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MEMORANDUM

To: Technical Work Group

From: Steve Gloss and Ted Melis, GCMRC

Subject: Experimental Flows

Attached please find material pertaining to our development of experimental flow recommendations pursuant to the AMWG motion passed in January. These materials are intended to provide a basis for discussion of this topic at the upcoming TWG meeting on February 26-27, 2002.

There are two Attachments. Attachment 1 is an updated draft of recommended flow scenarios which has been revised following our conference call of February 8. Attachment 2 is a document which captures questions asked in the conference call and provides answers to these questions. Since many of these questions may be asked by others, we are characterizing these as a set of frequently asked questions which will be provided with future drafts. The list of Q & A's will likely grow over time.

A word about the hydrograph figures associated with the flow recommendation scenarios. These are meant to be conceptual and illustrative only, particularly as regards the magnitude of flows or flow fluctuations during any particular period. They were developed mostly by piecing together elements of actual hydrographs from the past 10-15years, because these were data we could easily access and combine. While the concepts and purposes we present for different periods of the annual hydrograph are important, there may be flexibility attainable in the actual flows used to accomplish objectives.

We urge you to read this material before the TWG meeting so that GCMRC and the TWG can work together to meet our responsibility under the AMWG motion.

Experimental Flows Conference Call
February 8, 2002
Questions & Answers

Q: I understand there is little direct evidence of predation by non-natives on HBC: If this is correct, why is the focus by GCMRC on non-native fish?

A: Although, there is considerable uncertainty regarding the causal mechanism for the decline in adult HBC abundance, the predation / competition hypothesis has a higher likelihood than other mechanisms (disease/parasitism, hydrology, food-limitations, habitat degradation, etc.) for explaining the decline. In addition, this is a testable hypothesis using management flow prescriptions. Finally, it is plausible that the predation / competition hypothesis could overwhelm any benefits derived from management flow prescriptions intended to provide beneficial habitat conditions.

There is considerable circumstantial evidence that would suggest that predation could be influencing survivorship of YOY HBC. Specifically,

1. There is direct evidence of predation by trout, primarily BNT (8-10%); however, there is evidence of lower predation by RBT (1-0.5%) (Valdez and Ryel 1995; Rowell 2001).
2. The positive expansion in trout abundance system-wide in the Colorado River mainstem
3. The highest proportion of fish in the LCR inflow area are composed of trout.
4. The composition of trout, in the LCR-inflow reach, consist of 97% RBT, and 3% BNT.
5. There has been a 4-6 fold increase in relative trout abundance in the last 7 yr.
6. Assuming Valdez and Ryel (1995) mouth-gape analysis is correct, the size-class of vulnerable fish to predation is the same size-class that fails to recruit into the adult HBC population.
7. Assuming that these estimates are correct and taking into account the local distribution and change in abundance since 1990-1993, estimated annual consumption of HBC-YOY should have increased.
    a. Annual consumption of HBC corrected for recent change in relative abundance
        i. Rainbow trout = 1990-1993: 227,760 2001: >1,000,000
        ii. Brown trout = 1990-1993: 32,850 2001: 120,000

Alternately, using population estimates for just the LCR area would suggest that RBT occur in densities of approximately 10,000 fish/mile. If the region encompassing the first 5 miles around the LCR inflow represents the only part of the HBC population that successfully recruits back to the source population, and only 1% of the trout in this area prey on HBC, and HBC are only vulnerable during the year for a limited 3-month period (90d), and only 1-fish is consumed per predatory trout per day, then a conservative estimate would be 45,000 HBC consumed. This compares to an estimated annual recruitment of 10,000 – 20,000 HBC to the LCR population in recent years.

A final reason, given the uncertainty associated with the competition predation hypothesis is that from a biological and sediment resource perspective this is a low risk experiment, with testable hypotheses.

Q: -How does load-following benefit native fish?
-How is it low-risk to disadvantage non-natives and not affect native fish?

A: GCMRC believes the benefits to native fish will accrue indirectly through a reduction in predation/competition by non-native fish, primarily salmonids in the LCR reach. The model developed by Dave Speas and Carl Walters provides support for load-following to negatively impact RBT by interfering with and disrupting spawning activity as well as reducing the recruitment of young fish. The working assumption is that non-native fish overwhelm any benefits to native fish from management flows that improve habitat conditions.

