# THE GCMRC'S BASIS FOR BHBF II HYDROGRAPH DESIGN

*Perspectives Relative to Fine-Sediment Conservation and Related Habitat Sustainability*

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## I. Introduction

The attached BHBF II hydrograph is recommended by the GCMRC, to benefit both downstream sand bar restoration efforts, and to continue advancement of scientific understanding of how controlled floods may be useful in conserving fine-sediment resources downstream from Glen Canyon Dam. The GCMRC staff and cooperating scientists believe that a 45,000 cfs BHBF is the next logical step in any set of flow experiments conducted as part of the Glen Canyon Dam adaptive management program.

In addition, many cultural resources are located in sediment deposits along the channel. Recreational camping beaches are located on many sand bars and are included in the discussions on sand bars. Archaeological resources along the river corridor are contained in the sediment deposits which form the alluvial terraces. Since the completion of Glen Canyon Dam, the sediment resource has declined and the alluvial terraces have eroded. A system wide method for regenerating the river terraces and redistribution the sediment is generally considered an essential component to maintain integrity for these resources. Also, important ethnobotanical resources appear to have benefited from the re-deposition of new sediments along the channel margins.

The proposed BHBF II treatment is nearly identical to the BHBF hydrograph of 1996. The duration of the controlled flood has been changed to see if sand bar building can be accomplished through a similar magnitude, but smaller volume "flood flow." The recessional limb of the flood has been made more gradual in an attempt to create sand bars and backwaters with gentler sloping characteristics.

The GCMRC's physical resources program manager and the cooperating physical scientists anticipate that a great deal more new information on sediment transport and the fine-sediment budget will be gained from such a BHBF. On the basis of current knowledge about sediment resources and discussions held with stakeholders over the last 4 years, the following changes in the BHBF hydrograph are suggested: 1) Constant flows for 3 days of 15,000 cfs - before and after the flood for purposes of recording high-elevation bar building and other related changes to the ecosystem; 2) Reduced duration – designed to test the hypothesis on rapid rates of sand bar deposition measured in 1996, and 3) A modified recessional limb - that consists of an hourly down-ramping rate of 500

cfs/hr for slightly more than 2 days, to modify slope characteristics of new sand deposits. Maintaining the up-ramping rate of 4,000 cfs/hr (maximum allowed under the ROD) for the ascending limb of the BHBF is recommended to maximize sediment entrainment.

The 15,000 cfs constant flow periods for the pre- and post-flood aerial overflights will allow remotely sensed evaluation of the high-elevation impacts to sand bars, backwaters and vegetation, while avoiding the artificial desiccation of the near-shore food base that has established during relatively high-flow operations of the last several years, and stranding of fish, etc. The more gradual recessional limb following the BHBF is thought to have the potential for resulting in more gently sloping sand bar faces that promote stability of and access to return-current channels within backwater habitats. The reduced duration of 4 days will allow an opportunity to see whether sand bars can be restored with a smaller volume of water from Lake Powell.

Additionally, the proposed BHBF II hydrograph design will provide better understanding about the effects of floods on biological resources and processes, including recovery response time by the aquatic food base, and nutrient cycling along the river corridor.

While it is not possible to replicate the 1996 BHBF Test in a system like the Colorado River, we can propose a similar treatment and draw parallels from the previous event for responses by biological resources. While sediment measurements are often time independent, biological responses are affected by seasonality as well as treatment effects. Knowledge gained regarding biological resources from an experimental hydrograph would be most useful if the timing of the release were similar to the timing in 1996 (late March-early April). While the proposed BHBF II hydrograph differs somewhat from the original BHBF Test, the seasonal response would be similar to 1996.

At present, it is unclear what type of dam operations would follow a BHBF released under the triggering criteria once the post-flood aerial photography overflight is completed. The current Hydrologic Triggering Criteria (at least a 1.5 MAF release volume forecasted for the month) suggests that flow conditions would be high and constant following the BHBF until such time that either the forecasted runoff for April through July was reduced, or the relatively high monthly volume was released.

Cultural resources are likely to benefit from the proposed hydrograph in that the magnitude of the event will seem to deposit sediments that may buffer and slow erosion at alluvial terraces while providing a more gradual recessional limb that may result in more gently sloping bar faces and result in a reduced erosion rate following the high flow event. The slower down ramping rate may benefit plants and plant locations by reducing erosion rates within vegetated areas.

Under the reduced duration at 45,000 cfs, the flood-flow volume is decreased, but the prolonged recessional limb would counter that effect to some degree. None-the-less, the hydrograph design presented here, assumes that high, constant releases will follow the BHBF.

Following, is additional background information on the proposed BHBF II hydrograph forwarded to the Technical Workgroup by the GCMRC and its cooperating physical scientists.

