GLEN CANYON ENVIRONMENTAL STUDIES
BEACH HABITAT BUILDING FLOW
GLEN CANYON DAM, COLORADO RIVER, AZ

Presented at the Transition Work Group Meeting
May 21, 1996

In the spring of 1996 the Bureau of Reclamation initiated an important process at Glen Canyon Dam on the Colorado River, AZ. During the first two weeks of April 1996 additional water was released through Glen Canyon Dam to supplement the normal downstream flow of the Colorado River through the Grand Canyon for the express purpose of redistributing the sediments and rejuvenating critical habitats for native and endangered species in the Grand Canyon.

The flow event, termed the **Beach Habitat Building Flow**, was coordinated through the Bureau of Reclamation and included technical expertise from other Federal, State and Tribal entities along with other private and academic scientists. This purposeful release of high water was the first effort at the implementation of Adaptive Management and ecosystem restoration at Glen Canyon Dam.

The objective of this paper is to outline the background, objectives and initial results that have been realized through this historic dam release event. The program is outlined from both a scientific and an administrative perspective.

BACKGROUND

Glen Canyon Dam is one of fourteen Federal dams that control the delivery of water through the Colorado River system. The majority of the Federal dams were authorized by Congress and build prior the passage of the National Environmental Policy Act, the law requiring the evaluation of environmental impacts. Glen Canyon Dam was completed seven years before the passage of NEPA and had never been scrutinized from an environmental perspective.

Glen Canyon Dam, completed in 1963, created Lake Powell, a 27 million acre foot reservoir, which is over 180 miles long when full. Glen Canyon Dam has eight generators that can produce over 950,000 Kw of electricity when operating at full capacity. Glen Canyon Dam was initially authorized by Congress to provide two main objectives: (1) the conservation of water for the upper Colorado River basin states to allow delivery of required water supplies to the lower basin states of Arizona, Nevada and California and to the Republic of Mexico; and (2) the production

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of hydroelectric power to allow for repayment of the initial investment.

Lake Powell is a large, deep reservoir with water withdrawn in the hypolimnion through the penstocks for delivery downstream. The impacts associated with the dam are separated into two categories, those caused by the dam itself and those caused by the operations of the dam.

The dam caused impacts include effects related to the trapping of sediments in the upstream portion of the reservoir, colder water releases and changing nutrient dynamics. Impacts related to the operations of the dam include reduction in the annual variability in the total volume of water released, changing from a seasonal variability to a daily variability and finally, impacts related to the annual water volumes.

In 1982 the Department of the Interior and the Bureau of Reclamation initiated the Glen Canyon Environmental Studies (GCES) to document and quantify the environmental effects of the operation of Glen Canyon Dam. These studies were initiated after concern was raised by the public regarding the dams impacts on the downstream Grand Canyon environment. In 1989, after completion of the first phase of the GCES scientific program, the Department of the Interior directed that an environmental impact statement evaluating operations of the dam be initiated. In 1992 Congress passed the Grand Canyon Protection Act (P.L. 102-575) which directed a long-term monitoring program and additional guidance on completion of the EIS.

The EIS was coordinated by the Bureau of Reclamation in cooperation with other Federal, State, Tribal and public input and was completed in 1995. Finalization of the Record of Decision awaits completion of an audit by the General Accounting Office. The Beach Habitat Building Flow was identified in the Preferred Alternative as an important component for future ecosystem maintenance and restoration.

BEACH HABITAT BUILDING FLOW

Prior to the construction of Glen Canyon Dam, the Colorado River was a dynamic sediment-laden river, fluctuating according to the seasons, rainfall, snowmelt and sediment inflow from side canyons. Construction of Glen Canyon Dam altered the natural dynamics of the river, specifically the sediment flow, water supply and water quality.

The need for a controlled flood release was determined after extensive review of the scientific results of the GCES program. After review of the data collected from 1983 through 1992 it became apparent that in order for Grand Canyon riverine/riparian ecosystems to maintain their vitality, periodic high flow

disturbances are necessary. The Glen Canyon Dam Environmental Impact Statement further refined the scientific recommendation and integrated the concept of periodic controlled floods as a common element to each proposed alternative. The proposed Preferred Alternative for future operations of Glen Canyon Dam specifically identifies the Beach Habitat Building Flow as a critical element in the future operations scenarios.

Scientists determined that under any flow alternative the future of the Grand Canyon sandbars and sediment dependent habitats requires careful management of sand. Sandbars naturally erode as a function of the water flows, levels and sediment supply. Glen Canyon Dam controls the amount of sediment that is available for sandbar replenishment and defines the rate of erosion. Sediment movement subsequently fills in backwater and marsh habitats.

The Beach Habitat Building Flow was designed to provide the velocity and volume of water necessary to mobilize the sediment in the main channel bottom and allow for redistribution of the sediments to the eddies and other depositional areas along the river corridor.

The Beach Habitat Building Flow was scheduled to occur in late March and early April 1996. The maximum flow was calculated to be no more than 45,000 cfs (with 33,000 being the maximum power plant release), for a duration of seven days. Specific upramp and downramp rates were defined to assist in the development and stabilization of the laid down sediment deposits. The flow was scheduled during a time period which would have been a historic runnoff time and would complement the timing of native fish spawning and native bird nesting.