Load-following destabilizes or reduces the permanence of near shoreline habitat. Conceptually, YOY for most species of fish are found along the lentic edge of the river, occupying habitat that maximizes feeding opportunities while decreasing risk from predation. When there is a change in stage fish must move laterally while following the vertical change in water edge. Repeated movement by fish and increased distance traveled, results in lateral and longitudinal displacement that increases the likelihood for predation. The greater the magnitude in change and rate the greater the effect.

Load-following can equally affect both non-native and natives fishes. There are thought to be few HBC in the mainstem during the time of the year that load-following would occur and therefore, HBC will not be negatively affected. However, the hypothesis being tested is that the current abundance of nonnative fish has created a predator/competitor load that is too excessive. It is the abundance of predators that has overwhelmed survivorship of YOY along shoreline. The intent behind this flow prescription is to disadvantage non-natives rather then benefit native fish. This experiment would test alternate hypotheses whether or not YOY survivorship is habitat limited or is predator limited.

Q: If you won't benefit native fish in the fall, why do you go to steady flows?

A: There are a number of hypotheses to test:
Ho: Turbidity reducing predation

- This hypothesis, that turbidity reduces predation by visual sight feeders is considered hierarchically second to the reduction in predator loads.

Ho: Potential benefit to native fish from more stable near shore habitat.

- GCMRC has stated that the greatest number of YOY HBC enter the mainstem during fall monsoon events, therefore there is also the potential for stable flows following these events to provide warmer and more suitable habitat conditions for these fish during the fall. GCMRC should evaluate the downstream warming potential and the increase in suitable habitat of these mainstem conditions during the Sept – Nov time period.

- Expect this potential benefit may be overcome by non-native interactions.

Ho: Lower flows result in the retention of a more natural sediment mix and higher mainstem sediment concentrations for bar building in January. The more natural mix of sediment (fines through sand) will result in better bar stability and also affect nutrient cycling

Q: How can you conduct low steady flows or low load-following flows? Don't they violate the AOP?

A: The concerns expressed about monthly volumes and the AOP process are important ones. Annual release volumes are defined by statute and resulting operating criteria. Monthly release volumes are determined to meet annual requirements, support firm power generation commitments, and address the combined risks of powerplant bypasses, and over- and under-release of annual volumes. The GCPA did not alter the water development philosophy of the previous 1956 and 1968 Acts; thus, the financial integrity of the Basin Fund is of great concern to the States. As the AOP is developed each year, consideration is given to all the factors listed in the 1970 Operating Criteria, which include environmental concerns. The issue raised on the Feb. 8 conference call was not so much that the monthly volumes cannot be adjusted, but rather that the process of developing those monthly volumes must remain consistent with the water development and financial goals of previous Acts. If monthly volumes need to be adjusted from the typical decision making process in order to conduct an experiment, this issue would need to be addressed during the preparation of the 2003 AOP.

Q: If this is an 8.23 MAF year, July and August would be 800,000 Acre Feet and September, October, and November would be low volume months. How can you conduct the flows you describe, given these potential volumes?

A: The proposed hydrograph shows both the end of the 2002 water year (expected to be 8.23 maf) and the entire 2003 water year (expected to be about 10 maf). No adjustment to the 2002 water year hydrograph is proposed, with the possible exception of reacting to fall tributary inputs. Thus, July and August of the 2002 water year are expected to be about 800,000 af months, and GCMRC will monitor the effects of ROD releases during this year as part of a "baseline" data collection to determine the effects of ROD operations.

The reaction to fall tributary inputs is to recommend either a reduction to low steady releases (below 10,000 cfs) to conserve sediment inputs in the main channel or low fluctuating flows (5,000 – 10,000 cfs) to conserve sediment inputs in the eddies, or lastly the release of a HMF.

Q: Could you use a HMF to conserve sediment instead of low steady flows or low load-following flows?

A: You might potentially store some sand and possibly some limited amount of finer sediment within eddies, but the total sand conservation achieved would be far less than if the entire channel bed was available for storage of fines under the 10,000 cfs or less flow alternative. A comparison of results from the 1996 BHBF, and the 1997, 31,500 cfs spike flow provide some valuable insights on this matter. One important concept to keep in mind is that the total potential storage for sand within eddies is only a small fraction of what can be stored within the main channel, under flow conditions that limit downstream transport.

