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Using Adaptive Management at Glen Canyon Dam

Adaptive Management Strategies at the 1,312-MW Glen Canyon Dam Project are Helping the Bureau of Reclamation Determine How to Best Operate the Project While Conserving the Downstream Ecosystem

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Glen Canyon Dam on the Colorado River in Arizona was completed in 1963, and the 1,312-MW powerhouse began operating in 1964. The primary purposes of this dam, as set forth in the 1956 Colorado River Storage Project (CRSP) Act, are to store and release water to the Lower Colorado River Basin and to produce electricity.

Because there were few environmental regulations when the dam was built, the U.S. Department of the Interior's Bureau of Reclamation fulfilled these purposes without consistent monitoring of the effects on the environment.

However, over the following decade several laws were passed in response to the public's desire to ensure that federal actions be carried out with the knowledge of their environmental effects. This legislation included the National Historic Protection Act (1966), National Environmental Policy Act (1969), Clean Water Act (1972), and Endangered Species Act (1973). By 1982, controversy over the effects of operation of the dam became sufficiently great that the Commissioner of Reclamation ordered investigations to determine the extent of those effects on downstream natural resources.

The Glen Canyon Environmental Studies were the first concerted efforts to understand the effects of the dam's operations on environmental resources. These studies were performed from 1983 to 1996. In 1996, the National Research Council issued a review of those studies to assess the quality and breadth of the underlying science.

In addition, Reclamation issued an environmental impact statement (EIS) in 1995. The EIS assessed effects of dam operations on 11 resource categories: water, sediment, fish, vegetation, wildlife, endangered and special status species, cultural resources, air quality, recreation, hydropower, and non-use values.

As a result of the environmental studies, National Research Council review, and EIS, researchers concluded that operation of Glen Canyon Dam negatively affected some resources. These resources included sport and endangered fish, sediment, cultural resources, riparian vegetation, and recreation. However, researchers also determined that many cause-and-effect relationships were poorly understood and needed further study.[1]

Also, in 1992, Congress passed the Grand Canyon Protection Act. This act required the Secretary of the Interior to "operate Glen Canyon Dam in ... such a manner as to protect, mitigate adverse effects to, and improve the values for which Grand Canyon National Park and Glen Canyon National Recreation Area were established, including, but not limited to natural and cultural resources and visitor use." The Grand Canyon Protection Act also required the Secretary to undertake this requirement "in a manner fully consistent with and subject to the [body of laws] that govern allocation, appropriation, development, and exportation of the waters of the Colorado River basin."

Adopting an adaptive management program

Clearly, the Secretary faced a dilemma. Congress required operation of Glen Canyon Dam to protect and improve resources while fulfilling all water delivery purposes. However, there was insufficient knowledge of how to operate the dam to achieve all these purposes. Then, in 1996, the Secretary of the Interior issued a record of decision on operation of Glen Canyon Dam. The Secretary agreed to implement the modified fluctuating flow preferred alternative in the EIS. This alternative increased minimum daily releases but decreased hourly changes in releases, maximum daily releases, and maximum daily fluctuations. Eleven of the 12 cooperating agencies for the EIS agreed with Interior's decision.

However, in January 1995 the U.S. Fish and Wildlife Service (FWS) had issued a jeopardy biological opinion that called for testing a more restrictive dam release hydrograph, referred to as a seasonally adjusted steady flow alternative. The biological opinion contained a reasonable and prudent alternative, with actions that had to be

undertaken by Reclamation to avoid jeopardy. However, the opinion allowed that those actions could be undertaken through adaptive management, in a program of learning by doing.

Reclamation initiated the Glen Canyon Dam Adaptive Management Program in 1997 to deal with unresolved conflict over the effects of dam operations on downstream resources in Glen Canyon National Recreation Area and Grand Canyon National Park.[2]

Adaptive management is defined as "...a rigorous approach to environmental management designed to explicitly address and reduce uncertainty regarding the most effective on-the-ground actions for achieving management goals and objectives."[3] There are three approaches for structuring planning and management as an adaptive process:[4]

— Evolutionary, or "trial and error;"

— Passive adaptive, in which a single best estimate or system model is chosen and the system is monitored for response; and

— Active adaptive, in which experiments are conducted to test a range of alternative response models and a policy choice is made that reflects trade-offs among responses and the degree to which alternative models are correct.