The specific objectives of the Beach Habitat Building Flow were defined in the Glen Canyon Dam Environmental Impact Statement:

* Flush non-native fishes,
* Rejuvenate backwater habitats for native fish,
* Redeposition of sand bars at higher elevations; followed by decreasing erosion rates,
* Preserve and restore camping beaches,
* Protect cultural resources,
* Reduced near-shore vegetation,
* Provide water to old high water zone vegetation,
* Meet the above objectives without significant adverse impacts to:
    - Trout fishery
    - Endangered species
    - Cultural resources
    - Economics

The Glen Canyon Environmental Studies published the study plan for the proposed in March 1996 entitled *Final Proposals for Spring, 1996 Glen Canyon Dam Beach/Habitat Building Test Flow.* The U.S. Fish & Wildlife Service subsequently issued a Biological and Conference Opinion on the flow event on February 16, 1996. The National Park Service issued research permits for each supported proposal and issued river launch permits for the individual research and monitoring river trips.

AREAS OF STUDY

Three primary areas of field study were focused on during the course of the Beach Habitat Building Flow; Biological, Physical and Cultural resources. The Biological areas included evaluation of the native and non-native fish; riparian vegetation along the river corridor; native bird monitoring; water quality studies; and, endangered birds, fish and snails.

The physical areas of study included the study of beach formation; beach and substrate rejuvenation; backwater and marsh rejuvenation; and stabilization of sediment deposits. Study site locations are shown on Figure 1.

Cultural studies, based on recommendations from the eight affected Native American Indian Tribes, focused on specific archeological site evaluation and plant studies for cultural uses.

PRELIMINARY RESULTS OF THE EXPERIMENTAL FLOW

As the water from the Beach Habitat Flow receded the results of the high flows were evaluated. Final results will require several months to evaluate full response. Preliminary results, based on initial visual and scientific observations include the following:

Physical System:

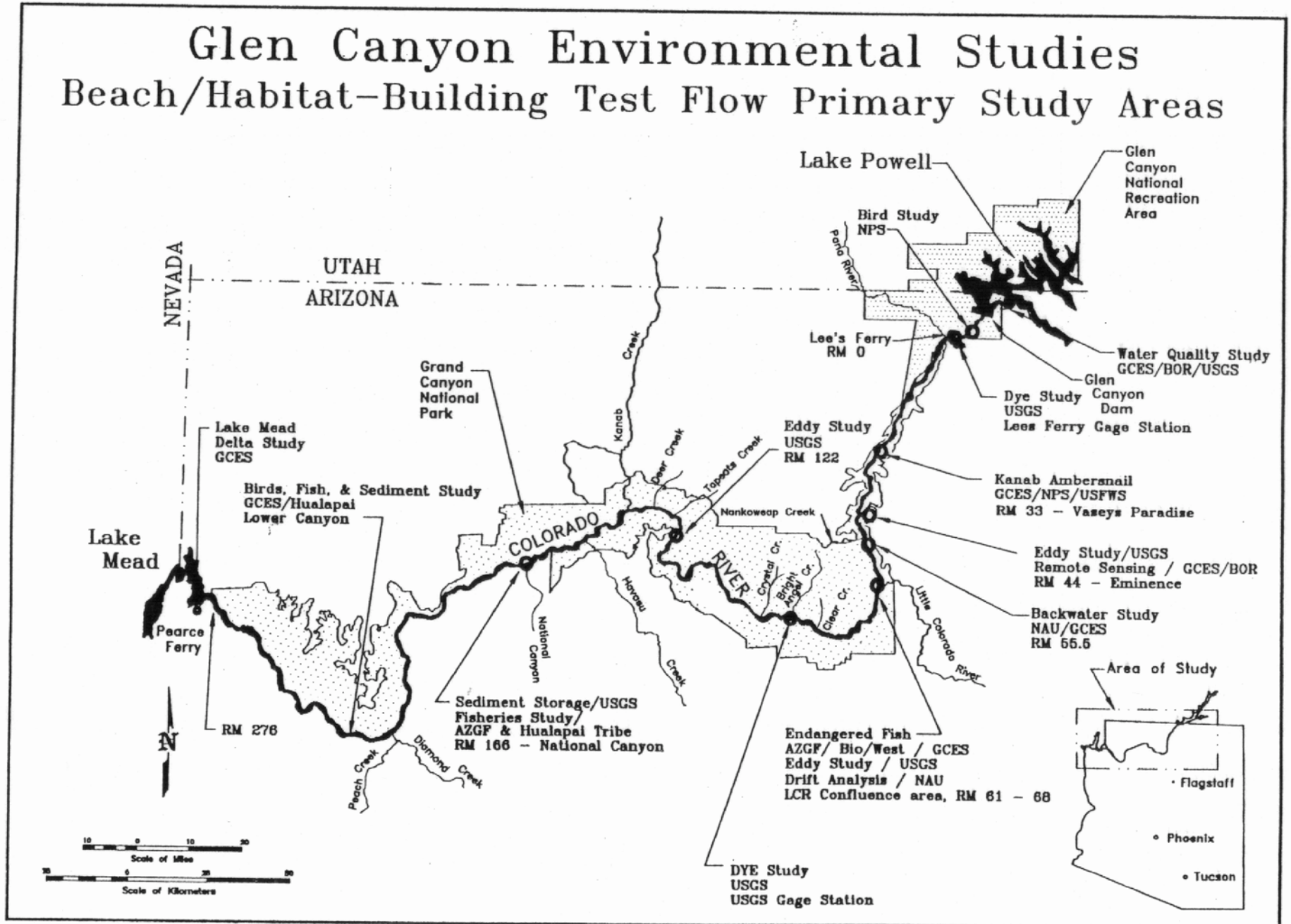
* More beaches in the Marble Canyon area of the Grand Canyon. An area which historically had been depleted of sediments.