Eddy-sand bars studied following the November 1997, spike flow (under relatively sediment-supply enriched conditions), showed a much finer grain-size distribution than bars created by the 1996 BHBF (under relatively greater sediment-depleted conditions). The 1997 eddy deposits were relatively cohesive compared with the 1996 deposits, and were much darker in color,

suggesting some higher content of organics. Unfortunately, the average thickness of most of the 1997 deposits was on the order of 10-20 cm, or relatively thin compared with bar thickness measured after the 1996 BHBF. One preliminary conclusion derived from the 1997, sediment experiment was that the 31,500 cfs spike flow produced a "stage-limited" response, and that thicker and larger bars might have been deposited in November 1997, had the stage been increased to above peak power plant levels. Flows preceding the November 1997 test were not as low as those being proposed for future experiments, yet there was still evidence to suggest that at least some portion of the summer sediment inputs remained in the channel by the time the high flow occurred.

Q: Could UC and LC talk about a way to work this out if deliveries are lower and water volumes need to be shifted for this experiment, especially since releases from Mead wouldn't be affected?

A: This can be done as long as the Compact and the specific annual release requirements contained in the 1970 Operating Criteria can't be violated.

Q: Are the purposes responsive to the motion?
Materials describe two purposes: (1) sediment, and (2) benefits native fish. I thought the motion was primarily about sediment.

A: The point of the motion was primarily to test the sediment Ad hoc group's second recommendation, but GCMRC interpreted the motion as a sediment conservation experiment within the framework of benefiting native fish.

Q: Is the GCMRC draft proposal in concert with the RPA?

A: Yes. As per the FWS RPA, the draft proposal identifies the need for the development of experimental flows to test, or the implementation of alternate flows as specified in the Biological Opinion of GCD. One such flow was the 2000-LSSF experiment (SWCA 2000) that used a holistic hydrograph that was intended to produce habitat improvements that would benefit HBC, rather than a mechanistic approach specifically applied to a life history component. The approach here is more discrete and testable than the former flow scenario.

Q: Would load-following confound measuring impacts of Brown Trout removal in Bright Angel?

A: Load-following is designed to be a more systematic treatment. One year of load following vs. one-year of Brown Trout evaluations are very different. Having both would enhance the potential effort.

The hypothesis that is being tested is whether or not predation is limiting YOY HBC recruitment. Whether we have multiple treatments that are each reducing predator loads does not affect the overall nature of the test. For the test, it is not what reduces trout more effectively (flows, tributary treatments, mechanical removal), but whether the reduction of trout abundance by some

means has an effect on YOY HBC recruitment? Depending on the ultimate test response (which remains unknown), a titration approach could be implemented that would allow for a measure of efficiency of one method over the use of an alternate method.

Q: Are the wheels in motion to do Brown Trout removal this Fall?

A: Grand Canyon National Park is supportive but the resources (staff and funding) are not there to do it this Fall.

Q: If FY 2002 is an 8.23 MAF year and one needs to take information from Summer of 2000 and compare it to ROD flows in 2001 and 2002, do you have the baseline data collection for that comparison?

A: A similar level of effort for monitoring downstream native and non-native fish has continued since the LSSF flows of 2000. Seining at a lower level of effort is continuing. The integrated sediment data is continuing to be collected. Reduced efforts on downstream temperature is ongoing. The level of resolution and many of the specific studies intended to answer specific effects of the LSSF treatment have not been continued. Once a set of experimental flows is established and the hypotheses to be tested are articulated, GCMRC will need to review the power of the existing monitoring activities.

Q: Is there any response of HBC to ROD flow changes? Do we know if there are changes in the LCR that may be the cause and that will be ignored by this effort?

A: We are beginning to look at the LCR hydrology record. One would expect to see changes in LCR hydrology due to development in the watershed resulting in groundwater depletion, surface water retention, and changes runoff patterns in response to paved areas, among others. It is not clear if we will be able to correlate these with changes in HBC. The working hypothesis is that predation and competition from non-natives will overwhelm habitat effects. This hypothesis also assumes that some portion of the LCR population recruited from fish which spent part of their early life history in the mainstem and that this portion of the recruitment is being negatively affected by non-native fishes.

There are other hypotheses that might explain the decline in abundance of HBC. Although there is considerable uncertainty around all of these alternate hypotheses. Not all of the hypotheses are experimentally testable to explain the causal nature of the recent decline of HBC. For this reason, we are suggesting an experiment to reduce predators in the mainstem because it is a practical and low risk treatment. However, if we were to implement such an experiment it does not imply that the current effort monitoring the species of concern would be discontinued, or that alternate mechanisms or factors that might be also contributing to the decline would be ignored, unconsidered or omitted from the present monitoring.

