Glen Canyon Dam Spillway Gate Extensions
An Analysis of Their Need and Their Impact on Spill Frequency and Duration

Introduction

The two spillways at Glen Canyon Dam are large tunnels bored through the abutment sandstone on either side of the dam and are controlled by a total of four 40- by 52.5-foot radial gates, two on each side of the dam. The gates are raised and lowered through a powered cable system located on the top of the dam. Figures 1 and 2 are plan and cross section views of the gates. In contrast to the approximate 45,000 cfs combined capacity of the powerplant and outlet tubes, the spillways can discharge about 210,000 cfs when fully opened with the reservoir at elevation 3700 feet.

This large release capacity was designed as a critical part of the dam's capability to accommodate large inflows. Because of the very large surface area of Lake Powell and the long duration of the spring runoff from snowmelt, most extreme inflow events can be handled through anticipatory powerplant releases in the months prior to the peak inflow. It was primarily the large scale general storm events that require the use of the spillways. These and other large hydrologic events produce inflows that challenge even the large capacity of Lake Powell. Inflows of the magnitude of the Probable Maximum Flood (PMF) would produce peak inflows of about 700,000 cfs, resulting in discharges exceeding 200,000 cfs for a 9-day period of time and in a maximum reservoir elevation of about 3710 feet. Fortunately, the statistical frequency of such events is extremely rare, perhaps only on the order of once in 10,000 years or longer.

The spillways were also designed to play a role in normal operations during high inflow years when there was also a large error in the forecasted runoff, such as 1983. Unanticipated extreme inflows could not be accommodated with the anticipatory powerplant releases cited above. There simply isn't enough time in those situations to evacuate sufficient reservoir storage space. Use of the spillways enables the safe passage of the peak inflows without overtopping the dam.

Since large dam releases have significant impacts on downstream resources, previous documents such as the GCDEIS contained recommendations on restricting the frequency of large releases above powerplant capacity, citing two options for controlling such releases. The ROD for the GCDEIS selected the option of installing spillway gate extensions rather than the option of providing a greater vacant storage space buffer to reduce the frequency of powerplant bypasses. The Grand Canyon Protection Act (GCPA) also addressed powerplant bypasses and their impact on the Grand Canyon.

The installation and use of these spillway gate extensions are the focus of this report. As in the recent Beach Habitat Building Flow (BHBF) triggering criteria report, the report will include discussions on the GCDEIS conclusions regarding spills, the recent change in thinking about spills, and the agreement reached between the Secretary of the Interior and the Basin States contained in the 1996 AOP. Additionally, there will an alternatives and impacts analysis on various options that exist regarding the spillway gates extensions.

GCDEIS and GCPA Conclusions Regarding Powerplant Bypasses

The majority of the GCES Phase 1 research work took place in the mid-1980's, when the releases from Glen Canyon Dam were at an all time high since the construction of the dam. These flood flows were so different than historic releases and caused such large effects downstream that they had a great influence on GCES recommendations.

On page 83 of the final GCES Phase 1 report, the first and foremost conclusion was that "Adverse downstream consequences are caused primarily by sustained flood releases significantly greater than powerplant capacity and by fluctuating releases", noting the erosive effect of floods on sand deposits and vegetation. Generally, these conclusions suggested the elimination or reduction of flood flows.

In the committee report accompanying the GCPA legislation, the Congress continued this thinking of adverse impacts by stating that "Flood releases from the dam erode beaches used by recreational rafters and campers. The river's now reduced sediment loads are inadequate to replenish beaches, even if flood releases occur once every twenty years. Flood releases destroy riparian vegetation and birds." The Act did not specify remedial measures, but seemed to imply that even the aggressive spill avoidance strategy that had been implemented to reduce spill frequency might be insufficient.

These conclusions produced the GCDEIS decision to reduce the return period of powerplant bypasses above 45,000 cfs to no more than an average of 1 in 100 years. The option of installing the spillway gate extensions was selected as part of the preferred alternative instead of the option of targeting an additional 500,000 acre-feet of vacant storage space when the reservoir filled in July. The additional vacant storage space option was rejected by the Basin States on the basis of reduced reservoir yield. The extensions were determined to be 4.5 feet in height, in contrast to the 8-foot high extensions installed during 1983. Additional questions about the need to reduce the frequency of powerplant bypasses and the desired magnitude and impacts of sustained high releases during extreme flood years now provide impetus to re-examine the original decision to install the extensions.

