volume would be approximately the annual volume divided by 12, except when response to forecast changes would be required. If forecasts changed, the volume of water to be released during the remainder of the year would be recomputed monthly based on updated forecasts, and the constant rate of release would be adjusted accordingly. The ability to maintain a constant rate of release for the entire year would depend on the accuracy of streamflow forecasts and the amount of space remaining in Lake Powell. Approximately half of the time, lake elevation would be high enough that forecast changes could cause some variations in monthly volumes.

MITIGATION

All environmental mitigation has been incorporated into the alternatives; no other mitigation elements are presently included. Future measures that could be considered as mitigation for the loss of power are described below.

Power Adjustments

The Grand Canyon Protection Act directs the Secretary of Energy to consult with other agencies and the public to identify economically and technically feasible methods of replacing any power generation that is lost

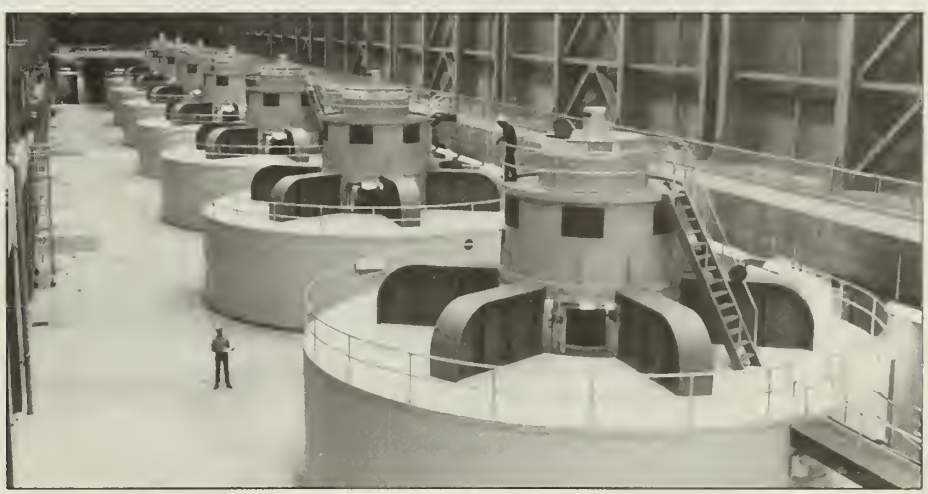
through changed operations at Glen Canyon Dam. The Secretary of Energy must present a report of the findings and draft implementing legislation, if necessary, not later than 2 years after adoption of new operating criteria (ROD). That process should result in acquisition of permanent replacement power.

How Western markets energy and capacity from Glen Canyon Dam would differ for each alternative. Some basic options to replace lost power are listed below.

- Purchase power from alternate sources
- Increase energy conservation
- Change transmission system capability
- Build new generating facilities

Some of these options may take 5 to 7 years to implement fully. Continuing use of the financial exception criteria allowed under interim operations is a potential short-term (5- to 7-year) mitigation measure. These financial exception criteria relate to Western's ability to demonstrate that unused generation capacity is available to meet firm (guaranteed) contract commitments at times when nonfirm thermal energy is being used to meet those commitments. Under interim operations, operational limits can be exceeded for financial reasons up to 3 percent of the time (22 hours) in any consecutive 30-day period, with no carryover.

Actually making use of unused capacity is unlikely. While Western's customers have benefited from having financial exception criteria available during interim operations, Western has not had to exceed operating criteria for financial reasons. If financial exception criteria are part of the selected alternative, the availability of capacity and energy would be maintained, and costs to customers would be expected to increase at a slower rate.



Generators at Glen Canyon Powerplant.

PERMITS AND REGULATORY APPROVALS

No permits or regulatory approvals would be necessary immediately to implement any of the alternatives. Depending on the results of long-term monitoring and research under adaptive management, permits under sections 402 and 404 of the Clean Water Act may be needed in the future.

ALTERNATIVES ELIMINATED FROM DETAILED ANALYSIS

During the scoping process, including formulation of alternatives, various alternatives and concepts were considered. Some were determined not reasonable for detailed analysis, as explained below.

Run-of-the-River Alternative

Many comments received during the scoping process expressed a desire that the dam be operated to mimic predam conditions in Grand Canyon. The EIS team responded by formulating the Run-of-the River Alternative, with the goal of achieving predam conditions through operational changes, sediment augmentation, and selective withdrawal.

Conclusion

A return to a seasonal streamflow pattern emulating the magnitude of historic spring flows would be very destructive to downstream resources unless a large-scale, long-term sediment augmentation program were added. However, sediment augmentation would cause an increase in turbidity and disrupt the aquatic food chain below Lees Ferry. Other potentially significant impacts are unknown. A sediment slurry pipeline would require 15 to 20 years to implement, and a plan to operate the dam in the interim still would be needed. If sediment augmentation is desired in the future, this action would be the subject of a separate EIS.

Without sediment augmentation, the flows under this alternative would cause more erosion to sediment deposits below Glen Canyon Dam than other alternatives, including no action.

Historic Pattern Alternative

This alternative was a modification of the Run-of-the River Alternative. It attempted to more closely follow predam water flow patterns, while still managing flows within current powerplant capacity. The Historic Pattern Alternative also included a sediment slurry pipeline and selective withdrawal.

Conclusion

This alternative was eliminated from detailed study for most of the same reasons as the Run-of-the-River Alternative. A sediment slurry pipeline would require 15 to 20 years to implement, and a plan to operate the dam in the interim still would be needed.

Without sediment augmentation, the flows under this alternative would cause more erosion to sediment deposits below Glen Canyon Dam than other alternatives, including no action. Mitigating these impacts by reducing seasonally high flows creates a flow regime incorporated into the Seasonally Adjusted Steady Flow Alternative. For these reasons, the Historic Pattern Alternative was not further considered.

Reregulated Flow Alternative

The EIS team responded to scoping comments requesting full use of Glen Canyon Dam Powerplant's generating capacity by developing the Reregulated Flow Alternative. The objective of this alternative was to initiate operational changes to fully use the powerplant's generating capacity (flows of 33,200 cfs) while reducing, to the extent possible, existing adverse impacts on downstream resources by constructing a reregulation dam.

Conclusion

Constructing a reregulation dam in Glen Canyon National Recreation Area would require changes in existing laws that protect the values for which the recreation area was established and prohibit construction of a dam within a national park or monument. While most downstream resources would experience improved conditions over the No Action Alternative, resources in the Glen Canyon reach would experience significant negative impacts.

Resources in the Glen Canyon reach that would be significantly impacted include sandbars, riparian vegetation and associated terrestrial wildlife, *Cladophora* and associated algal and invertebrate communities, a regionally important trout fishery, recreation potential, Native American cultural and sacred sites, and archeological and historic areas/sites. Impacts to the *Cladophora*-based aquatic food chain could have effects throughout Grand Canyon.

Most of these impacts would result from the greater frequency and magnitude of fluctuations behind the reregulating dam constructed to protect downstream resources from those same fluctuations. A reregulating dam would require $60 to $110 million to construct and 5 to 15 years to implement without any opposition.

Impacts in the Glen Canyon reach could be mitigated by reducing the frequency and magnitude of daily river fluctuations. However, without maximum fluctuations, there would be no need for a reregulation dam.

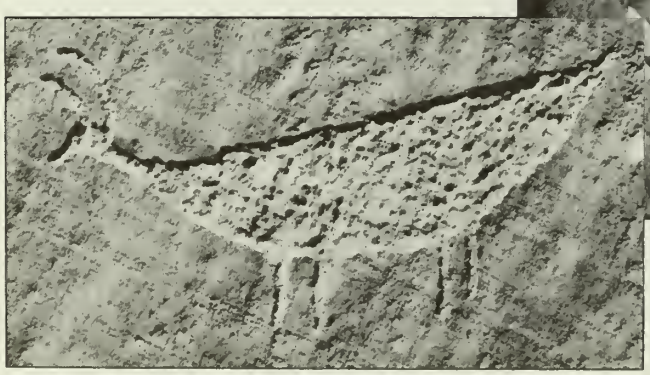
Reduced fluctuations, and elimination of the reregulation dam create conditions identical to those evaluated under other fluctuating flow alternatives, including no action.