* Over 53% of the beaches have increased in size. 37% are roughly the same size and approximately 10% are reduced in size.(Based on visual documentation)

* Larger beaches in the upper end of the Grand Canyon. The first 61 miles (to the confluence with the Little Colorado River) gained the most in numbers.

Glen Canyon Environmental Studies

Beach/Habitat-Building Test Flow Primary Study Areas



Graphic courtesy of Sherry L. Jacobs, Applied Technology Associates, Inc. & Valerie Saylor, Glen Canyon Environmental Studies

* There are 55 new camping beaches of which 67% are above the Little Colorado River.

* Initiation and development of the sediment deposits occurred at a fast rate, with over 80% of the erosion and deposition occurring in the first 20 to 48 hours (Figure 2). Aggradation in the eddies occurred from downstream to upstream. The last sediment deposited makes up the campable areas. Long-lasting sands may be deposited last.

* Development of sediment deposits along the lateral margins of the Colorado River. Analysis utilizing the GCES Map Image Processing programs indicates that total areal change varied from -19.6% to +62.10% (Table 1)

* Of 12 beaches surveyed, 9 have increased in size, 2 decreased in size and 1 stayed the same size

* Rejuvenation of the backwaters and marshes on the uppermost surfaces

* Reshaping of the distal (front) ends of debris flows forming the rapids of the Grand Canyon.

* The dye moved through the Grand Canyon at a rate of 1.8 meters per second in comparison to 1 meter per second at 15,000 cfs.

* The dye concentration curves were narrow, peaked and symmetrical.

The story of the sediment movement seems to follow the script that initially the sediments were mobilized by the high releases, the eddies began to fill, resulting in changed flow dynamics and patterns in the eddies. As each eddy filled a threshold was often reached at which point the eddies had a tendency to evacuate the sediments that had been deposited. Each eddy type responded differently.

Biological System:

* The first two days of the high water saw a great deal of organic debris in the flow. Much of this organic debris was assimilated into the depositing sediment deposits resulting in a potential for increased nutrient surge.

* At several backwaters the increased organic matter has decomposed quickly, resulting in a nutrient surge.