Regardless of approach, the important point is that adaptive management is an iterative learning process that recognizes uncertainty and invokes science in decision-making. Policies are treated as experiments and must be tested.

Under the adaptive management program, operation of Glen Canyon Dam and other actions under the authority of the Secretary of the Interior are formulated in a series of management experiments. This is closest to the active adaptive approach. However, the central paradigm for dam operations is constrained by the preferred alternative from the 1995 EIS, rather than being a range of response models crafted by program members.

Experiments conducted under the program are developed by a science group in the U.S. Geological Survey's (USGS) Grand Canyon Monitoring and Research Center, in cooperation with a 25-member Technical Work Group. The 25 members who make up this science group represent a diverse cross-section of federal and state agencies, Native American tribes, recreational groups, environmental groups, and hydroelectric utility consortia. Twelve members were cooperating agencies for the EIS, and Interior added the remainder.

Work performed under the program

Once Glen Canyon Dam began impounding water, the river changed from a sediment-laden river subject to significant seasonal fluctuations to a controlled river. Sediment accumulated upstream of the dam. Beaches in Glen Canyon and Grand Canyon eroded, and non-native vegetation was established. During 1983 and 1984, natural floods rejuvenated beaches, scoured non-native plants from the riverbanks, and provided other benefits. However, many of these benefits were short-lived, as normal dam operations again led to erosion.

Emerging from the 1995 EIS, the major controversies over dam operation concerned the extent to which controlled floods and steady flows should replace daily hydropower fluctuations. Although the adaptive management program was not yet formally recognized and sanctioned in early 1996, the members were in place, meeting were held, and the first experiment was planned. This experiment involved delivering a high release of 45,000 cubic feet per second (cfs) from the dam for one week. The purposes were multiple, but two were paramount. The first was to rebuild beaches. The second was to rejuvenate and recreate attendant native fish habitats, the backwaters that form between sandbars and river banks. By building beaches and backwaters, managers and scientists hoped to also provide habitat for use by young native fish, especially in their first year of life.[5] In March 1996, Reclamation released the first experimental flood waters from Glen Canyon Dam.

From its earliest days, the Glen Canyon Dam Adaptive Management Program has been engaged in developing and implementing research and monitoring to assess the effects of dam operation on Colorado River resources. Because of the emphasis on active adaptive management, the program purposefully perturbs the Colorado River ecosystem and measures the resource responses. As the program has progressed, these experiments have diversified from concentrating on dam releases to a combined emphasis on flow and non-flow actions.

Results in recent years

One major concern of this adaptive management work is the condition of the downstream ecosystem with regard to fine sediment that forms sandbars and habitat for rearing of native fish. Since that initial controlled flood in 1996, Reclamation has conducted two additional high flow releases at Glen Canyon Dam. The second, in which the duration of the release was reduced to 60 hours from one week, was completed in November 2004. From the results of these two experiments, scientists determined that the sediment conservation paradigm used to develop EIS alternatives overestimated the residence time of fine sediment under the preferred alternative operations.[6] This discovery led to development of minimum tributary sediment input criteria that must be met before a controlled flood.[7] Consistent with learning under adaptive management, these criteria are adjusted as more is learned about the relationship between the amount of sediment in the river, the distribution of the sediment, and the resulting response from a high dam release.

The most recent high flow release at Glen Canyon Dam occurred in March 2008. Scientists are analyzing, synthesizing, and integrating the data gathered during this experiment into reports and publications. The reports will be presented to technical level managers, who will convey their impressions of what has been learned to their Federal advisory committee counterparts. The Adaptive Management Work Group will once again meet and make its recommendations — considering scientific, legal, and policy perspectives — to the Secretary of the Interior. And the Secretary will, with the advice of his policy group, use those recommendations to balance the priorities for which the dam was built with those that have come about through ensuing laws.