## II. State of Knowledge - Fine-Sediment Transport and Dam Operations

[Post-1996 BHBF Controlled Flood Experiment]

1 Review of the sand bar survey time series collected by NAU – Kaplinski et al., indicates that sand bars that were deposited by the 1996 BHBF Test were significantly eroded by April 1999, despite continued implementation of ROD dam operations. These sand bar monitoring data also indicate that sand storage within eddies has recovered from the scoured conditions that were measured immediately after the 1996 flood.

2 Average to above-average sand inputs from the Paria and Little Colorado Rivers between 1997 and present, suggest that implementation of a second BHBF as soon as possible would likely be beneficial to downstream sediment resources.

3 Research since 1996, indicates relatively higher fine-sediment transport rates (leading to system-wide export) under ROD operations than previously estimated in final EIS. This fact has significant implications for accumulated channel storage of sand (particularly fine sand) with respect to the concept that ROD operations promote multi-year sand storage throughout the main channel.

Points of Supporting Evidence for Limited Sand Storage in Main Channel:

- Unstable suspended-sediment transport rating curve at long-term measurement sites means that sand transport rates rise dramatically immediately following tributary inputs of sand and finer sediment,
- Conceptual modeling and ongoing monitoring and research indicate that sand-storage potential in the main channel is quite limited relative to average annual inputs of sand from the Paria and Little Colorado Rivers,
- Rapid winnowing of sand on the bed of the main channel occurred during: the 1996 BHBF Controlled Flood Experiment, the 1997 Test Flow, dam operations between 1997 and 1999, and during pre-dam times, suggests that main channel storage sites are limited. Evidence points to eddies as the primary sites for sand-storage changes that are readily detectable; however the full storage potential of the system is still poorly known.
- Low-elevation sand-storage zones within Marble Canyon eddies recovered prior to significant sand inputs from the Paria River that began in summer 1997. Once storage sites were filled, much of the Paria River-input sand were transported downstream from critical reaches.

## State of Knowledge - Biological Resources and Dam Operations

1. Relative high steady releases that followed the 1996 BHBF Test, and that occurred in 1997, benefited aquatic productivity at lower and higher trophic levels.

2. Results about the effect of the 1996 BHBF Test on aquatic resources were confounded by the low steady flows (8,000 cfs) conducted prior to and following the Experiment. The low flows prior to the experiment resulted in desiccation and may have increased drift downstream.

3. Productivity of riparian vegetation also increased following the 1996 BHBF Test along the shoreline, but this was more likely due to the subsequent high steady releases, rather than the effects of the flood.

4. Nutrients were recycled locally (within eddy complexes) during and after the 1996 BHBF Test. How these nutrients are distributed downstream, or if there is a dilution or accumulation of nutrients downstream is not known.

5. Backwaters were filled in following the 1996 BHBF Test, but its is unclear if the receding limb of the hydrograph was too steep, if the 8,000 cfs steady flows contributed to the eddies filling in, or if the subsequent high flows had the greatest effect on these habitats.

## III. Recently Identified Information Needs with respect to Fine-Sediment

- Recent science data indicates a critical need for more robust monitoring of fine-sediment storage with respect to grain-size distributions of channel-bed and bar deposits, as well as bar volumes to anticipate bar-building responses during controlled high flows.
- Ungaged tributary contribution of sand in the Marble Canyon reach is now estimated to be about 20 percent of the annual contribution by the Paria River, but may be somewhat higher. The volumes, grain-size characteristics and timing of ungaged sand inputs, versus export characteristics, need to be verified through ongoing monitoring.
- Although streamflow and sediment transport models for the gaged tributaries are being completed, only streamflow can be accurately modeled for the main channel. Additional research to evaluate the effects of the ROD is still required to obtain predictive capabilities for estimating fine-sediment transport in the main channel relative to sand inputs, storage and export.
- Future BHBF dam releases are needed to fill gaps in the knowledge about the residence time of sand inputs relative to the required timing and frequency of such management actions aimed at sustaining downstream sediment resources.

## Identified Information Needs with Respect to Biological Resources

- The fate of dissolved organics and drift as it moves through the system.

- What is the recovery time for the Aquatic food base to a hydrograph that lacks the preliminary desiccation event (8,000 cfs steady flow for three days)?

- Backwaters are by their nature unstable (return current channels and reattachment bars resulting from flood condition and receding hydrograph). But is there a

hydrodynamic model and operating scenario that scours the return current channels and makes them available in the subsequent months when young fish may utilize them.