* Stimulation of the substrates for riparian plant development

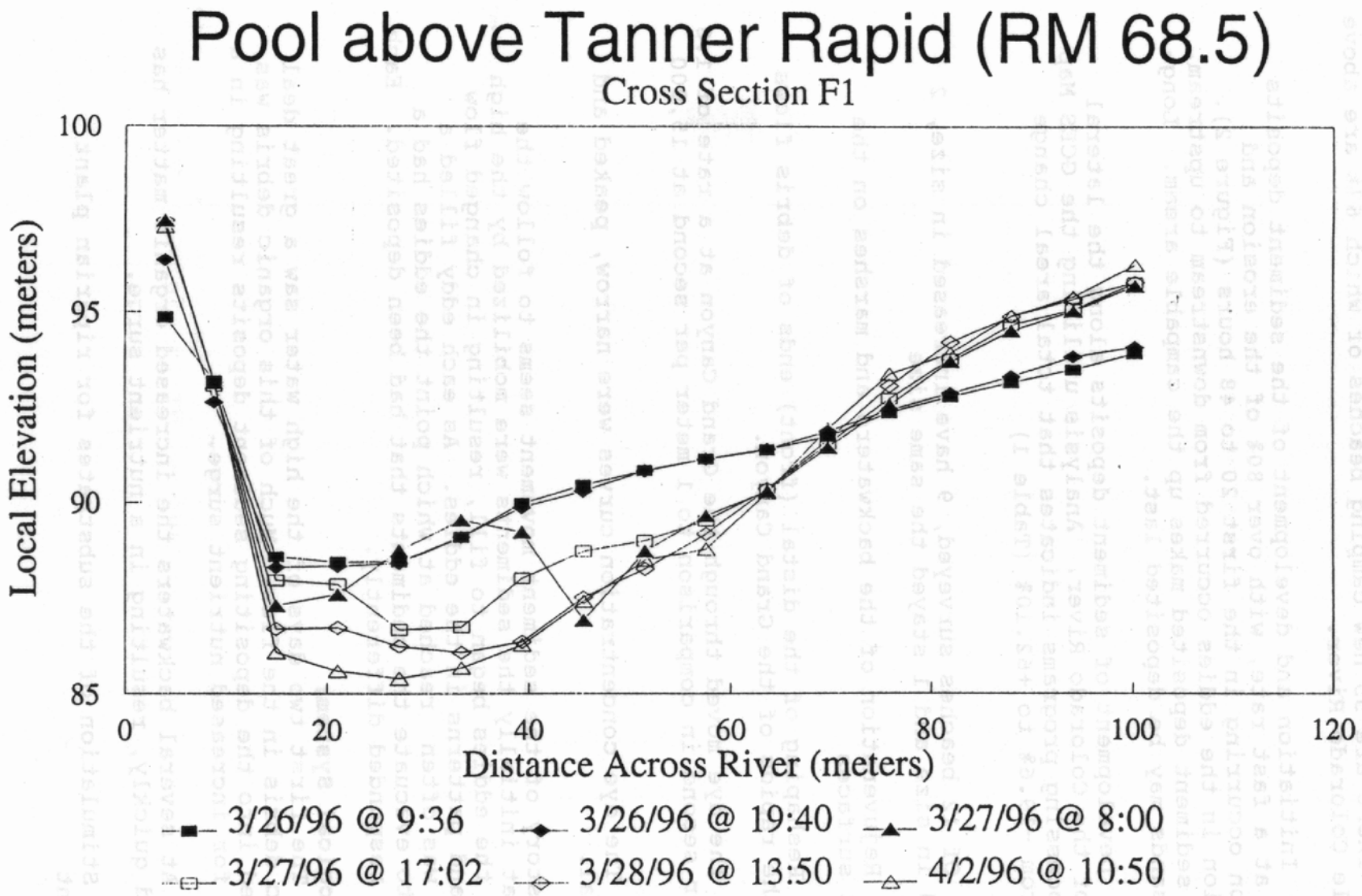


Figure 2. Cross-sectional changes at Tanner Pool during the controlled flood

Table 1. Mean Pre- and Post-flood Beach Areas from the Grand Canyon Corridor based on 10 vector area polygons.

Beach/RM	Pre-flood area (m^2)	Post-flood area (m^2)	Change in area (m^2)	% Total change
House Rock (17R)	2017.83	2409.14	+ 391.30	+16.25
North Canyon (20.7R)	8720.84	10484.41	+1763.57	+16.82
24.5 mile beach	1793.64	3625.75	+1832.11	+50.5
Nautiloid Canyon (34.8L)	1299.24	3149.54	+1850.30	+58.74
Buck Farm (41R)	547.41	1444.64	+ 897.23	+62.10
Below the LCR				
Lower Carbon (64.7 R)	785.30	1978.68	1193.38	+60.31
Lower Crystal (98 R)	594.82	636.35	+ 41.53	+ 6.6
Backeddy (137.0L)	3879.03	3118.51	- 760.52	-19.60

All changes in areas were significantly different for a one-tailed t-test at the 0.05 level .

* Limited scour of the clay and vegetation bases in the backwaters and marshes

* Development of marsh habitats

* Trout fishery did not loose quantifiable numbers of your fish downstream. Most trout remained on feed during the event.

* Aquatic food base was scoured below the dam. Recovery has already begun with growth being measured on the cladophora.

Cultural System:

* Stabilization of cultural sites throughout the Grand Canyon.

* Stabilization of erosion rates in side channels and tributary areas.

Geographic Information System and Data Management

* Pre-flood data integration was accomplished for GIS reaches 1,2, 4 and 5. Photographs being input onto optical discs for distribution and analysis.

* Black and white aerial photography was collected from Glen Canyon Dam to Lake Mead at the 8,000 cfs level for the pre-flood and post-flood conditions. High winds limited some photography.

* Video imagery was collected and input into the Map Image Processing System.

* Metadata being established for each project.

* Bathymetric data being collected through GCES for the underwater sampling sites.

* Denver Reclamation and Utah State University are linking the data for selected sites. Validation and analysis will be concurrently completed.

Lake Powell

* Dropped 3.5 feet during the flood flow. A total of 360,000 acre feet of water was released through the Hollow Jet tubes.

* Withdrew water from the top of the hypolimnion. This has resulted in a freshening of the water at the 91m level for increased oxygen and lower salinity (Figure 3).