Eliminated Concepts

Some comments received during the scoping process suggested the following concepts that were not formulated in detailed alternatives.

- Sand pumping
- Beach protection
- Remove Glen Canyon Dam
- Move hydropower peaking from Glen Canyon Dam to Hoover Dam

The last remaining reach of the Colorado River in Glen Canyon.



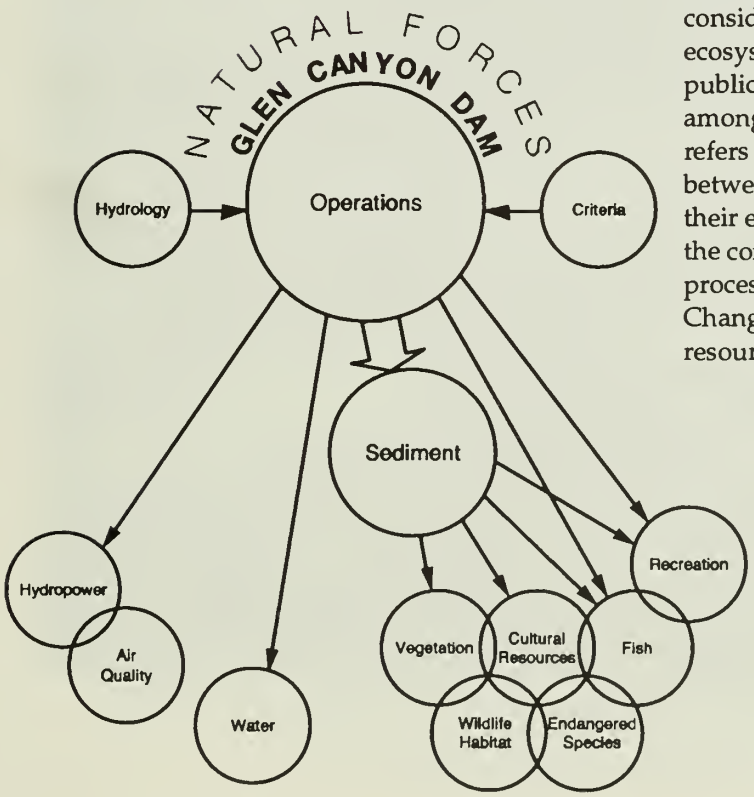
Rock art found on canyon wall in the Glen Canyon reach.

Affected Environment and Environmental Consequences

This section describes how resources in the Colorado River system are linked, what resources are affected in the study area, and evaluates the effects of the alternatives on these resources. The baseline conditions described are those that existed in 1990, prior to the GCES research flows. The summary table at the end of this section compares the alternatives and their impacts.

COLORADO RIVER SYSTEM RESOURCE LINKAGES

Resources downstream from Glen Canyon Dam through Grand Canyon are interrelated, or linked, since virtually all of them are associated with or depend on water and sediment. This section gives an overview of these linkages to better illustrate the interdependence of processes and resources in the study area.



During the EIS scoping process, many comments from the public called for consideration of the Grand Canyon ecosystem as a whole, showing that the public is aware of the interrelationships among resources. The term "ecosystem" refers to the system formed by interactions between communities of organisms and their environment. A "system" is based on the concept that resources and the processes that drive them are linked. Changes in a single process can affect resources throughout the entire ecosystem.

The EIS emphasizes the holistic pattern of system behavior rather than impacts to separate elements. However, it cannot provide a complete, scientific evaluation of the Grand Canyon ecosystem because such an approach is too technically detailed for the purpose and scope of this document. Also, all

the linkages among resources of the Grand Canyon ecosystem are not fully understood at this time. A program of monitoring and adaptive management is required to expand our understanding of how changes in processes affect this system. The Glen Canyon Dam EIS focuses on the following processes, resources, and their linkages:

- Water release and sediment transport patterns
- Aquatic and terrestrial "indicator resources" within the system

The system of concern in this study is the Colorado River corridor—from Glen Canyon Dam through Grand Canyon to Separation Canyon—and includes resources located in the river channel and in a narrow band of adjacent land (figure 4). Resources within this system depend on factors outside these operationally defined boundaries, such as the physical and biological constraints of Lake Powell and—to a lesser extent—Lake Mead and tributaries.

The Grand Canyon ecosystem originally developed in a sediment-laden, seasonally fluctuating environment. The construction of Glen Canyon Dam altered the natural dynamics of the Colorado River. Today, Grand Canyon's ecological resources depend on water releases from the dam and inconsistent sediment input from tributaries. The alternatives evaluated in this EIS must take into account not only the short-term needs of the environment but also the long-term requirements for maintaining and supporting the ecological elements of Grand Canyon.

Lake Powell traps water, sediment, and associated nutrients that once traveled down the Colorado River. Interruption of riverflow and regulated release of lake water now support aquatic and terrestrial systems that did not exist before Glen Canyon Dam. Some changes are lamented while others are valued. The present interactions among water volume and release patterns, sediment transport, and downstream resources have created and support a complex system much different from predam conditions. The following discussion addresses this current system.

Water Volume and Pattern of Release

The major function of Glen Canyon Dam (and Lake Powell) is water storage. The dam is managed to release at least 8.23 maf of water annually to the Lower Basin and Mexico. 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 and its pattern of release directly or indirectly affect physical, biological, recreational, and cultural resources within the river corridor.

Photo by Gary Ladd

Figure 4.—Photograph of Colorado River corridor looking downstream from Nankoweap Creek.

Predam annual flows ranged seasonally from spring peaks sometimes greater than 100,000 cfs to winter lows of 1,000 to 3,000 cfs. Water releases now vary on a daily or even hourly basis. 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.

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. The powerplant has eight generating units with a maximum combined capacity of 1,356 megawatts. When possible, higher releases are scheduled to generate more electricity in high-demand winter and summer months. Glen Canyon Powerplant has produced about $55 million in revenue in a minimum water-release year (8.23 maf).

Daily releases can range from 1,000 to 31,500 cfs, but actual daily fluctuations have been less than this maximum range. These fluctuations result in a downstream "fluctuating zone" between low and high river stages (water level associated with a given release) that is inundated and exposed on a daily basis. In this analysis, flows are defined as fluctuating if they change more than 2,000 cfs in 24 hours.

Glen Canyon Dam also affects downstream water temperature and clarity. Before the dam, water temperature varied seasonally from highs around 80 °F to near freezing. Now, water released from Glen Canyon Dam averages 46 °F and varies only a few degrees year-round. Very little warming occurs downstream. Lake Powell traps sediment that was historically transported 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

Exposed sediment deposits (including beaches) through Glen and Grand Canyons are very important for cultural, recreational, and biological resources. Sediment stabilizes archeological sites and camping beaches, creates backwater fish habitats, transports nutrients, and provides a foundation for vegetation that serves as 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 river returned to lower levels. Natural cycles of deposition and erosion generally kept vegetation from growing near the river.

The river's capacity to transport sediment has been reduced along with the sediment supply. Maximum water releases (31,500 cfs) are much lower than the peak flows that occurred before Glen Canyon Dam. Without these peak flows, the riverbed and low elevation sandbars tend to build up, and high elevation sandbars tend to erode. The only sources for resupplying sediment to the river below the dam are tributaries—primarily the Paria River, LCR, and Kanab Creek.

The 1983-86 floodflows transported sand stored within the river channel, eroded low elevation sandbars, and built high elevation sandbars. 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 after riverflows subsided. 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 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 in the Southwestern United States. High flows—whether daily or annual—are necessary to replenish sand deposits, but high flows occurring too frequently in the dam-altered river eventually will lead to net erosion and loss of sediment.

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 (water) and terrestrial (land) resources downstream. The resulting system can be described as "naturalized," meaning a mixture of native and non-native plant and animal communities supported by postdam conditions. The river is forever changed. That change—brought about by Glen Canyon Dam—permitted this naturalized ecosystem to exist.

Well-defined volumes of cold, clear water annually pass through Glen and Grand Canyons. Native fish that could not tolerate these conditions have declined or disappeared from the canyon. Other species and communities that were rare or nonexistent before the dam are now abundant. None of the alternatives considered in this EIS has the potential to return the system to predam conditions.