The Evolution of Understanding Regarding High Releases

Despite the enormous beaches created particularly by the 1983 spill event, the general thinking at that time was that there was a very limited supply of sediment below Glen Canyon Dam and that spills destructively moved much of this sediment out of the Grand Canyon. During the high flow years of 1984 - 1986, the main channel sediment storage was likely much lower than prior to 1983, and the deposition rate during the 1984 - 1986 spills was lower as a result. Sediment experts then believed that the river downstream of the dam was in a sediment-starved condition. Sediment supply thus became one of the primary driving forces behind ecological recommendations for changing powerplant operations.

After the passage of the GCPA, the thinking of some sediment experts began to change, primarily as the result of the hypothesis that the sediment rating curves below the dam were not

static with time. Additional thought was also being given to the location of stored sediment in the canyon and the mechanisms for moving sediment from the channel bottom to eddy areas. , Extensive modeling by the sediment researchers changed to a great degree the way in which transport mechanisms were viewed. The long term balance of sediment in the Grand Canyon continued to be an important issue in these discussions.

Sediment researchers now believe that flood flows counteract the possible adverse impacts that fluctuations have on beach erosion, thus rebuilding the deposits that would eventually slough back into the eddies, regardless of the nature of the powerplant operations. Some suggested that more frequent floods could allow higher levels of fluctuations.

The Agreement Contained in the 1996 AOP

With this evolving positive view towards spills, a desire for a test of the GCDEIS Beach Habitat Building Flow was expressed by the Transition Work Group beginning in 1994. This request for a purposeful powerplant bypass was strongly opposed by the Basin States because of the GCDEIS language triggering such bypasses, claiming a violation of the 1968 Colorado River Basin Project Act provision of avoiding anticipated spills, interpreted as powerplant bypasses. This opposition created an impasse that blocked such a test.

Additional discussions between members of the Transition Work Group and the Basin States resulted in a proposal for a modification of the GCDEIS preferred alternative, that of moving Beach Habitat Building Flows (BHBF) from years of low reservoir conditions (when spills would not be required for hydrologic reasons) to years of high reservoir conditions and high inflows. Thus a BHBF would occur in years when there was an expectation of having a hydrologically induced spill. This agreement was institutionalized in the 1996 Annual Operating Plan for the Colorado River, signed by the Secretary of the Interior in December 1995. A subsequent BHBF test was conducting in April 1996, confirming the hypothesis that high flows could rebuild sandbar deposits. In December 1996, the GCDEIS Record of Decision was signed by the Secretary of the Interior and included this modification of the preferred alternative.

Options and Impacts of Using Spillway Gate Extensions

This section addresses key questions raised earlier in this report which combined raise the issue, "Should the extensions be installed?".

The need to reduce the frequency of powerplant bypasses

Current thinking among sediment experts is that, given high flow conditions resulting from large runoff years, releases above 25,000 cfs should be preceded by BHBF's. The BHBF should be greater in magnitude than the highest expected future release. This not only moves sediment higher on beaches away from future releases, but also coarsens the main channel bed which reduces future sediment transport.

The occurrence of high release years is fundamentally tied to the statutory operation of Lakes

Powell and Mead. Reservoir equalization and Upper/Lower Basin consumptive uses all affect the cyclic drawdown and refilling of Lake Powell. High runoff years when the reservoir is full produces high powerplant releases and increased risk of powerplant bypasses.

Some sediment experts believe that there is sufficient regeneration of main channel sediment supplies to allow BHBF's in all years that such events would be allowed by the 1996 agreement, even every year if possible. Longer duration spills may have different effects than the short duration BHBF's, so additional sediment transport modeling would help clarify the allowable frequency of such spills.