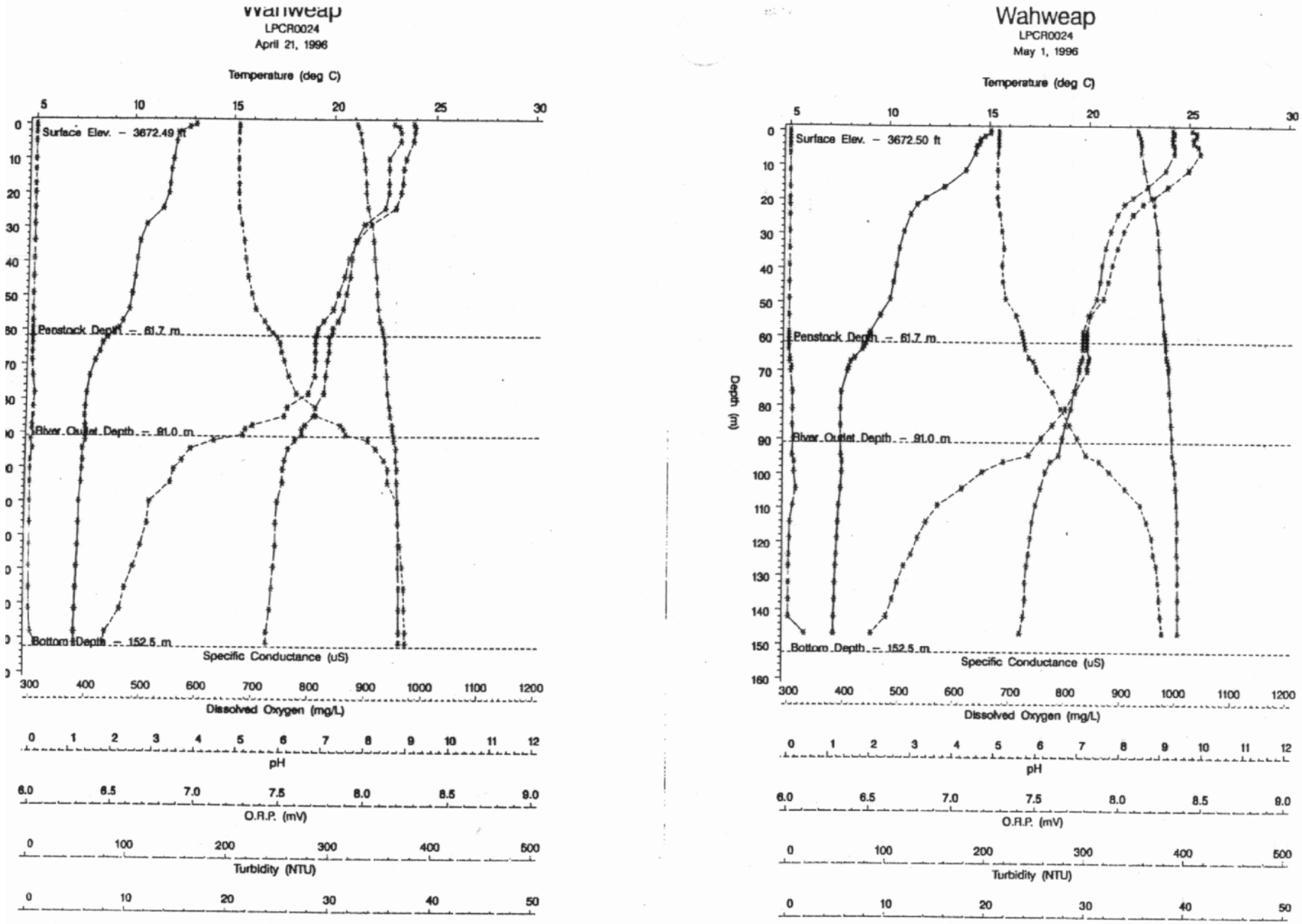


Figure 3. Lake Powell limnological changes after the Beach Habitat Building Flow

THE COSTS

The costs of the Beach Habitat Building Flow were born through revenues generated through the sale of electricity at Glen Canyon Dam with augmentation of the scientific funds from other affected offices. The costs include:

Scientific costs -	$ 1. 5 million
Lost Power costs -	$ 1.5 to 4 million

The GCES program is coordinating the post flood event through the Transition Monitoring Program. This program will be in place throughout fiscal year 1996 and is expected to terminate at the end of fiscal year 1997, or sooner if the long-term monitoring plan can be implement earlier.

FOLLOW-UP

The evaluation of the long-term response of the sediment and biological system will continue in fiscal year 1996 through the GCES Transition Monitoring program. We recommend that aerial photography be collected in the fall to allow for evaluation of the response of the sediment deposits to the summer flow releases. An integrated report and workshop on the beach habitat building flow will be developed. All reports are to be delivered to GCES in draft form by September 30, 1996 with final reports due by December 31, 1996.

SUMMARY

Overall the Glen Canyon Dam Beach Habitat Building Flow provided a unique opportunity to test the ability to operate Glen Canyon Dam for environmental purposes. Historically Glen Canyon Dam has been operated to deliver water downstream and to maximize the production of hydroelectricity. The flows released during the spring of 1996 provided the Bureau of Reclamation with an opportunity to put into action the concept of Adaptive Management at Glen Canyon Dam.

The Beach Habitat Building flow worked for what it was intended for. We were able to collect the information necessary to validate the hydraulic and sediment models. Sediment was deposited in the critical reaches. Administratively the event occurred within the time frames and requirements specified. The final evaluation of the event will require analysis of the data.

Success of the program has been measured in two arenas, the physical and biological responses and the administrative support. Technically we appear to have the ability to restore and

Glen Canyon Environmental Studies
Beach Habitat Building Flow
Budget Allocations
Total Budgt = $1,500,000