Q: Are there other options for sediment conservation in September-December? Options might include HMFs or steady 8,000 -10,000 cfs flows? Load-following between 5000-9000 cfs? Would the conceptual model or Wiele efforts help sort this out?

A: The conceptual model is not predictive in the sense that we can calculate the expected outcome of an experiment, but it may have utility in comparing the results of several options for portions of the proposed hydrograph.

Wiele's bar-evolution modeling simulations indicate that bars are most effectively deposited when a combination of high suspended-sediment concentrations and high-stage conditions occur simultaneously. Limiting downstream transport of newly input fine sediment until the release of a controlled flood is the most probable means of achieving both of the above conditions, if releasing a controlled flood during or immediately after tributary inputs is not a viable option. The conceptual model's sediment dynamic sub-model is based on the same basic premise: when abundant sand supply is available, then it will get mobilized by a high-flow release and the result will be an increase in sand storage at high stage elevations.

Q: What reservoir elevation do we need to be at to use the spillways?

A: By January 2003, Lake Powell storage elevation needs to be at 3657 feet to have 14,000 cfs of flow in either of the spillways. This level of discharge is needed for the spillway to function in a safe manner. For January 2003, the lake level is projected to be 3648 feet. As a result, there seems to be little hope that the BHBF proposed for January 2003 could exceed 45,000 cfs.

Q: December is a high power demand month, is it possible to do fluctuating flows up to 15,000 cfs. What would this do to sediment storage for a January BHBF?

A: Load following between 9,000 and 15,000 cfs during December 2002, is certainly one of the possibilities being evaluated following summer/fall sediment inputs. If the sediment inputs occurred in September, and the flows were released to 10,000 cfs or less through November, then there would be less downstream transport during the proposed December load following than if normal operations occurred throughout the September through December period. The impact on downstream transport of newly input sand during the December operations is most easily evaluated by reviewing figure 2, included in the Rubin et al. memorandum of August 2000.

Assuming: 1) that at least 500,000 tons of sand entered the main channel from the Paria River in September 2002, 2) that flows were immediately reduced to 10,000 cfs or less from the time of the input until December 1st, and 3) that the average flow for December 2002, was about 12,000 cfs – figure 2 suggests that about one-half of the newly input sediment introduced in September 2002, would be transported downstream in about 45 to 250 days, once December's operations started. Likewise, if we assume that the proposed BHBF occurred at the start of January 2003, then there is reason to believe with some certainty that less than one-half of the September sediment input would be exported downstream before the January BHBF was released.

Q: If sediment is stored in the eddies in an HMF, why do you go to monthly low flows?

A: The HMF approach foregoes hypotheses related to storing the fuller range of sediment components and the turbidity effects. Also, there is only a limited volume of sand that can be stored in the eddies and it is much less than the volume of fine-sediment that can be stored in the channel bed throughout the entire river channel. Results of the November 1997, sediment experiment (31,500 cfs) indicated that sand storage increased within eddies, but that this increase in storage was very limited compared to the volume of sand that might have been conserved had a higher flow been released that would have taken advantage of higher-elevation storage locations along shorelines. There is no basis at this time for concluding that the potential eddy-storage volume within the ecosystem is sufficient to sustain sand-bar maintenance long term. In light of this, the most conservative scientific experimental approach is to conduct the flow experiment that has the greatest likelihood of optimizing sediment conservation and sand-bar restoration/maintenance. Doing less optimal sediment treatments in the future may very well be justified during periods when reduced-flow operations are not possible, or on the basis of new findings that indicate that the fullest range of channel storage is not required for long-term sand bar sustainability.

Q: Why not test a BHBF in Fall?

A: This is viewed as outside the current interpretation of the Law of the River.

Q: Could you move the load-following period to February to address the possible public concern of stranding adult trout?

A: This can be considered. One is not sure if it will have the same effect of reducing non-native spawning. Using slower down ramp strategies as well could reduce stranding of adults.

Q: Concerned that load-following is outside the ROD? Do we have compliance for fluctuating flows that violate daily ranges and proposed upramp rates?

A: GCMRC believes that this would be covered as an experiment under the ROD. We do need to check into compliance.

Q: I want to ask you to look at trade-off in fine sediment losses through a two-stage approach: -HMF followed by a BHBF and the benefit of doing low load-following during winter-peak demand

A: Because we don't have a very robust numerical predictive capability, with respect to sediment dynamics in this system, the best way of quantifying these differences is by conducting the proposed experiment, and then comparing the results to those of the proposed alternatives. The next best way is by using empirically derived methods for estimating sediment transport, such as the method shown in figure 2, of the Rubin et al. (2000) memorandum.