As a result of this adaptive management work, we have determined that we have the ability to release water through the dam and rebuild beaches. However, we also know that the river never rests and ensuing flows will gradually reclaim the sediment thrown temporarily above its normal flow lines (see Figure 1). Thus, the principle question for sediment researchers is whether there is a sustainable mode of dam operation that will rebuild and maintain sandbar habitats over decades without resorting to augmenting the sediment naturally supplied by tributaries.

In case the work group determines that this balance cannot be achieved without additional intervention, the Glen Canyon Dam Adaptive Management Program convened a feasibility assessment for a pipeline to deliver fine sediment from Navajo Canyon on Lake Powell to below Glen Canyon Dam or 16 miles downstream from the dam at Lees Ferry.[8] This appraisal-level assessment indicates an initial cost range of $140 million to $430 million, plus $3.6 million to $17 million a year for operations. In addition to the large commitment to capital funds, Reclamation would have to determine where the money would come from for operations. However, this must be compared with the estimated cost increases of $15.2 million to $44.2 million as a result of changing operation of the dam to accommodate the preferred alternative in the 1995 EIS, as well as the financial cost to utilities (as a result of lost generation) of $89.1 million per year (see sidebar on page 35).

Flows released from the dam for the next five years have been agreed on through the Adaptive Management Work Group. Until the USGS science group analyzes the results from the third high flow event and conveys its findings to the work group, Reclamation will not perform another high flow test.

There are several reasons for this decision. First, there is an agreement in place from the 1996 record of decision that the reservoir behind the dam must be at a certain level before a beach-building high flow can take place. This requirement has not been enforced for previous experimental high flows, but this determination must be made individually for each experiment. Currently, the level in the reservoir is too low to meet this requirement. Second, work group members are concerned that if you perform enough experiments they no longer can be considered experiments but instead a mode of operation for the dam. And third, with three experiments done the results from the 2008 high flows likely will determine the future of the high flow events. Thus, care must be taken to ensure this decision is the right one.

A second major concern in the Colorado River below Glen Canyon Dam is the endangered humpback chub. Between 1989 and 2001, adult abundance in the area decreased by almost 50 percent. In 2003, the Glen Canyon Dam Adaptive Management Program embarked on a plan to mechanically remove non-native fish in the area where the Colorado and Little Colorado rivers join, under the hypothesis that competition and predation by these fish was negatively affecting the endangered humpback chub. This is a critical area for the humpback chub because most of the population exists in this area and almost all reproduction occurs in the Little Colorado River.

A credible series of population estimates for humpback chub was not available to the FWS when it reached its determination of jeopardy in 1995. Newly developed age-structured mark-recapture model estimates show that about 7,400 adults were present at that time. Adult numbers fell to about 5,000 in 2001 but have since risen to about 6,000.[9] This turnaround, in conjunction with conservation measures being undertaken by Reclamation through the adaptive management program, has convinced the FWS to rescind its 1995 jeopardy opinion in favor of a nonjeopardy opinion.[10]

In 2007, Glen Canyon Dam Adaptive Management Program members began to develop desired future conditions for humpback chub and sediment, referred to as management objectives in the 2001 strategic plan for the program. The Technical Work Group and the USGS science group developed these objectives and submitted them to the Adaptive Management Work Group with a request for direction to proceed with an evaluation of additional resource categories.

Finally, it is important to discuss how litigation has affected the adaptive management process at Glen Canyon Dam. During the first years, program members might have argued that the very nature of adaptive management serves as an insulator against legal action. Major experiments were carried out, and no lawsuits were threatened or filed against the program.

However, in February 2006, five environmental groups sued the Secretary of the Interior and Reclamation, claiming violations of the Grand Canyon Protection Act, Endangered Species Act, and National Environmental Policy Act. The lawsuit was settled in August 2006 without proceeding through the courts. The settlement provided for initiation of National Environmental Policy Act and Endangered Species Act compliance by January 31, 2007, and finalization by October 15, 2008.

With the 2006 lawsuit settled, the adaptive management program moved forward in developing a long-term experimental plan to cover about ten years of scientific studies, beginning in 2008. Reclamation and 16 cooperating agencies prepared alternative experimental designs to select a preferred alternative in an EIS. However, in September 2007, one of the environmental groups in the adaptive management program delivered a notice of intent to sue Reclamation for violations of the Endangered Species Act. The suit was filed in December 2007, and a decision is expected in the spring of 2009.