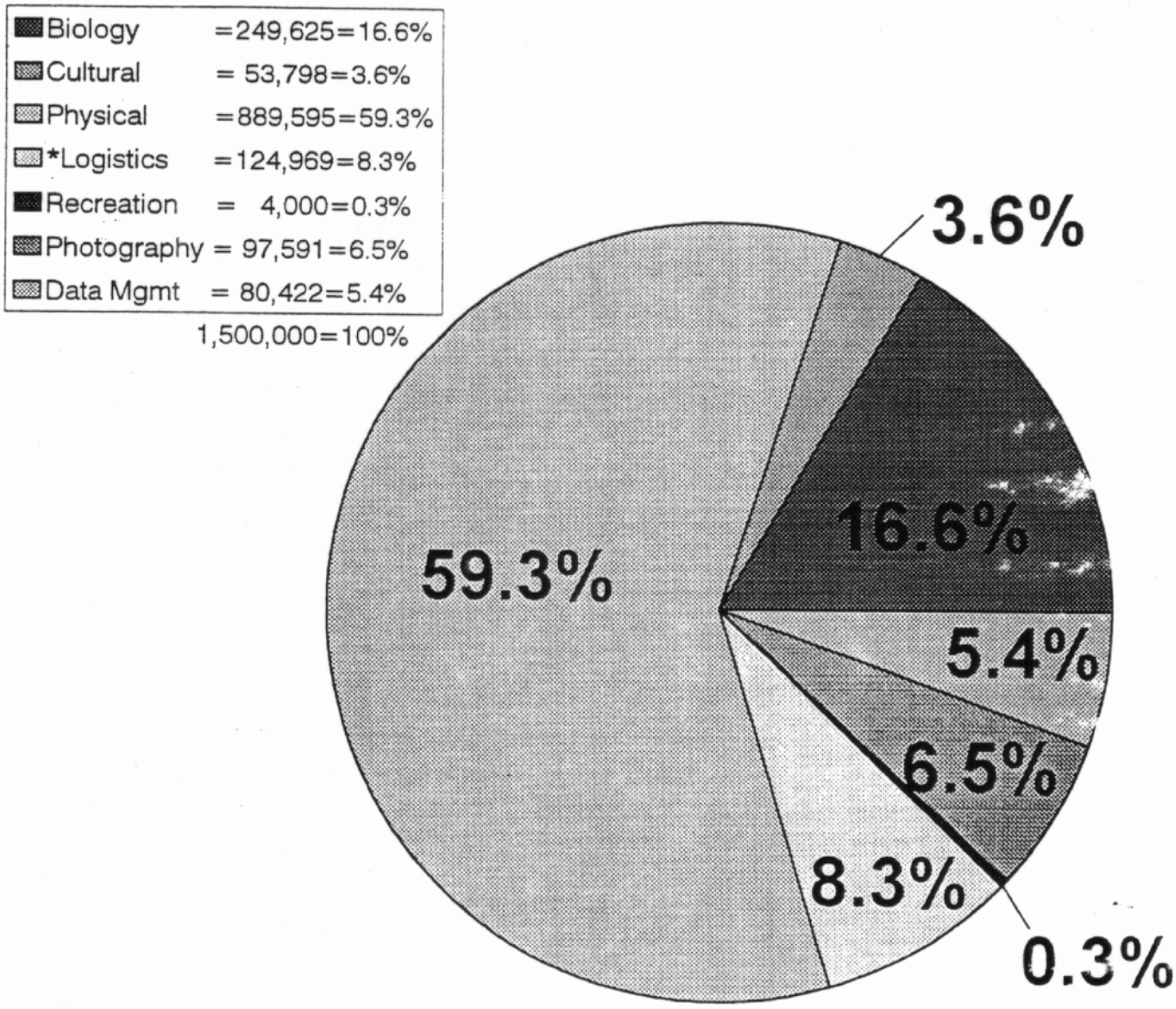


Figure 4. Cost allocations for the Beach Habitat Building Flow.

NOTE:

*Actual Logistics Cost was $205,000

rejuvenate critical ecosystem process and elements through the operation of Glen Canyon Dam. The duration of the restored ecosystem and useability by the biological elements remains to be resolved.

The administrative success of the program is equally laudable. Administratively the Bureau of Reclamation was able to coordinate the approval to conduct the Beach Habitat Building flow through the seven Colorado River Basin states, the power customers, the endangered species concerns and the native American tribes. This was accomplished by relying upon the science to guide the way.

The use of controlled floods at Glen Canyon Dam provides the operators and river system managers with a unique tool for better management of the Colorado River ecosystem. The results of the GCES and the Glen Canyon Dam EIS provide a new and innovative approach to meeting the governments social obligations while finding ways to restore and revitalize critical habitats for the unique resources of the Colorado River.

Dave Wegner, GCES
May 21, 1996

Grand Canyon Monitoring and Research Program

U.S. Department of the Interior
U.S. Geological Survey

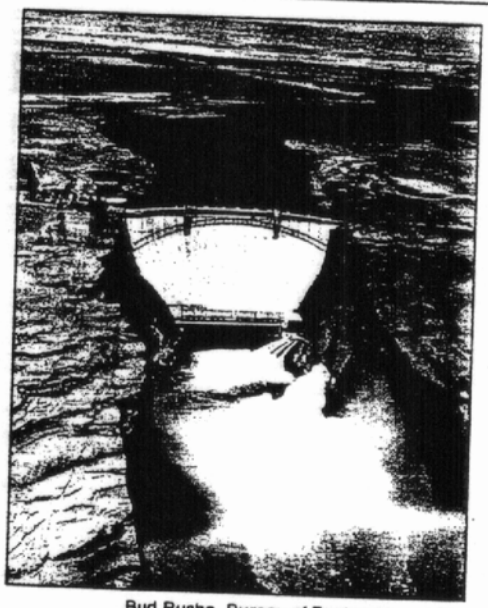
Controlled Flooding of the Colorado River in Grand Canyon: the Rationale and Data-Collection Planned