Aquatic Resources

The biological foundation of the aquatic system in the postdam Colorado River below Glen Canyon Dam is *Cladophora glomerata*, a non-native filamentous green alga. River conditions created by the dam—low temperatures, nutrients from Lake Powell, and clear water—make possible its abundant growth. *Cladophora* filaments provide attachment sites for single-celled organisms (diatoms) and hiding places for insect larvae. A non-native small crustacean, *Gammarus lacustris*, feeds on the diatoms and

uses *Cladophora* as a refuge. Together, these organisms 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 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, and food-chain organisms decrease. The sediment particles' abrasive action also decreases the abundance of food organisms. As the food supply decreases downstream, trout decrease in abundance and condition.

Before the dam, eight native fish species inhabited the river. Now several species face survival problems, and only three native fish species remain relatively common in tributaries and certain sections of the river. The reasons for these survival problems are undoubtedly complex, but habitat changes brought about by construction of Glen Canyon Dam and the introduction of non-native fish are principal known factors.

Because of cold water temperatures, reproduction of the remaining native fish species is confined to the tributaries, which are mostly outside the influence of the dam. The slow-moving water in backwaters and near-shore areas protect young fish from the stress and dangers of the main channel. Under the proper conditions, backwaters have higher water temperatures than the main channel and better food conditions for young fish.

The native fish populations that remain in Grand Canyon may derive some indirect protection from cold water. Year-round releases of uniformly cold water may discourage further invasion and reproduction of warmwater non-native fish that prey on or compete with native fish.

Not only do the physical characteristics of water affect aquatic resources, but how water is released from the dam also affects them. For example, extended periods of exposure can adversely affect *Cladophora* and its associated invertebrates. Fluctuating discharges may dislodge segments of *Cladophora* and carry drifting clumps of this important food-bearing resource downstream for trout and other organisms. The fluctuating zone supports fewer aquatic invertebrates than those sites that are always under water.

Large flow fluctuations affect trout and native fish spawning. Although the trout fishery is maintained by stocking, mature trout attempt to spawn at suitable river sites and in certain tributaries. Rapid decreases in discharge can strand spawning trout, and low river stages can expose their nests and limit their access to tributaries. Fluctuating releases also may affect native fish access to tributaries and backwater habitat. Bald

eagles—which only passed through Grand Canyon before the dam—now stop at Nankoweap Creek during the winter to feed on spawning trout and fish stranded by fluctuating flows.

Water release patterns also affect water-based recreation in the river corridor. 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. While some bank fishing occurs, most anglers are also boaters who motor upstream from Lees Ferry. Rapid reductions in flows can expose submerged cobble bars and make navigation difficult.

Terrestrial Resources

Riparian (near water) vegetation is a major terrestrial "indicator resource" below the dam. Before Glen Canyon Dam, seasonally high riverflows reworked sediment deposits and scoured most vegetation from the river corridor below the 100,000- to 125,000-cfs river stage elevation. The only riparian vegetation present along the river developed above this scour zone in what is known as the old high water zone (OHWZ).

Following dam construction, riparian vegetation developed below the OHWZ in what has become known as the new high water zone (NHWZ). Today, this new zone of vegetation provides several hundred acres of habitat for native wildlife. Riparian vegetation reflects water release patterns and is an excellent example of how resources are linked in the terrestrial system. A mixture of native and non-native plant species helps stabilize sediment deposits and provides habitat for numerous species of mammals, birds, amphibians and reptiles, and terrestrial invertebrates. Many of these plants and animals have cultural significance to Native Americans.

Emergent marsh vegetation, such as cattails, often develops in areas with low water velocity and high concentrations of silt and clay. Even though emergent marsh plants make up less than 2 percent of the total riparian vegetation, it greatly enhances diversity in the river corridor.

While riparian vegetation supports its own insect populations, it also provides habitat for insects emerging from the river. The diverse riparian plant communities and abundant invertebrates make the riparian zone—especially the NHWZ vegetation resulting from dam-regulated flows—valuable wildlife habitat. The riparian zone is attractive to mammals because it provides them with cover and food, and some mammals—like bats—eat the insects in the river corridor.

Birds depend on riparian vegetation for nesting cover. Over half of the bird species nesting along the river corridor nest in riparian vegetation. Many birds eat insects or feed insects to their young, relying on the river and riparian vegetation for this important food. Some breeding bird densities in the riparian zone are among the highest recorded. One of the

highest known densities of peregrine falcons in North America resides in Grand Canyon, feeding on the swallows, swifts, and bats there (figure 5).

The importance of riparian zone resources as wildlife habitat is easily demonstrated by the distribution of lizards. These species are most abundant near the shoreline where invertebrates, including insects, are common. Densities of lizards in some Colorado River corridor locations are higher than anywhere else in the Southwest.

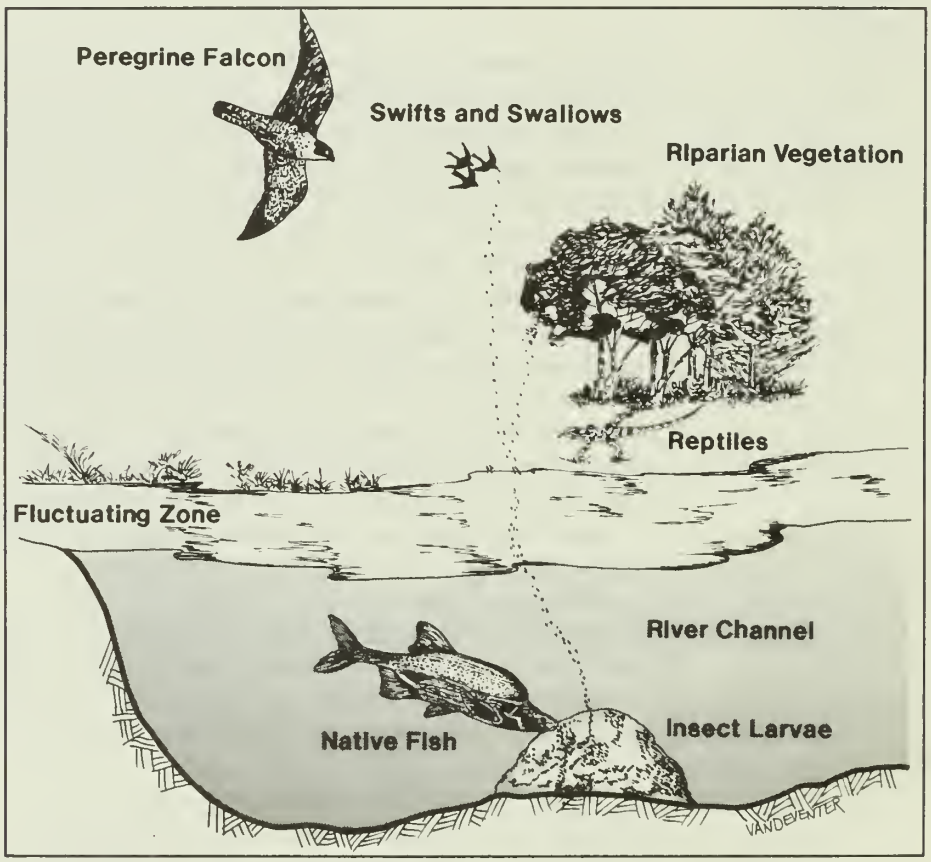


Figure 5.—Insects are an important linkage between aquatic and terrestrial systems in Grand Canyon. Swallows, swifts, and bats feed on insects; peregrine falcons—an endangered species—feed on these foraging species.

WATER

Issue *How do dam operations affect the amount and quality of WATER available from Lake Powell at specific times?*

Indicators

Acre-feet of **streamflows**
Frequency and volume of **floodflows and other spills**
Reservoir storage in Lakes Powell and Mead
Acre-feet of annual **water allocation deliveries**
Acre-feet of **Upper Basin yield determination**
Chemical, physical, and biological characteristics of **water quality**

Affected Resources

Existing statutes and rules guide the determination of annual **streamflows**—volumes of water released from Glen Canyon Dam—to spread the benefits of the Colorado River among the seven Basin States. The target minimum annual release from Lake Powell is 8.23 maf.