Q: Given that the motion focuses on sediment, how does the low load-following benefit the sediment?

A: The winter load following component of the experiment is not intended to benefit the sediment resource. However, there may be some advantage derived from the winter load-following with respect to modifying the newly formed bar morphologies.

Q: Will the load-following erode the recently deposited sediment from the BHBF? What sediment-related hypotheses does the load-following test?

A: Any operation following the BHBF will result in reworking of the newly deposited sand bars. This bar reworking can be viewed as "erosion," but there is no way to avoid it. The basic question remains as to what operation will export the least volume of sand downstream for any range of antecedent sand-storage conditions? A secondary consideration concerns how the operations that follow the BHBF will affect the morphology of the new bars with respect to ecosystem value. A few hypotheses might be considered:

Ho: Winter load-following does not result in a increased export of stored sediment.

Ho: Winter load-following does not modify new eddy bars in a manner that makes them more stable of greater resource value.

Ho: Winter load-following does not achieve eddy bar morphologies that allow for greater access to recreational users.

Q: There are non-ROD elements in Figure 1, load-following, low Fall releases, could include BHBF outside ROD period and HMF outside the ROD. Recommends two Figures: an ideal hydrograph and one that balances legal/policy trade-offs.

A: Given the provision in the ROD that calls for experiments if the resources are not responding as expected to the ROD flows, no elements of the proposed flows are thought to be outside the ROD. GCMRC and the TWG should review this more thoroughly.

Q: Why is a fall BHBF outside Law of the River?

A: The current interpretation of the Law of the River would prevent a BHBF from occurring for other than dam safety purposes. The triggering criteria developed to address that provide a window between January to July for conducting BHBFs.

Q: Why isn't this a program of flows?

A: Given that the motion asks for a proposal to be brought back to the AMWG in April for WY 2002-2003, this is intended to be an element of a program of flows. It is clear from the conference call that there are a number of alternative ideas for experimental flows. This is the flow GCMRC recommends the AMP try first, with the understanding that this single year's flow would fit into an overall program of flows.

Q: Integrated Ecosystem Experiment: I recommend that the experiment should be less ambitious and should simply test the sediment paradigm. The experiment should be within Law of the River and the ROD. We do have to get through July and August with meeting power supplies.

A: The AMP is intended to use an ecosystem-science approach in testing the effects of dam operations. It also recognizes that the Endangered Species Act mandates that the Department of the Interior take action to protect these species. At the January AMWG meeting, GCMRC presented data that indicated sediment resources and HBC are not responding to the ROD as anticipated in the EIS. It would be irresponsible for GCMRC to make a recommendation to the AMWG for an experimental flow that does not take an ecosystem science approach and that does not address the resources of concern. It is our belief that the flows proposed in the February 8 (Version 1.1) draft are within that portion of the ROD that allows for experimentation, if ROD flows are not achieving the intended benefits. GCMRC also believes that after the AOP process considers the experimental flow request and determines WY 2003 monthly volumes, the proposed flows are in compliance with the current interpretation of the Law of the River as all of the flow elements that are proposed for testing could be implemented, following appropriate compliance, within the current interpretation of the Law of the River.

Q: If you go to the low load-following proposed, can you test the up- and down-ramp rates and their effects?

A: Addressing the sediment-transport dynamic issues related to ramping rates is a difficult challenge that requires very high-resolution data sets, or a very sophisticated numerical predictive capability. GCMRC has been examining an optically-based technique (LISST) for measuring suspended sediment. Results to date look promising. We will know by summer if we can use this approach to examine changes on up- and down-ramp rates. In the event that LISST technologies prove adequate for monitoring suspended-sediment transport in the Colorado River ecosystem, then these methods will be used for evaluating issues of ramping rates and relationships to sand resources, etc. Researchers at University of Arizona have studied issues of ramping rates and their impacts on the dynamics of sand bars previously. These EIS results can be reviewed again, and additional numerical simulations can be run and evaluated, pending approval by managers and on the basis of funding availability.

Q: What's next? When will the public be informed?

A: This is the conceptual phase. The questions and concerns we heard today will be used to refine what we bring to the TWG in February. The TWG will provide an opportunity for public input. Following the TWG, a recommendation will be forwarded to the AMWG. We assume that detailed design work with scientists and detailed public impact will occur following that and final approval will be obtained in July? GCMRC and the AGFD held a preliminary meeting with the Fishing Guides at Lees Ferry on February 12 to provide the same conceptual material that was presented on February 8 and invite their input.