Controlled flooding of the Colorado River by releases from Glen Canyon Dam has been proposed as a way to manage sediment and other resources in the Grand Canyon. Floods are a natural occurrence of rivers and, in the case of the Colorado River, the architect of the Grand Canyon landscape. Scientists have proposed a controlled flood in response to resource managers' request for ways to restore some of the pre-dam resource conditions. Floods are expected to suspend sand moved to the river bottom by lower flows and deposit it along the river banks where it will be above water after the flood recedes. In this way, the limited sand resources can be utilized to preserve habitat for plants and animals and for use by river runners and campers. Because some effects of a clear water flood from Glen Canyon Dam are uncertain, the U.S. Geological Survey (USGS), in cooperation with the Bureau of Reclamation and the National Park Service, has planned a short period of controlled flooding to provide information for science-based decision-making.

Background

Glen Canyon Dam began to store water in 1963. The dam made possible the production of electricity and the irrigation of crops and created new opportunities for recreation. By many measures, life in the Southwest has been improved. But the presence of the dam and regulation of flow have greatly reduced the size and frequency of floods, the amount of sediment in the river, and the annual variation in water temperature.

The river environment changed within Glen Canyon National Recreation Area, Grand Canyon National Park, and tribal lands of the Navajo, Havasupai, and Hualapai people—in other words, areas set aside for the preservation of the cultural and natural resources. Concern about the environmental effects of the dam and its operation caused the Bureau of Reclamation to initiate a series of studies known as the Glen Canyon Environmental Studies (GCES). Efforts by concerned parties resulted in the enactment into law of the Grand Canyon Protection Act of 1992 and the completion of an Environmental Impact Statement (EIS). The Act and the EIS provide for use of Glen Canyon Dam to manage the resources of the river corridor, including the use of periodic controlled flooding.



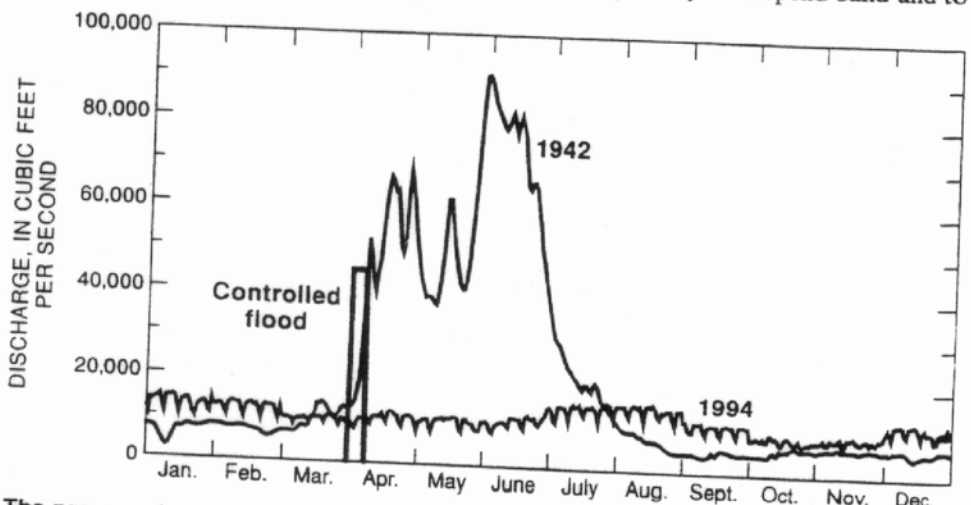
Bud Rusho, Bureau of Reclamation, 1984

High-flow release from Glen Canyon Dam in 1984.

Controlled-Flood Rationale

Before 1963, melting snow in the upper Colorado River basin produced high flows that raced through the Grand Canyon each spring. An average peak discharge of 93,400 ft^3/s scoured large volumes of sediment from the river bottom. Later in the summer, receding floodwaters deposited this scoured sediment and also sediment carried in from tributaries. This annual scour and fill process maintained large sand bars along the river banks, kept sand bars clear of vegetation, and kept debris fans—deposits of cobbles and boulders that form at the mouths of tributaries—from constricting the river. Reduced frequency of flooding since flow regulation began has reduced the size of sand bars and allowed vegetation to encroach on the channel, debris fans to build up, and backwater areas used by native fish to fill in.

The last decade of study has greatly expanded scientists' understanding of the Colorado River in Grand Canyon. On the basis of this knowledge, scientists predict that periodic high flows can be used to retain sand in the canyon by depositing it along river banks. Sand submerged in the river is not stationary but is slowly being moved downstream along the river bottom. Floods have the hydraulic energy necessary to suspend sand and to



The proposed controlled flood compared to pre-dam (1942) and post-dam (1994) flows.

form bars higher up the river banks. These sand bars are less subject to erosion and more useful for camping than bars formed by lower flows. Backwater areas will be scoured of accumulated fine sediments and vegetation. This cleaning or rejuvenation process will recreate low-velocity habitat for fish. Debris fans will be eroded and the character of the rapids changed.