Floodflows are releases in excess of the 33,200-cfs powerplant capacity. **Other spills** are excess annual releases from Lake Powell—greater than legally required—caused by scheduling difficulties (usually a substantial decrease in actual inflow from the initial forecasts). Any flows in excess of 33,200 cfs bypass the powerplant, with a corresponding loss in generated 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. The water storage necessary to carry the Upper Basin through a long drought would be reduced if alternative dam operations resulted in increased water releases.

Water allocation deliveries are the allowances of water diverted by each of the Basin States and delivered to Mexico under the "Law of the River." **Upper Basin yield** is the legally determined maximum volume of water available for annual depletion by the Upper Basin States. Water depletions that New Mexico plans to use on an interim basis—in excess of its entitlement—are based on this determination.

Glen Canyon Dam altered downstream **water quality** by changing water temperature and clarity. Before the dam, water temperatures varied seasonally from about 80 °F to near freezing. Now water releases average 46 °F year-round, and very little warming occurs downstream. Lake Powell traps sediment, so the dam releases clear water, and the river becomes muddy only when downstream tributaries contribute sediment.

Effects of the Alternatives

Annual **streamflows** (release volumes) would differ only negligibly from no action under all alternatives and, therefore, are not expected to affect the distribution of benefits among the Basin States. The slight differences would result from modified monthly release patterns or from floodflow reduction measures.

The flood frequency reduction measures included in the restricted fluctuating and steady flow alternatives would reduce the frequency of unscheduled **floodflows** (greater than 45,000 cfs) from an average of once in 40 years to once in 100 years. **Other spills** would differ only negligibly from no action under all alternatives. Any differences would be due to more difficult water scheduling as a result of floodflow reduction measures or from revised monthly release patterns.

Reservoir storage under all fluctuating flow alternatives would be essentially the same as under the No Action Alternative. The steady flow alternatives could cause storage differences of a few feet within the year (due to revised monthly release patterns), but year-end storage would be essentially unchanged.

Water allocation deliveries would be affected negligibly under all alternatives. However, if reserving more space in the reservoir is used to reduce flood frequency, the **Upper Basin yield determination** would be reduced from 6 maf to 5,960,000 acre-feet—reducing the New Mexico interim excess yield from 69,000 acre-feet to 29,000 acre-feet. If the height of the spillway gates is raised to reduce flood frequency, the Upper Basin yield determination would be unchanged.

None of the alternatives affect **water quality** under normal reservoir levels, which occur 95 percent of the time.

SEDIMENT

Issue *How do flows affect SEDIMENT throughout Glen and Grand Canyons?*

Indicators

Probability of net gain in **riverbed sand**
Active width and height of **sandbars**
Erosion of **high terraces**
Constriction of **debris fans and rapids**
Elevation of **lake deltas**

Affected Resources

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. Sand is the most abundant sediment temporarily stored in Grand Canyon. Most sand moves through the canyon in long sequences of deposition and scour, while silt and clay pass through quickly.

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 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 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 ground water stored during rising river stages from the sandbars, thus accelerating sandbar erosion.

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 are directly exposed to erosion during floodflows. 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 very large riverflows. These debris fans can constrict the river channel, creating **rapids** that may become narrower and steeper over time. 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.

The rates of growth of Lake Powell **deltas** are independent of dam operations, but delta crest elevation may vary in response 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. The Lake Mead delta crest elevation may vary with the water release pattern at Glen Canyon Dam, in combination with the release pattern at Hoover Dam.

Effects of the Alternatives

Potential changes in **riverbed sand** storage and in **sandbar** size and stability vary across the alternatives.

- Alternatives with high daily or annual maximum flows have greater potential to transport sand and deposit it at higher elevations, but over the long term would have relatively little sand to deposit.
- Alternatives with low daily or annual maximum flows have more sand to deposit but relatively little capacity to transport and deposit it at high elevations.

Under any circumstances, the long-term (50 years) sand load transported by the river will equal the long-term supply from the tributaries, although gains and losses may not balance out in the short term (20 years). How that sand is distributed determines sandbar size and stability.

Under any alternative, the river reach between the Paria River (river mile (RM) 0) and the LCR (RM 61) is the most susceptible to short-term net loss of sand. In the clear water reach upstream from the Paria River, sand loss would continue but at a very slow rate. Long-term net changes downstream from Phantom Ranch (RM 88) are expected to be negligible.

The Modified Low Fluctuating Flow Alternative has a higher probability of net gain in riverbed sand than the No Action, Maximum Powerplant Capacity, and High Fluctuating Flow Alternatives; about the same as the Moderate and Interim Low Fluctuating Flow Alternatives; and somewhat less than the steady flow alternatives. With habitat maintenance flows, however, the Moderate and Modified Low Fluctuating and Seasonally Adjusted Steady Flow Alternatives have potential to build sandbars about as high as under alternatives with greater daily fluctuations.

Eddy backwaters (return-current channels) would tend to fill under all alternatives, but the filling rate would be greatest under steady flow alternatives without habitat maintenance flows (Existing Monthly Volume and Year-Round Steady Flow Alternatives). Periodic flood releases and beach/habitat-building flows may restructure many backwaters.

The range in effects of the alternatives on other sediment resources is not as great. **High terraces**, not replenished under any alternative, would continue to erode. The river's capacity to move large boulders on **debris fans** would be about the same under all alternatives, including no action, making some **rapids** narrower and steeper under any alternative.

Lake delta crest elevations would be the same under all alternatives except the Seasonally Adjusted and Year-Round Steady Flow Alternatives. Lake Powell delta crest elevations under these two alternatives could range from 0 to 2 feet lower than under the other alternatives; similarly, the Lake

Mead delta crest elevation could range from 0 to 1 foot higher. Over the long term, the growth rate of the Lake Mead delta would be approximately 12 million tons per year—the amount of sediment delivered by tributaries—under any alternative.

FISH

Issue

How do flows affect FISH—their life cycles, their habitat, and their ability to spawn?

Indicators

Abundance of *Cladophora* and associated diatoms for **aquatic food base**
Reproduction, recruitment, and growth of **native fish**
Reproduction, recruitment, and growth of **non-native warmwater and coolwater fish**
Reproduction, recruitment, and growth of **trout**

Affected Resources

The aquatic ecosystem below Glen Canyon Dam is the result of complex interactions between habitat, released water, and the organisms that inhabit it. 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. The number of native and non-native warmwater fish has declined and some species have disappeared from the river, while introduced trout have flourished and been developed into a blue ribbon sport fishery. Changes in water temperature and turbidity resulting from dam construction play a large part in these responses.

Because of the dynamic interaction between resources and riverflow, changes in water release patterns would be 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 all alternatives on all aquatic resources is beyond the scope of the report. Therefore, the four indicators listed above were selected for detailed evaluation of impacts on fish.

Effects of the Alternatives

None of the alternatives under consideration would affect the temperature of dam releases, which is too cool for reproduction by **native and non-native warmwater fish**. Thus, reproduction would continue to be restricted to tributaries. Alternatives that provide a minimum reliable flow

of 5,000 cfs—all alternatives except the No Action, Maximum Powerplant Capacity, and High Fluctuating Flow Alternatives—would permit unlimited access to tributaries.

Increased minimum flows would benefit the **aquatic food base** and the fish and wildlife that depend on it. Increased minimum flows also would benefit **trout** spawning in the main channel. However, even at 8,000-cfs flows, up to an estimated 59 percent of known trout nests would be exposed. Increased minimum flows under the Modified Low and Interim Low Fluctuating Flow Alternatives and the three steady flow alternatives may permit a self-sustaining trout fishery to develop.

Maintenance of backwaters, important as rearing habitat for young native fish, is a concern. Backwaters would experience greater warming under steady flow alternatives. However, the exact effects of this warming on native and non-native warmwater fish are unknown. Backwaters would be maintained by habitat maintenance and beach/ habitat-building flows designed to restructure return-current channels.

In years when they occur, endangered fish research flows would have impacts on fish similar to those under the Seasonally Adjusted Steady Flow Alternative (see page 61).