Q: In your next draft, please address impact this might have on the old high water zone (OHWZ) vegetation?

A: Okay.

Q: How much money do we have for this?

A: The experimental flow fund will contain about $1 million by January 2003. Any remaining funding needs will be sought as an appropriation request or through reprioritizing AMP activities.

Draft Scenarios and Rationale for Experimental Flow Design in WY 2002-2003.

For Consideration by the TWG, February 26-27.

Intended to address the Motion passed at the AMWG Meeting on January 18, 2002 instructing GCMRC, in consultation with the TWG to design experimental flows for WY 2002 – 2003. The full motion states:

Motion: ***In concert with RPA flows for native fish during 2002-2003 request that the GCMRC, in consultation with the TWG, design an experimental flow sequence that tests hypotheses for conservation of sediment. Report to AMWG in April 2002 on the proposed flow sequence.***

Introduction. This document was prepared by GCMRC staff and is intended to serve as the basis for discussion between GCMRC and the TWG in anticipation of agreeing on an experimental flow recommendation for WY 2002 – 2003 that is to be made at the April 2002 AMWG meeting. The WY 2002 – 2003 experimental flow recommendation is intended to have two primary purposes:

1) improve retention of sediment in the CRE, and
2) benefit native fish populations (primarily HBC).

In addition these recommendations consider impacts to other resource areas. The recommendations are consistent with goals of the AMP, especially goals 2 & 8.

[NOTE: A broader set of recommendations for experimental flows that should be tried over the next five to ten-years whether the hydrology is wet or dry is also being developed. The experimental flows being recommended here are consistent with that larger program of flows.]

Specific objectives of the WY 2002 – 2003 experimental flows recommendation include:

A) for sediment
- decrease downstream export of tributary input sediment from Marble Canyon
- increase retention of sediment stored in channel through BHBF or HMF's

B) for native fish
- improve survival and recruitment of HBC by reducing competition and predation from non-native fish (primarily rainbow trout)[1]
- improve and maintain habitat for young native fish

WY 2002 – 2003 Hydrology Assumption: These experimental flow recommendations assume that WY 2002 and perhaps WY 2003 will be relatively low runoff years with low antecedent reservoir storage in Lake Powell. Thus **these recommendations are based on an 8.23 maf water year scenario.** As noted above, GCMRC is also developing, with the experimental flows ad hoc group, a longer term set of flow recommendations in view of the need for repeated and long term experimentation as part of adaptive management and in recognition that basin hydrology over the long term will be variable.

Working Hypotheses:

- **Sediment-** Monitoring data indicate that tributary inputs of sand do not accumulate within the river channel over multi-year periods as predicted by the final EIS, and that such inputs are transported out of the CRE at a relatively fast rate under most ROD operations. On the basis of results from the summer 2000 flow experiment, as well as historical sediment-transport data, new inputs of sand should be retained more effectively within main channel storage sites during extended periods of dam releases at or below about 10,000 cfs. If such operations promote retention of sand (and finer sediment as well), then implementation of a Beach/Habitat-Building Flow following such periods should greatly increase the effectiveness of such controlled floods in restoring and maintaining terrestrial sand bars and related resources. More efficient retention of fine sediment and silt prior to controlled floods shall result in more rapid rates of sand bar deposition, as well as sand bars with finer grain-size distributions. Finer-textured sand bars may be less prone to rapid erosion following bar building. Enhanced conservation of tributary sediment inputs in the channel should result in elevated suspended-sediment concentrations during BHBF's, leading to rapid depositional rates during sand-bar building. Elevated rates of sand-bar deposition should reduce the required duration for BHBF's, and hence will limit spill volumes.

- **Native Fish**-The LCR population of HBC has not demonstrated a positive response to the mainstem flow regimes under ROD operations. Sediment loss has continued in the CRE under ROD operations as described above. Within the ROD, there is a need to implement experimental flows, which may conserve sediment and improve survival and recruitment of HBC. The LCR population of HBC is comprised of fish resident in the LCR and in the mainstem near the LCR confluence. Therefore flows, which affect changes in

[1] It is anticipated that reducing the population numbers of RBT will increase the average size of fish in the Glen Canyon reach and may lead to improvement in the overall quality of the Lees Ferry trout fishery.

HBC status in the mainstem, may positively influence the overall LCR/HBC population.