## IV. Integrated Physical Resource FY2000 Science Program Related to Potential Beach/Habitat-Building Flow

### A. Emphasis on Baseline Monitoring and Research Goals for Physical Sciences in FY 2000, with or without a BHBF –

- Continue testing the hypothesis that fine-sediment-storage potential is relatively limited with respect to average annual sand inputs,
- Continue historical synthesis on sediment and streamflow data, including extension into Glen Canyon Reach,
- Continue interpretation of hypotheses that deal with compressed flood-frequency resulting from dam regulation, as well as the seasonal shift in patterns of main channel hydrology (highest flows in late spring) versus seasonality of fine-sediment inputs (late summer through fall),
- Continue development of a long-term monitoring design that redirects focus on critical upstream reaches where sand inputs are most limited, that tracks grain-sizes of sand inputs versus deposits throughout the main channel to understand and manage fine-sediments, and that benefits from increasing predictive modeling capabilities related to sand transport.

### B. In the Event of a BHBF (See attached BHBF II Hydrograph Design)

Over the past three years, the GCMRC has developed a generalized, multi-part scientific design for ongoing monitoring and research of future BHBFs. The GCMRC distributed this high-flow science prospectus to the Glen Canyon Dam Technical Workgroup in December 1998, for consideration and comment.

Hydrologic Triggering Criteria that currently regulate implementation of managed floods, result in a *passive* Adaptive Management approach, but much can still be accomplished if the ongoing management actions are consistently implemented in conjunction with sound monitoring and research activities designed under an approach termed "Method of Multiple Working Hypotheses." With respect to dam operations and their relationship to impacts to downstream fine-sediment resources, the following thoughts provide a basis for the recommended BHBF II hydrograph design (attached).

## V. Currently Proposed Multiple Working Hypotheses - *to be Addressed in Future High Flow Experiments that Have Bearing on Long-Term Fine-Sediment Sustainability*

With respect to ROD Dam operations that include periodic implementation of BHBFs under current Hydrologic Triggering Criteria:

1) **$H_1$** – [CONCEPT – BHBF duration can be reduced with no loss of bar-building benefit].

Hypothesis to be tested: Reducing the duration of the BHBF by nearly 50 percent from that of the 1996 controlled flood will not reduce the effectiveness of the high flow to restore sand bars and related habitats.

*Comment:* If supported, then this will reduce the magnitude of the "flood-flow" and related economic costs of this component of the ROD.

2) **$H_2$** – [CONCEPT – "It's a Sponge" All of the fine-sediment that enters the ecosystem between BHBFs is stored in the main channel].

Hypothesis to be tested: 100 percent of all gaged tributary fine-sediment inputs (sand and finer) stays in channel storage until a BHBF occurs and redistributes the sand to higher elevations along the bank.

*Comment:* This would represent an idealized result of the EIS preferred alternative with respect to conservation and sustainability of sediment and related habitats. In this scenario, sand export only occurs during BHBFs as a cost of rebuilding sand bars, as was directly measured during the 1996 and 1997 Flow Tests.

3) **$H_3$** – [CONCEPT – "It's a Pipe" What comes in (usually in the late summer and fall) is basically exported by normal operations to Lake Mead before such time that a BHBF can be implemented (spring to early summer).]

Hypothesis to be tested: Zero percent of gaged fine-sediment inputs (sand and finer) accumulate over multi-year periods within the main channel, and little accumulation occurs over even a few months (seasonal).

*Comment:* This would constitute the worst-case scenario with regard to fine-sediment sustainability, and would raise serious concerns about the long-term effectiveness of the ROD to keep sufficient amounts of sand in the ecosystem.

4) **$H_4$** – [CONCEPT – Limited, but Insufficient Intermediate Storage Occurs].

Hypothesis to be tested: Only about 20 percent (likely the coarsest fifth percentile of sand) can remain in low-elevation channel settings from one year to the next, and it is not enough to sustain sand bars and related habitats long-term, in spite of the fact that BHBFs occur periodically (say, 1-2 times per decade).

*Comment:* Such a situation might appear to be sustaining sediment resources for a time, but gradually the system becomes depleted of fine sand to the point that BHBFs of the 1996 magnitude no longer build sand bars, but in fact cause erosion, and sand deposits that do exist are so greatly winnowed that they no longer support a functional ecosystem.