VEGETATION

Issue *How do flows affect VEGETATION throughout Glen and Grand Canyons?*

Indicators Area of **woody plants** and species composition
Area of **emergent marsh plants**

Affected Resources

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, sediment, and plants interact in this riparian zone. Water transports and deposits sediment, and the availability of water at sediment deposits supports plants that otherwise could not survive in a desert climate. The type of vegetation present in the riparian zone reflects the water release pattern that supports it.

Because of the dynamic interaction between riparian vegetation and water availability, changes in water release patterns would affect the plant abundance and distribution. Since many different plants grow in the riparian zone and have differing water requirements, a comprehensive evaluation of the effects of all 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: **woody plants** (trees and shrubs) and **emergent marsh plants** (cattails and others).

Effects of the Alternatives

The Maximum Powerplant Capacity Alternative would result in reduced area of riparian vegetation because its maximum flows would be higher than the No Action Alternative and would increase erosion.

The No Action and High Fluctuating Flow Alternatives would affect riparian vegetation similarly because of their identical (31,500-cfs) maximum discharges. **Woody plants** would be maintained within a zone equivalent to flows between about 22,000 and 40,500 cfs. Under the High Fluctuating Flow Alternative, area coverage would increase slightly. Periodic inundation would maintain **emergent marsh plants** where they now exist.

The Moderate, Modified Low, and Interim Low Fluctuating Flow Alternatives and all the steady flow alternatives would permit riparian vegetation to expand (in differing amounts) into suitable sites made available by reduced maximum flows; acreage of **woody plants** would increase. The potential area available for plant expansion would increase from 0 to 40 percent (Moderate Fluctuating Flow Alternative) to 94 percent (Year-Round Steady Flow Alternative) over no action.

Some new establishment of **emergent marsh plants** would occur at the mouths of return-current channels and at other suitable sites. Alternatives that include periodic habitat maintenance and beach/habitat-building flows would maintain both existing and newly established woody plants as well as restructure return-current channels that support emergent marsh plants.

WILDLIFE AND HABITAT

Issue *How do flows affect area WILDLIFE AND their HABITAT?*

Indicators Area of **woody and emergent marsh plants** for riparian habitat
Abundance of **aquatic food base** for wintering waterfowl

Affected Resources

Wildlife is both diverse and abundant within the river corridor through Glen and Grand Canyons. Riparian vegetation plays an important role as habitat to support wildlife by providing food and cover for numerous mammals, birds, reptiles and amphibians, and invertebrates. Wintering

waterfowl are attracted to and use the Colorado River below Glen Canyon Dam. Waterfowl depend on the aquatic food chain associated with the abundant green alga, *Cladophora glomerata*, that has developed in the clear, cold water below the dam.

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. However, like other resources in the study area, this system is linked to the river and, ultimately, to dam operations. The indicators listed above provide a way to analyze effects of the alternatives on wildlife and their habitat.

Effects of the Alternatives

As a result of the linkages among water, sediment, and riparian vegetation, alternative dam operations would affect wildlife by changing their habitat. Because of higher maximum flows, the Maximum Powerplant Capacity Alternative would reduce riparian vegetation and thus reduce wildlife habitat, while the area of **woody and emergent marsh plants** either would not change or would increase slightly under the No Action and High Fluctuating Flow Alternatives.

Riparian vegetation and wildlife habitat would expand into suitable sites made available by reduced maximum flows under the Moderate, Modified Low, and Interim Low Fluctuating Flow Alternatives and all the steady flow alternatives. The increased area available for plant expansion would range from 0 to 40 percent (Moderate Fluctuating Flow Alternative) to 94 percent (Year-Round Steady Flow Alternative) over no action conditions. Some additional patches of emergent marsh plants would be established at suitable sites. Habitat maintenance and beach/habitat-building flows would maintain these habitats.

Changes in minimum releases would affect wintering waterfowl by changing the **aquatic food base**. It is assumed that increased minimum flows would benefit the aquatic food base and wintering waterfowl. Because minimum flows would remain at 1,000 cfs under the No Action and Maximum Powerplant Capacity Alternatives, no changes are anticipated in the aquatic food base or the waterfowl using it. The remaining alternatives would increase minimum flows in amounts ranging from 3,000 cfs under the High Fluctuating Flow Alternative to 11,400 cfs under the Year-Round Steady Flow Alternative.

ENDANGERED AND OTHER SPECIAL STATUS SPECIES

Issue *How do flows affect the populations of ENDANGERED AND OTHER SPECIAL STATUS SPECIES throughout Glen and Grand Canyons?*

Indicators
Tributary access, backwaters, and nearshore habitat for **humpback chub**, **razorback sucker**, and **flannelmouth sucker**
Trout and aquatic food base for **bald eagle**
Aquatic food base for **belted kingfisher**
Area of woody plants for **southwestern willow flycatcher**

Affected Resources

The 10 special status species that occupy or use the river corridor through Glen and Grand Canyons are a diverse group. One species, the southwestern river otter, is believed eliminated. Three others—the peregrine falcon, osprey, and Kanab ambersnail—would not be adversely affected by dam operations. The remaining six species (see indicators above) are evaluated in detail.

Clear, cold releases from Glen Canyon Dam; the introduction of non-native fish; and other factors have contributed to a decline in native fish populations. The humpback chub, razorback sucker, and flannelmouth sucker are native to the Colorado River Basin. The **humpback chub**, an endangered species, is found at specific sites in the main channel and reproduces in the LCR. The endangered **razorback sucker** is rare in the study area, and no reproduction is known to occur. The **flannelmouth sucker** is a candidate for listing under the Endangered Species Act, but this fish is relatively abundant and reproduces in several tributaries.

Effects of the Alternatives

Since all alternatives would continue to release clear, cold water from the dam, native fish reproduction would be limited to suitable tributaries. Backwater habitat, important to early life stages of humpback chub and flannelmouth sucker, would be warmer in the summer under steady flow alternatives. Nearshore and backwater habitats would also be more stable under steady flows.

The endangered **bald eagle** is linked to dam operations because it eats trout during the winter spawning period. All alternatives except the No Action and Maximum Powerplant Capacity Alternatives would provide minimum reliable flows greater than 1,000 cfs, which would improve trout spawning conditions.

The **southwestern willow flycatcher** has been proposed for listing as endangered under the Endangered Species Act. This bird winters in the tropics and nests in riparian vegetation in the Southwest; numbers are limited in the Grand Canyon. All alternatives except the Maximum Powerplant Capacity Alternative would result in at least some increase in riparian vegetation. These increases would add potential nesting habitat for flycatchers but would not necessarily result in more birds using the Grand Canyon.

The **belted kingfisher** is an Arizona species of concern. All alternatives except the No Action and Maximum Powerplant Capacity Alternatives would increase minimum flows and thus benefit the aquatic food base. Improvements in the food base should benefit this bird species.

The draft FWS biological opinion on the preferred alternative stated that the Modified Low Fluctuating Flow Alternative would likely not jeopardize the continued existence of the bald eagle, peregrine falcon, and Kanab ambersnail but would likely jeopardize the humpback chub and razorback sucker. To address this issue, the preferred alternative was designed to include research to study flows and their relationships to native fish (see description on page 23).

During years when they occur, endangered fish research flows would have impacts on endangered fish similar to those under the Seasonally Adjusted Steady Flow Alternative (see page 63). However, these flows are not expected to result in any additional impacts on other endangered species.

CULTURAL RESOURCES

Issue *How do flows affect the continued existence of CULTURAL RESOURCES in Glen and Grand Canyons?*

Indicators
Number of **archeological sites** directly, indirectly, or potentially affected
Number of **Native American traditional cultural properties** directly, indirectly, or potentially affected

Affected Resources

Cultural resources include **archeological sites** (both prehistoric and historic) and **Native American traditional cultural properties**. The affected area containing these sites and properties includes a 255-mile section of the Colorado River corridor within Glen and Grand Canyons and lands adjacent to the Navajo Nation, the Havasupai and Hualapai Reservations, and Lake Mead National Recreation Area. These resources 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 affected environment. Of these, 313 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, was listed on the National Register in 1974. All other historic properties within the area are considered eligible for inclusion on the National Register.