Initial flow experiments to modify habitat have not shown a strong response in increased HBC abundance. This could be due to a number of factors including both the power of the experiment, the ability of monitoring programs to detect a change, and the short time since the most recent experiment (LSSF) has been conducted. Another possibility is that non-native and native fish interactions (i.e., predation and competition) are over-riding any potential positive effects from flows that improve habitat conditions. The experimental flows described here are intended to test this possibility and produce a measurable affect on non-native fish and hence on non-native and native fish interactions. The hope is that this will result in a positive effect on HBC and lead to the designing of experimental flows or other management actions that also can improve habitat for native fish, including HBC that will address Goal 2 of the AMP strategic plan.

Scenarios: –We assume the antecedent and contemporary conditions for experiments conducted in WY 2002-2003 will be so called 8.23maf or at best average inflow years, thus allowing GCD operations to achieve constant Low-Flows in fall 2002 or load following flows below 10,000 cfs, and perhaps in subsequent seasons. GCMRC is recommending three versions of experimental flows for late in WY 2002 and during WY 2003. Each is described briefly below and a figure depicting a hydrograph for the particular flow is provided. While these hydrographs show specific daily flow levels, they are intended to be **conceptual hydrographs** whose precise nature (specific floors and ceilings, up-ramp and down-ram rates, and durations) will need to be determined.

A) **Figure 1.** This scenario provides for a set of experimental flows aimed at conserving sediment only. From October 2001 through June 2002 the dam follows normal ROD operations. **Following Sediment Inputs** in the July - October 2002 period the dam is operated at a constant 8,000 cfs following sediment inputs (or perhaps a low level, e.g. 5-9,000 cfs ROD flow) until January 2003. In January 2003 a BHBF of limited duration is conducted. Later winter, spring and summer 2003 operations would follow monthly volumes under the ROD. This hydrograph could be repeated in WY2003-04.

The BHBF to be released in January 2003 should have a magnitude of at least 10,000 cfs above peak powerplant discharge, or higher depending on lake elevation. **A year with significant sediment inputs would be defined as an instantaneous discharge of 2,000 cfs or greater from the Paria River or an instantaneous discharge of 10,000 cfs or greater from the LCR during the period August 1-October 31.**

B) **Figure 2.** This scenario provides for experimental flows aimed at **both** conserving sediment and benefiting native fishes. From October 2001 through June 2002 the dam follows normal ROD operations. **Following Sediment**

Inputs in the July - October 2002 period the dam is operated at a constant 8,000 cfs following sediment inputs (or perhaps a low level, e.g. 5-9,000 cfs ROD flow) until January 2003. In January 2003 a BHBF of limited duration is conducted. This is followed by experimental (non MLFF) Load-Following flows for the duration of the non-native spawning and emergent/juvenile season (perhaps several months). Spring and summer 2003 operations would follow monthly volumes under the ROD. This hydrograph could be repeated in WY2003-04.

The BHBF to be released in January 2003 should have a magnitude of at least 10,000 cfs above peak powerplant discharge, or higher depending on lake elevation. **A year with significant sediment inputs would be defined as an instantaneous discharge of 2,000 cfs or greater from the Paria River or an instantaneous discharge of 10,000 cfs or greater from the LCR during the period August 1-October 31.**

C). **Figure 3.** This scenario represents a year when there are no significant monsoonal sediment inputs but there are **sediment inflows in winter.** It also includes flows intended to benefit native fishes. If there are No Sediment Inputs in the July through October period the dam would be operated under normal ROD operations until December 2002. Beginning in January 2003 experimental (non MLFF) Load-Following for duration of non-native spawning and emergent/juvenile season (perhaps several months) would be implemented. Spring and summer operations would follow monthly volumes under the ROD. Under this condition, a BHBF would occur if significant sand inputs occurred during the winter/spring runoff period (e.g. LCR in Jan.-Feb. 1993). If sand inputs occur in winter/spring, then a BHBF would be released as soon as possible and in the same month that the sediment input(s) occur. The BHBF would have a magnitude of at least 10,000 cfs above peak powerplant discharge, or higher depending on lake elevation.

Hydrograph segment rationale

- The reduced-flow period (10,000 cfs or less) in August-December - is intended to provide some benefit to native juvenile fish, and conserve sediment in the main channel when significant tributary sediment supplies are introduced to the ecosystem. The potential advantage to native fish habitat would likely be marginal, and not accrue until year two under these recommendations. **H1**: Reduced-flows following sediment inputs reduce downstream transport while turbidity levels are elevated, such conditions provide some additional predator avoidance benefit to YOY native fishes. **H2**: Reduced flows in the August-October period do not decrease juvenile HBC mortality in the main channel of the Colorado River. **H3**: Reduced flows following sediment input does not conserve fine-sediment in the main channel.