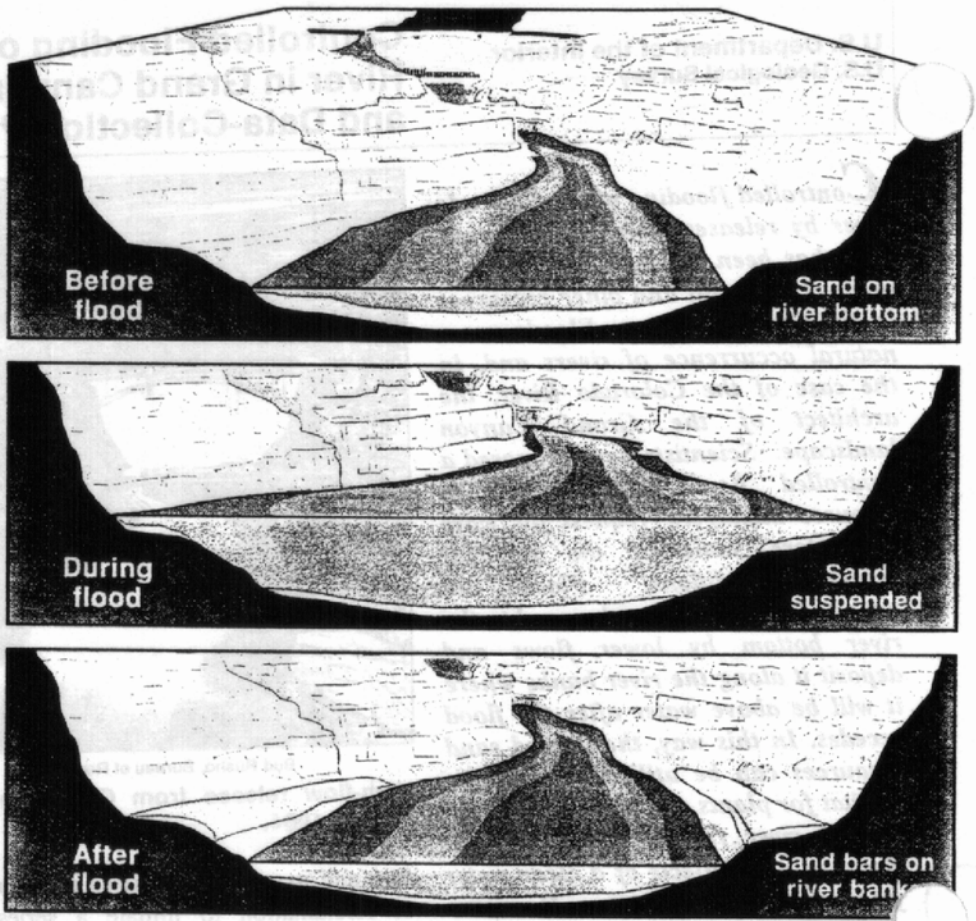
A controlled flood from Glen Canyon Dam is proposed to rebuild sand bars along the river banks and to provide data needed to predict the movement of water and sediment during floodflows. Methods for predicting the movement of water and sediment were developed and successfully applied by USGS and other scientists at lower discharges. Measurements at floodflows are needed to extend the usefulness of these methods. Once tested with data from a wide range of flow conditions, methods can be used to predict how flow and sediment would be affected by a wide range of dam releases.

Data-Collection Planned

A controlled flood is planned for late March 1996 at a discharge of 45,000 ft^3/s, which approaches the maximum that can be released from Glen Canyon Dam without using the spillways. Data will be collected before, during, and after the proposed controlled flood by the USGS and many other agency partners. The USGS will measure the following:

Flow of Water

Discharge will be monitored at five main-stem and three tributary sites. The **velocity** of water as it travels down the river will be measured by the injection of dye and its timed arrival at known distances downstream. Velocity will allow estimation of basic river-channel characteristics needed to extend methods for predicting flow and sediment transport to include floodflows. River **stage** will be measured at about 40 sites. Stage data will be used to test methods of predicting the arrival time of the floodwave and to determine unmeasured tributary inflows.



Sand on the river bed will be suspended by the controlled flood and deposited as sand bars along the banks.

Transport of Sediment

About 100 **cross sections** of the river channel will be measured before and after the controlled flood to determine the changes in sand storage. Selected cross sections will be measured during the flood to determine the rate of change. **Suspended-sediment** concentration and particle-size data will be collected at several main-stem sites. Several **eddies** will be intensively monitored to document the flow patterns and accumulation of sand. These data will help explain the critical role of eddies in trapping and storing sand along the river banks.

Erosion of Debris Fans

Debris fans that have built up since the last flood in 1986 will be monitored for any changes caused by the controlled flood. Two fans will be monitored during the floodflows to determine the rate at which these changes occur.

Water Chemistry

Physical and chemical measurements of the water in Lake Powell will be made near the dam on a daily basis during the flood. These measurements will help define the zone in Lake Powell from which the controlled-flood water is drawn. Measurements of river water will be made just downstream from the dam before and after the controlled flood to document how the physical, chemical, and biological processes were affected.

—Mark T. Anderson, Julia B. Graf, and G. Richard Marzolf

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