While archeological data can 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—ranging from spiritual shrines to mineral collection areas—are considered important by each tribe. The locations of these traditional cultural properties are sometimes 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. All natural resources are considered sacred by Native Americans. 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.

Effects of the Alternatives

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 the river. None of the alternatives considered in this EIS 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, the rate at which impacts would occur could be affected by alternative operations. Similarly, many of the **Native American traditional cultural properties** (especially plant and animal species) also depend on sandbars and high terraces along the river.

Generally, alternatives that would maintain the sand balance and allow for its distribution along the river corridor would be preferred because they would enhance long-term preservation of cultural resources. The most favorable alternatives would produce a positive net sand balance in the system, while maintaining higher elevation sand deposits. Alternatives

that fulfill these requirements are the Moderate and Modified Low Fluctuating Flow Alternatives and the Seasonally Adjusted Steady Flow Alternative.

Given the potential impacts of Glen Canyon Dam operations, Reclamation and NPS have 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 a programmatic agreement that will ensure that Reclamation's and NPS's responsibilities under the act are satisfied. 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.

AIR QUALITY

Issue *How do dam operations affect other power production in the area, including those methods that have impacts on AIR QUALITY?*

Indicators Sulfates in **Grand Canyon air**
Tons of sulfur dioxide and nitrogen oxides in **regional air**

Affected Resources

The 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—results in a summertime average visibility of only 100 miles. Sulfates, which are produced from sulfur dioxide (SO_2), are the major contributors to haze at Grand Canyon.

Navajo Generating Station near Page, Arizona, has been identified as a major source of SO_2 and, therefore, sulfates in Grand Canyon air. In response to these findings, the Environmental Protection Agency mandated that modifications to reduce emissions begin in 1995 with completion by 1999. Navajo Generating Station is independent of Glen Canyon Dam operations. The modifications will be made, and improvements in **Grand Canyon air** quality will be the same regardless of which alternative is implemented.

Effects of the Alternatives

Changes in Glen Canyon Dam operations would only slightly affect **regional air** quality. If power production at the dam is reduced or altered,

that power would have to be replaced elsewhere in the system. If the alternative source of power uses fossil fuel, a net change in system emissions of SO_2 and nitrogen oxides (NO_x) would result.

The alternatives may increase emissions of SO_2 and NO_x compared to no action conditions because more power facilities would need to be added sooner. To put these increases into perspective, however, changes in total emission of SO_2 and NO_x would be less than plus or minus 1 percent under any of the alternatives over the 50-year period of analysis.

RECREATION

Issue *How do flows affect RECREATION in the study area?*

Indicators

Fishing trip attributes, safety, and access
Day rafting trip attributes and access
White-water boating trip attributes, camping beaches, safety, and wilderness values
Lake activities and facilities
Net **economic value** of recreation

Affected Resources

Fishing in Glen Canyon occurs mostly from boats, but some anglers wade in the area around Lees Ferry. The magnitude and rate of change in river stage increases the danger for anglers wading in the Glen Canyon reach.

Anglers fishing upstream from Lees Ferry must reach their desired fishing sites by boat. Access over Three-Mile Bar can be particularly hazardous during flows less than 3,000 cfs. Damage to boats and motors is more likely during the low flow periods that typically occur in the morning before peak-power generation periods—the time when many anglers are traveling upstream to reach fishing sites.

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 fluctuations detract from a trip's wilderness character.

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 create additional risks of capsizing. The safety and ease of access for handicapped individuals largely mirrors these safety concerns.

Usable beach area, the area above the high water line, is quite limited in some 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.

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 recreators who participate in each activity, the timing of their participation during the year, and the value of each trip taken.

Effects of the Alternatives

Since fluctuations are reduced and the rate at which river stage rises is constrained, **fishing** safety would improve under the Moderate, Modified Low, and Interim Low Fluctuating Flow Alternatives. All of the steady flow alternatives essentially eliminate river stage changes, producing a major improvement in angler safety.

Upstream fishing access under the Maximum Powerplant Capacity Alternative is the same as under no action. Increased minimum flows under the High Fluctuating Flow Alternative would result in a negligible increase in the ease of upstream access by anglers. Increased minimums and changes in the magnitude of up and down ramp rates would greatly improve upstream access under all other alternatives.

The flood control measures included in the restricted fluctuating and steady flow alternatives would reduce the probability of flood events and the corresponding need to launch from Lees Ferry, thus improving the quality of the **day rafting** experience in Glen Canyon.

The risk of **white-water boating** accidents would be highest under the No Action and Maximum Powerplant Capacity Alternatives, slightly lower under the High Fluctuating Flow Alternative, and decreased under the remaining restricted fluctuating flow alternatives. All steady flow alternatives would decrease the risk of white-water boating accidents 50 percent from no action.

Wilderness characteristics would improve as variations in riverflow are reduced. To the extent that habitat maintenance and beach/habitat-building flows maintain beaches and reduce the rate of vegetative encroachment, the alternatives with these flows would further enhance wilderness values.

In the short term, the greatest increase in available beach area would occur under the steady flow alternatives. In the long term, low steady flows would remove all the system's natural variation. The absence of natural system cycles is likely to encourage vegetation growth and result in the net loss of campable beach area. Available beach area would be slightly increased under the Moderate, Modified Low, and Interim Low Fluctuating Flow Alternatives in the short term. In the long term, habitat maintenance flows (included in the Moderate and Modified Low Fluctuating and Seasonally Adjusted Steady Flow Alternatives) would help maintain the number and the campable area of beaches.

Since riverflows and the magnitude and frequency of fluctuations differ under each alternative, the net economic value of recreation also would differ. These economic values do not take into account long-term changes in the number and size of camping beaches.

The Maximum Powerplant Capacity and High Fluctuating Flow Alternatives have no effect on the net economic value of recreational benefits relative to no action. The Moderate Fluctuating Flow Alternative increases the net economic value of recreation approximately $0.40 million in equivalent annual terms, followed by the Year-Round Steady Flow Alternative, which would increase the net economic value by $2.93 million. The Modified Low Fluctuating Flow Alternative would increase benefits by $3.74 million; and the Interim Low Fluctuating Flow and Existing Monthly Volume Steady Flow Alternatives would increase the net economic value by $3.94 million.

The Seasonally Adjusted Steady Flow Alternative would provide the most economic benefits, increasing the net economic value of recreation by $4.76 million.

HYDROPOWER

Issue *How do dam operations affect the ability of Glen Canyon Powerplant to supply HYDROPOWER at the lowest possible cost?*

Indicators **Power operations** flexibility
Power marketing resources, costs, and rates

Affected Resources

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

Western sells the power generated at Glen Canyon Dam to public, nonprofit utilities and organizations, including over 180 wholesale utility customers throughout a six-State area in the Western United States. In turn, these utilities sell electricity to over 3 million people. Federal hydropower consistently is one of the lowest-cost power sources available. Hydropower produces electricity without polluting the air or using nonrenewable fossil fuels.

The amount of power produced depends on the amount of water released through the powerplant. Western's Salt Lake City Area markets more than 4 billion kilowatthours (kWh) from Glen Canyon Dam each year.

The law requires Western to keep prices as low as possible, but high enough to pay for all construction, operation, maintenance, and transmission costs. If dam operating restrictions reduce the amount of power generated during periods of high demand and higher value, then electricity rates must increase.

As part of its **power marketing** program, Western sells power primarily on a firm (guaranteed), long-term basis. However, Western does not try to sell all available power from Glen Canyon Dam in this manner, since the amount of water and resulting electricity vary from year to year. The total annual amount of power marketed from the dam is based on actual water conditions. When flows allow, short-term sales are made to sell the power generated in excess of firm commitments or to take advantage of market conditions.

The flexibility of **power operations** at Glen Canyon Dam allows the powerplant to quickly and effectively respond to demand for electricity by instantaneously increasing or decreasing water releases. Coal-fired or nuclear powerplants cannot respond as quickly. Western uses the flexibility of Glen Canyon Dam to generate more power when needed, provide electrical service assistance to other utilities, and take advantage of changing market conditions to sell short-term power.

Power is most valuable when it's most in demand—during the day when most industry and businesses are operating, and even more so during the hottest summer days and the coldest winter days when more power is needed to control building temperatures. Consequently, releasing more water during these times generates more power when it is most valuable. Western thus has historically asked Reclamation to release more water during the day and less at night.