Future challenges

The scientific foundation of the Glen Canyon Dam adaptive management program has progressed remarkably over the past 11 years. The iterative, cyclical process has greatly improved knowledge of the Colorado River ecosystem. Numerous journal articles have been published, and the results of many investigations are available for use in addressing policy decisions. However, for adaptive management to be successful, this knowledge must make its way into policy decisions that promote a balance between the historical primary purposes of Glen Canyon Dam (i.e., water delivery and hydropower production) and the more recently considered protection of natural resources in the Colorado River ecosystem.

To achieve this balance, agreements must be reached on desired future conditions for these competing resources. Knowledge gained through science can aid managers and stakeholders in making decisions about what is achievable, but there is an important sociopolitical interaction that must be integrated with the science to achieve such agreements.

A significant challenge to the Glen Canyon Dam adaptive management program is for members to agree on how much knowledge is necessary before recommendations can be made for policy change. For example, there is disagreement on whether and under what conditions additional high flow experiments will be conducted. Underlying these differences of opinion are fears that repeating these experiments is leading to a de facto agreement that they will become part of the future operation of Glen Canyon Dam. As any individual knowledgeable of Colorado River law well knows, it is impossible to separate river science and river law, so this deliberation contains the seeds of both.

Finally, a share of the reflection on the future of the adaptive management program is directed inward. Program members have expressed a desire to improve its effectiveness, likely a recognition of their dissatisfaction with the relationship of time passed and expectations realized. An ad hoc group comprised of representatives of the four major program groups — Adaptive Management Work Group, Technical Work Group, Grand Canyon Monitoring and Research Center, and science advisors — has produced a draft report with recommendations for improving program effectiveness.

As in the situation with desired future conditions, no process has been agreed upon by which this improvement will be made. This is not to say that improvements will not be made, for Glen Canyon Dam adaptive management program members have characteristically risen to meet such challenges.

Notes

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Costs of Adaptive Management at Glen Canyon Dam

One criticism of adaptive management, particularly of large programs like that for Glen Canyon Dam, is that it is expensive. Since its inception in 1997, about $92 million has been spent on this program, with the primary source of funding being hydropower generation. Views among the adaptive management program members, and indeed the public, vary greatly on whether this expenditure will result in desired future resource conditions and an equitable balance among the differing interests.

The change in hydropower production under the preferred alternative in the 1995 environmental impact statement was projected to be a decrease of 442 MW of capacity in winter and 463 MW in summer.1 Economic cost increases of $15.2 to $44.2 million per year were estimated, and the financial costs to utilities were estimated at $89.1 million per year.2 Both costs relate to lost capacity, but the former is estimated from a societal or national perspective, whereas the latter is estimated from the perspective of an individual utility or groups of utilities. Attribution of effects to hydropower, including supplemental purchases, from the adaptive management program experiments is difficult and has not been done in a comprehensive manner. However, the cost of replacement power for the 2008 high flow test was estimated at $4.1 million.

It is clear from hydropower generation data supplied by the U.S. Department of the Interior's Bureau of Reclamation that annual energy production at Glen Canyon Dam has decreased since the 1996 record of decision. Costs for replacement power must be added. However, there are a number of confounding factors, not the least of which is the loss of head from declining reservoir elevations during the recent protracted drought, that challenge this analysis. Efforts now under way (Tom Veselka, Argonne National Laboratory, personal communication, November 2008) will soon close this gap and estimate the economic cost of constraints to hydro production imposed by the 1996 record of decision under the adaptive management framework.

Notes

1. "Final Biological Opinion for the Operation of Glen Canyon Dam," memorandum from Field Supervisor, U.S. Fish and Wildlife Service Arizona Ecological Services Field Office, to Deputy Regional Director, Upper Colorado Region, Bureau of Reclamation, Salt Lake City, Utah, 2008.
2. "Operation of Glen Canyon Dam Final Environmental Impact Statement," U.S. Department of the Interior, Bureau of Reclamation, Salt Lake City, Utah, 1995.

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