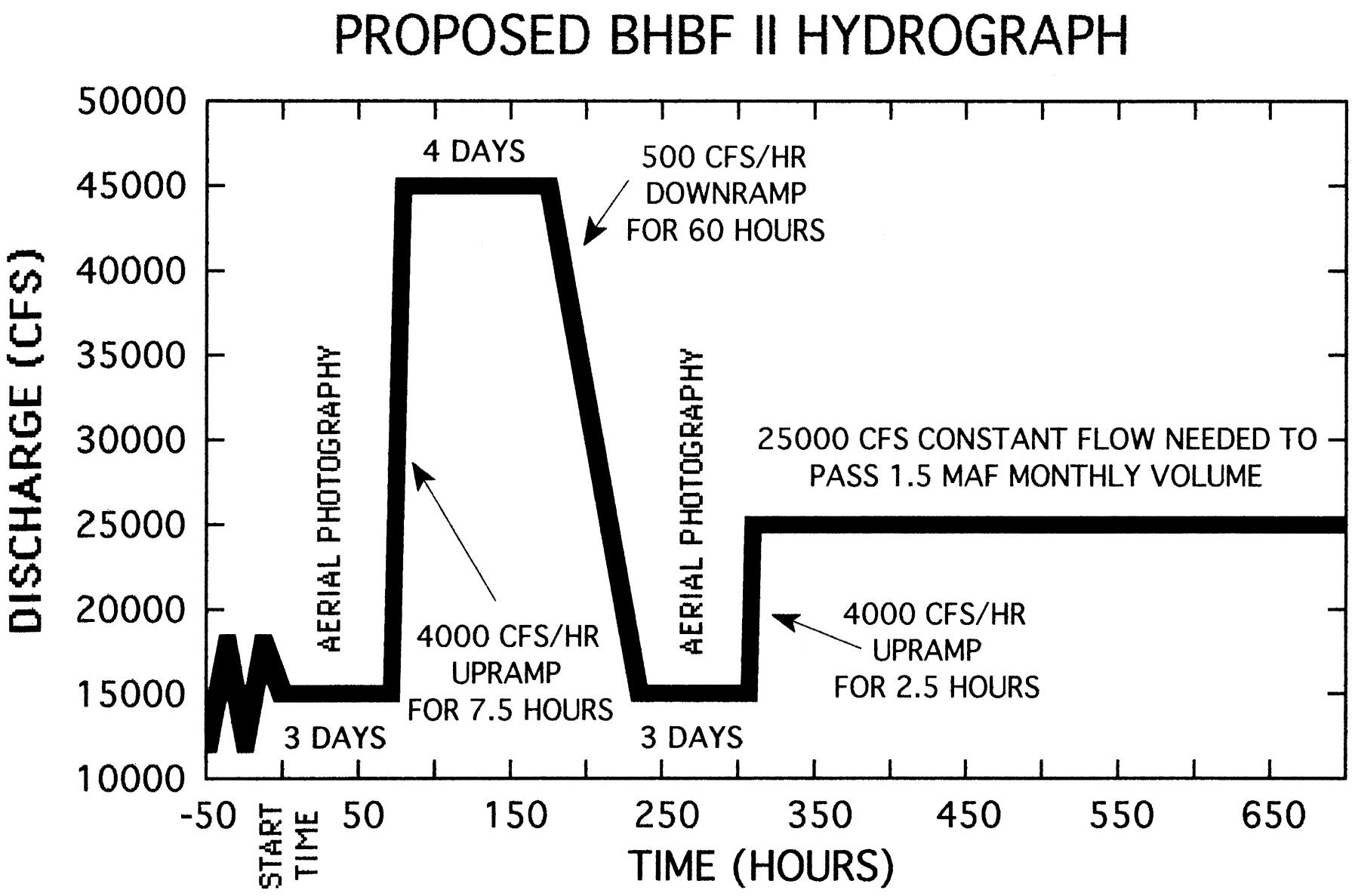
5) **$H_5$** – [CONCEPT – Limited, but Sufficient Intermediate Storage Occurs].

Hypothesis to be tested: No more than about 50 percent of the fine-sediment inputs (sand above D-50) to the system can be accumulated in low-elevation channel settings for a year or longer, yet this level is sufficient to sustain sand bars and related habitats long-term as long as periodic BHBFs occur periodically (say, 1-2 times per decade).

*Comment:* This condition could be seen to represent the post-dam scenario relative to long-term management of fine-sediment resources.

## VI. Summary

In conclusion, under this method of "learning-by-doing," the goal of future high-flow monitoring and research, relative to sediment-transport, the fine-sediment budget, and dam operations, is to systematically eliminate the above hypotheses that can not stand the test of new data and integrated interpretations. This approach of eliminating inferior hypotheses continues until science focuses on the one hypothesis, or combination of hypotheses, that most closely fit the data and related knowledge base. By doing this, managers are provided with a clearer perspective on the extent to which ROD operations or other flow options might be implemented to achieve management objectives.


PROPOSED BHBF II HYDROGRAPH
DISCHARGE (CFS)
50000
45000
40000
35000
30000
25000
20000
15000
10000
4 DAYS
500 CFS/HR
DOWNRAMP
FOR 60 HOURS
AERIAL PHOTOGRAPHY
AERIAL PHOTOGRAPHY
25000 CFS CONSTANT FLOW NEEDED TO
PASS 1.5 MAF MONTHLY VOLUME
4000 CFS/HR
UPRAMP
FOR 7.5 HOURS
4000 CFS/HR
UPRAMP
FOR 2.5 HOURS
3 DAYS
3 DAYS
-50
START
TIME
50
150
250
350
450
550
650
TIME (HOURS)