Effects of the Alternatives

The restrictions that would be imposed on operations at Glen Canyon Dam under all alternatives except No Action and Maximum Powerplant Capacity Alternatives would reduce the flexibility of **power operations** and increase **power marketing** costs and rates. Specifically, restrictions would:

- Decrease the amount of firm capacity and value of energy that could be marketed
- Decrease the amount and value of power and electrical service assistance that could be offered to utilities
- Increase the cost of electricity to utilities and their customers
- Create a regional need to build additional powerplants and associated powerlines 5 to 10 years sooner than would otherwise have been necessary

Replacement powerplants would likely be either coal-, oil-, or gas-fired, which use nonrenewable resources.

Increases in retail rates for small utilities that rely on generation from Glen Canyon Dam would increase the average household's electric bill by $6 to $40 per year (0.9- to 6.4-percent increase) under the restricted fluctuating flow alternatives. Under the steady flow alternatives, the average household's electric bill would increase by $51 to $69 per year (8- to 11-percent increase).

Impacts on the national economy range from a gain of $2 million annually under the Maximum Powerplant Capacity Alternative to a cost of $119 million annually under the Seasonally Adjusted Steady Flow Alternative.

Endangered fish research flows would have impacts on power economics that fall within the range of impacts between the Modified Low Fluctuating and Seasonally Adjusted Steady Flow Alternatives. If such research flows occur only during the initial years of implementation, impacts would be closer to those under the Modified Low Fluctuating Flow Alternative. However, if steady flows were permanently incorporated in the operating criteria, impacts would be closer to those under the Seasonally Adjusted Steady Flow Alternative.

NON-USE VALUE

Issue *What effects do changes in the operations of Glen Canyon Dam have on NON-USE VALUE?*

Indicators Non-use economic value (dollars)

Affected Resources

Studies have shown that individuals are affected by changes in the status of the natural environment, even though they may never visit or otherwise use a specific site. The value expressed by these non-users about changes in the environment or its features is termed non-use value. Non-use value is relevant if people care about the resources, can differentiate the effects of the alternatives on them, and can place value on these effects.

Effects of the Alternatives

The pilot testing phase of the non-use value study is underway, and the results are expected in 1994. While it is impossible to estimate the magnitude of non-use value at this time, it is possible to characterize—in a relative fashion—the likely results of the study.

Since non-users have indicated that they are most concerned about impacts on vegetation and its associated wildlife, native fish, Native Americans currently living near Grand Canyon, and archeological sites, the alternatives that most benefit these affected resources are also likely to have the highest non-use value.

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 anticipated construction projects on the Colorado River between Lakes Powell and Mead, there are no cumulative impacts in the immediate area.

Power

Some economic sectors would experience greater than average impacts. Irrigation districts in the region typically receive a substantial portion of the power they use for pumping ground and surface water from the CRSP. Any increase in the price of CRSP power would increase the cost of irrigation, a significant portion of production cost in this arid region.

Air Quality

Changes in total emissions of SO_2 and NO_x would be less than plus or minus 1 percent under any of the alternatives over the 50-year period of analysis. Additional pollution control measures could mitigate the decline in air quality but would result in increased construction costs with correspondingly higher power rates.

UNAVOIDABLE ADVERSE IMPACTS

Unavoidable loss of peaking power would result from implementation of any of the restricted fluctuating or steady flow alternatives.

INDIAN TRUST ASSETS

Bureau of 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. Lands, minerals, and water rights are common examples of trust assets. No adverse impacts to Indian trust assests are anticipated under the preferred alternative.

SUMMARY COMPARISON OF ALTERNATIVES AND IMPACTS

The following table summarizes the environmental impacts of the alternatives on each of the affected resources described in detail in the EIS.

Because the endangered fish research flows initially included in the Modified Low Fluctuating Flow Alternative might not occur every year and because results will need to be evaluated, effects of these flows could not be integrated into the summary table. When they occur, these research flows would have impacts that fall within the range of impacts between the Modified Low Fluctuating and Seasonally Adjusted Steady Flow Alternatives.

Summary Comparison of Alternatives and Impacts Table

	No Action	Maximum Powerplant Capacity	High Fluctuating Flow	Moderate Fluctuating Flow
WATER				
Streamflows (1,000 acre-feet)				
Annual streamflows				
Median annual release	8,573	8,573	8,559	8,559
Monthly streamflows (median)				
Fall (October)	568	568	568	568
Winter (January)	899	899	899	899
Spring (May)	587	587	592	592
Summer (July)	1,045	1,045	1,045	1,045
SEDIMENT				
Riverbed sand (percent probability of net gain)				
After 20 years	50	49	53	61
After 50 years	41	36	45	70
Sandbars (feet)				
Active width	44 to 74	47 to 77	44 to 70	28 to 47
With habitat maintenance flows				41 to 66
Potential height	10 to 15	10 to 16	10 to 15	6 to 10
With habitat maintenance flows				9 to 15
FISH				
Aquatic food base	Limited by reliable wetted perimeter	Same as no action	Minor increase	Moderate increase
Native fish	Stable to declining	Same as no action	Same as no action	Same as no action
Non-native warmwater and coolwater fish	Stable to declining	Same as no action	Same as no action	Same as no action
Trout	Stocking-dependent	Same as no action	Same as no action	Increased growth potential, stocking-dependent
VEGETATION				
Woody plants (area)				
New high water zone	No net change	0 to 9% reduction	Same as no action	23 to 40% increase
With habitat maintenance flows				0 to 12% increase
Species composition	Tamarisk and others dominate	Tamarisk and others dominate	Tamarisk, coyote willow, arrowweed, and camelthorn dominate	Tamarisk, coyote willow, arrowweed, and camelthorn dominate
Emergent marsh plants				
New high water zone				
Change in maximum stage	No net change	5% increase	Same as no action	29% decrease

Modified Low Fluctuating Flow	Interim Low Fluctuating Flow	Existing Monthly Volume Steady Flow	Seasonally Adjusted Steady Flow	Year-Round Steady Flow
8,559	8,559	8,559	8,554	8,578
568	568	568	492	699
899	899	899	688	703
592	592	592	1,106	699
1,045	1,045	1,045	768	699
64	69	71	71	74
73	76	82	82	100
24 to 41	24 to 41	10 to 19	16 to 29	0
41 to 66			37 to 60	
6 to 9	6 to 9	3 to 5	4 to 7	0 to 1
9 to 14			9 to 13	
Potential major increase	Potential major increase	Major increase	Major increase	Major increase
Potential minor increase	Potential minor increase	Potential minor increase	Potential major increase	Potential minor increase
Potential minor increase	Potential minor increase	Potential minor increase	Potential major increase	Potential minor increase
Increased growth potential, stocking-dependent	Increased growth potential, stocking-dependent	Increased growth potential, possibly self-sustaining	Increased growth potential, possibly self-sustaining	Increased growth potential, possibly self-sustaining
30 to 47% increase	30 to 47% increase	45 to 65% increase	38 to 58% increase	63 to 94% increase
0 to 12% increase			0 to 12% increase	
Tamarisk, coyote willow, arrowweed, and camelthorn dominate	Tamarisk, coyote willow, arrowweed, and camelthorn dominate	Tamarisk, coyote willow, arrowweed, and camelthorn dominate	Tamarisk, coyote willow, arrowweed, and camelthorn dominate	Tamarisk, coyote willow, arrowweed, and camelthorn dominate
37% decrease	37% decrease	48% decrease	43% decrease	64% decrease