The desired magnitude of BHBF's

At a BHBF symposium held in April 1997, many researchers expressed the opinion that, while the 45,000 BHBF of April 1996 achieved some of the intended results, periodic higher releases would be helpful to scour non-native vegetation, rework backwater areas, and deposit sand high enough on the beaches to be less vulnerable to succeeding flows. Estimates of 60,000 to 90,000 cfs were discussed as appropriate flow levels for these purposes.

Additional modeling and analysis should be devoted to this question of the magnitude of high releases. This should address both the short duration BHBF's and the potentially longer duration uncontrolled powerplant bypasses.

GCDEIS expectations related to spillway gate extensions

One of the GCDEIS conclusions was to reduce the return period of bypasses above 45,000 cfs to a long term average of not more than 1 in 100 years. Thus, releases below 45,000 cfs were allowed as part of normal operations, but the extreme spillway releases such as occurred in 1983 were essentially forbidden. This threshold level of 45,000 cfs seemed to indicate that flows below that level were acceptable from an ecological perspective while higher flows were deemed too damaging. It is interesting to note that the current opinion of at least the sediment researchers is just the opposite.

The CRSS modeling which formed the hydrologic basis for many of the GCDEIS decisions determined that bypasses were rare events, and if a small amount of buffer space were provided, such releases greater than 45,000 cfs could be avoided. Since it uses a monthly time step, the CRSS model could not really estimate the peak bypass release other than to average the release over the month in which it occurred. Thus some judgment was used in estimating the frequency of releases greater than 45,000 cfs.

The limited value of the spillway gate extensions

The GCDEIS commitment to install the 4.5-foot extensions would produce about 500,000 acre-feet of surcharge storage space above the normal maximum water surface of 3700 feet. While this is a large amount of reservoir space, it is small in comparison to either the 7.8 MAF April - July inflow or the 2.1 MAF forecast error term for June 1 (5 percent exceedence level). A buffer

of this size would affect primarily moderately high years in which bypasses were on the range of several hundred thousand acre-feet. Such bypasses could be reduced or eliminated entirely by storage the excess inflow behind the gate extensions until it could be released through the powerplant.

Inflow volumes of extremely high inflow years such as 1983 or 1984 had return periods of about 1 in 100 years. These are the types of years which would produce releases in excess of 45,000 cfs, perhaps for an extended period of time as occurred in 1983. The volumes of bypasses in these types of years are very large, 3.4 MAF in 1983 and 1.0 MAF in 1984. The greatest determining factor in the amount of bypass is the forecast error associated with high inflow years.

In contrast, moderately high inflow years such as 1985, 1986, and 1995 would cause bypasses of about 100,000 to 800,000 acre-feet using current operating practices. These bypass volumes could be released through the outlet tubes in 3 to 25 days, thus limiting total releases to 45,000 cfs or less. During these types of years, it would be very unlikely that use of the spillways would be required. It appears from this discussion, that only inflow years with a return period of about 1 in 100 years would force the use of the spillways and release more than 45,000 cfs. Reclamation believes that current operating practices would initiate high powerplant releases and bypasses early enough as required to safely operate the dam, thus meeting the intent of the GCDEIS provision without requiring either the additional storage buffer or the spillway gate extensions.

The positive value of the spillway gate extensions

Although the extensions are not required to limit spillway use to the 1 in 100 year return period cited in the GCDEIS, some limited value can be gained from their installation during years in which peak releases would be less than 45,000 cfs. In these cases, if the total bypass volume was expected to be 500,000 acre-feet or less, then the entire expected bypasses could be stored behind the extensions and released later in the summer. This might produce some environmental benefits by not releasing greater than 30,000 cfs if such releases would cause ecological harm.

However, it would also carry the dam safety risks associated with purposefully storing more water in the reservoir than was assumed during the design of the spillways. If an extremely rare high inflow event occurred, it could conceivably overtop the dam, even with full use of the spillways.

Proposed Recommendation for the Spillway Gate Extensions

As a result of the limited value of the extensions in controlling extremely high runoff years, the ability to control more common inflow events without the use of the spillways, and the risk associated with using the extensions for release moderation rather than emergencies, it is Reclamation's recommendation that the 4.5-foot spillway extensions not be installed. However, we do recommend that the original 8-foot extensions continue to be stored at Glen Canyon Dam for use only in case of dam safety or hydrologic emergencies.