Summary Comparison of Alternatives and Impacts Table -Continued

	No Action	Maximum Powerplant Capacity	High Fluctuating Flow	Moderate Fluctuating Flow
WILDLIFE AND HABITAT				
Riparian habitat	*See vegetation.*			
Wintering waterfowl (aquatic food base)	Stable	Same as no action	Same as no action	Potential increase
ENDANGERED AND OTHER SPECIAL STATUS SPECIES				
Humpback chub	Stable to declining	Same as no action	Same as no action	Same as no action
Razorback sucker	Stable to declining	Same as no action	Same as no action	Same as no action
Flannelmouth sucker	Stable to declining	Same as no action	Same as no action	Same as no action
Bald eagle	Stable	Same as no action	Same as no action	Potential increase
Peregrine falcon	No effect	No effect	No effect	No effect
Kanab ambersnail	No effect	No effect	No effect	No effect
Southwestern willow flycatcher	Undetermined increase	Same as no action	Same as no action	Same as no action
CULTURAL RESOURCES				
Archeological sites (Number affected)	Major (336)	Major (336)	Potential to become major (263)	Moderate (Less than 157)
Traditional cultural properties				
Native American traditional use areas	Major	Same as no action	Same as no action	Same as no action
Native American sacred sites/resources	Major	Same as no action	Same as no action	Same as no action
AIR QUALITY				
Regional air quality				
Total emissions (thousand tons)				
Sulfur dioxide	1,960	Less than ±1% change	Less than ±1% change	Less than ±1% change
Nitrogen oxides	1,954			

Modified Low Fluctuating Flow	Interim Low Fluctuating Flow	Existing Monthly Volume Steady Flow	Seasonally Adjusted Steady Flow	Year-Round Steady Flow
Potential increase	Potential increase	Potential increase	Potential increase	Potential increase
Potential minor increase	Potential minor increase	Potential minor increase	Potential major increase	Potential minor increase
Potential minor increase	Potential minor increase	Potential minor increase	Potential minor increase	Potential minor increase
Potential minor increase	Potential minor increase	Potential minor increase	Potential major increase	Potential minor increase
Potential increase	Potential increase	Potential increase	Potential increase	Potential increase
No effect	No effect	No effect	No effect	No effect
No effect	No effect	No effect	No effect	No effect
Same as no action	Same as no action	Same as no action	Same as no action	Same as no action
Moderate (Less than 157)	Moderate (Less than 157)	Moderate (Less than 157)	Moderate (Less than 157)	Moderate (Less than 157)
Same as no action	Same as no action	Same as no action	Same as no action	Same as no action
Same as no action	Same as no action	Same as no action	Same as no action	Same as no action
Less than ±1% change	Less than ±1% change	Less than ±1% change	Less than ±1% change	Less than ±1% change

Summary Comparison of Alternatives and Impacts Table–Continued

	No Action	Maximum Powerplant Capacity	High Fluctuating Flow	Moderate Fluctuating Flow
RECREATION				
Fishing				
Angler safety	Potential danger	Same as no action	Same as no action	Major improvement
Day rafting				
Navigation past 3-Mile Bar	Difficult at low flows	Same as no action	Negligible improvement	Major improvement
White-water boating				
Safety	High risk at very high and very low flows	Same as no action	Negligible improvement	Minor improvement
Camping beaches (average area at normal peak stage)	Less than 7,720 square feet	Same as no action	Same as no action	Minor increase
Wilderness values	Influenced by daily fluctuations	Same as no action	Minor increase	Moderate increase
Economic benefits				
Equivalent annual net benefits (1991 $ millions)	0	0	0	+0.40
POWER				
Wholesale and retail rates (1991 mills/kWh)				
Wholesale rates	18.78	18.78	19.38 (+3.2%)	23.18 (+23.4%)
Retail rates (median)	62.17	62.17	62.72	65.77
Annual economic cost (1991 $ millions)				
Hydrology	0	-2	+2	+44
Contract rate of delivery	0	0	+3	+36
NON-USE VALUES	*No data.*			

Modified Low Fluctuating Flow	Interim Low Fluctuating Flow	Existing Monthly Volume Steady Flow	Seasonally Adjusted Steady Flow	Year-Round Steady Flow
Major improvement	Major improvement	Major improvement	Major improvement	Major improvement
Major improvement	Major improvement	Major improvement	Major improvement	Major improvement
Minor improvement	Minor improvement	Major improvement	Potential to become major improvement	Major improvement
Minor increase	Minor increase	Major increase	Potential to become major increase	Major increase
Moderate to potential to become major increase	Moderate to potential to become major increase	Major increase	Major increase	Major increase
+3.74	+3.94	+3.94	+4.76	+2.93
23.67 (+26.0%)	23.18 (+23.4%)	25.22 (+34.3%)	28.32 (+50.8%)	26.78 (+42.6%)
66.15	65.77	67.20	69.03	68.09
Not available	+36	+65	+76	+67
+41	+36	+69	+119	+86

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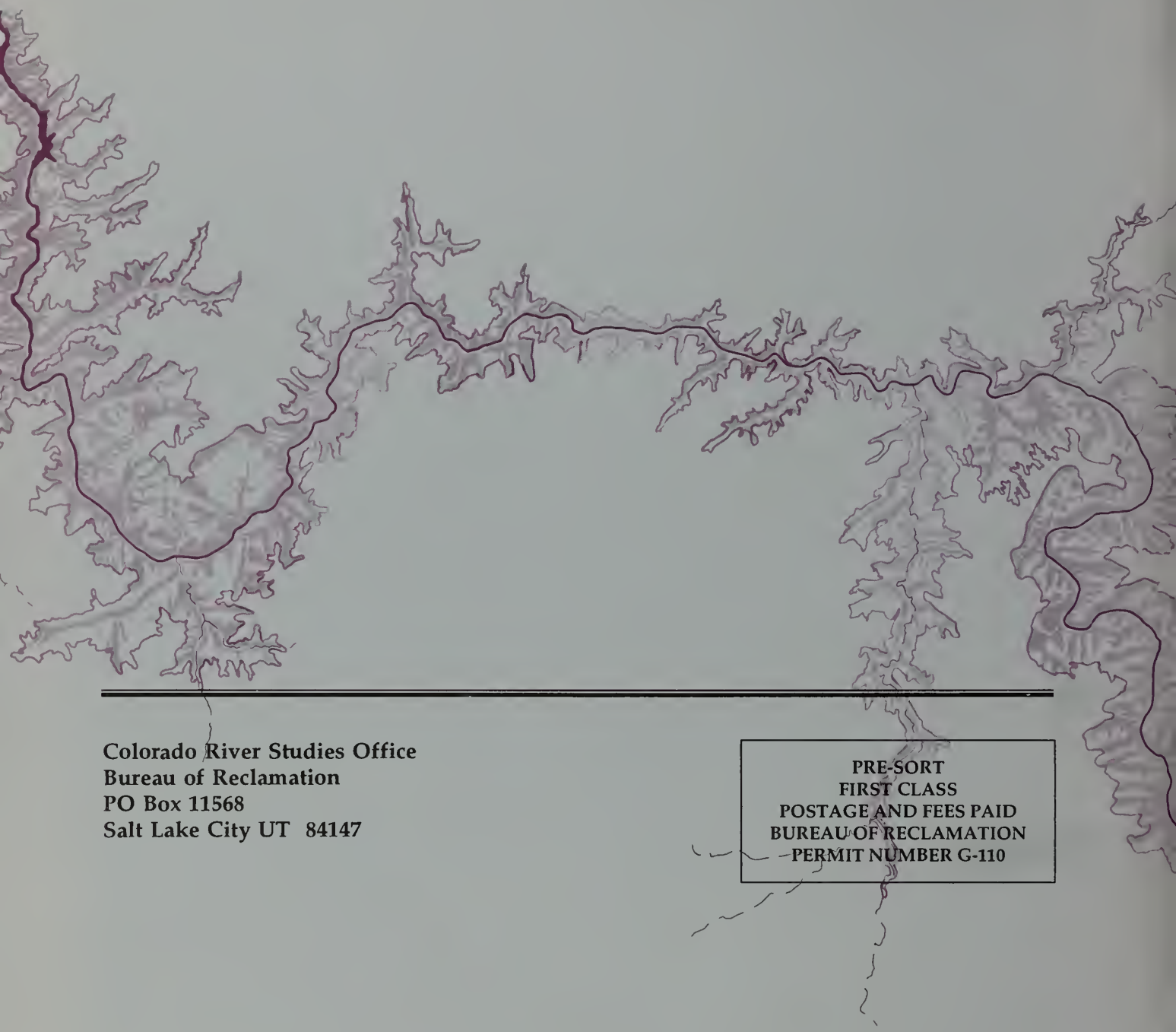
As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources, protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. Administration.

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



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