- January BHBF, following Sediment Inputs and Reduced Flows - is intended to mobilize channel-stored fine sediment from the river bed and re-deposit them as sand bars along shorelines under optimal conditions of high suspended-sediment concentrations and grain sizes approximating natural bar textures. **H4**: The January BHBF does not result in sand-bar deposition that is equal to the response measured in April 1996 (sand bar area and volume above the 25,000 cfs stage). **H5**: The January BHBF results in a more rapid depletion of the ecosystem's fine-sediment supply then was measured during the 1996 BHBF (2-3 days). **H6**: The grain-size distribution of sand bars deposited during the January BHBF is not as fine as grain-size distributions measured from sand bars deposited during the 1996 BHBF.

- Experimental (Winter) Load-Following – this element of the hydrograph is mainly intended to disadvantage non-native fish recruitment in the main channel, thereby achieving the most effective long-term control on predation/competition through reduced population size. This reduction in population size in non-native fish would result from a combination of spawning disruption and creating unfavorable conditions for survival of young non-native fish. Winter Load-Following, similar to operations that occurred under "No-Action" era would provide the greatest disadvantage to non-native fish, and might be most effective at reducing the non-native fish populations by causing lower recruitment over several years of implementation. This may actually improve the quality of the Lees Ferry trout fishery. Over the course of multiple years, reduction of RBT and BNT abundance is intended to result in increased HBC recruitment. **H7**: Winter load following does not reduce recruitment of RBT and BNT in Grand Canyon. **H8**: Winter load following does not increase export of ecosystem sand. **H9**: Winter load following does not produce eddy-bar morphologies that are more conducive to recreational and other ecosystem uses. **H10**: Winter load following will not adversely impact food base resources. Only the lower limit of the diurnal range would be constrained for purpose of limiting detrimental impact to phyto-benthos resources. **H11**: HBC recruitment is not limited by RBT or BNT predation.

Figure 1. Proposed Water Year 2002-03 Experimental Flow *with* Sediment Input

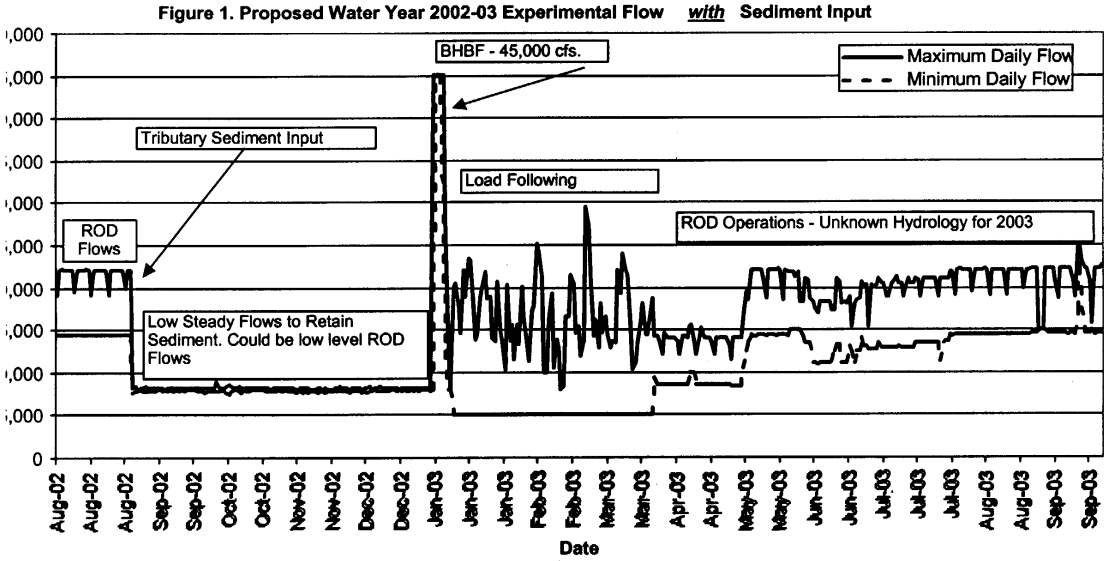

Figure 2. Proposed Water Year 2002-03 Experimental Flow *with* Sediment Input

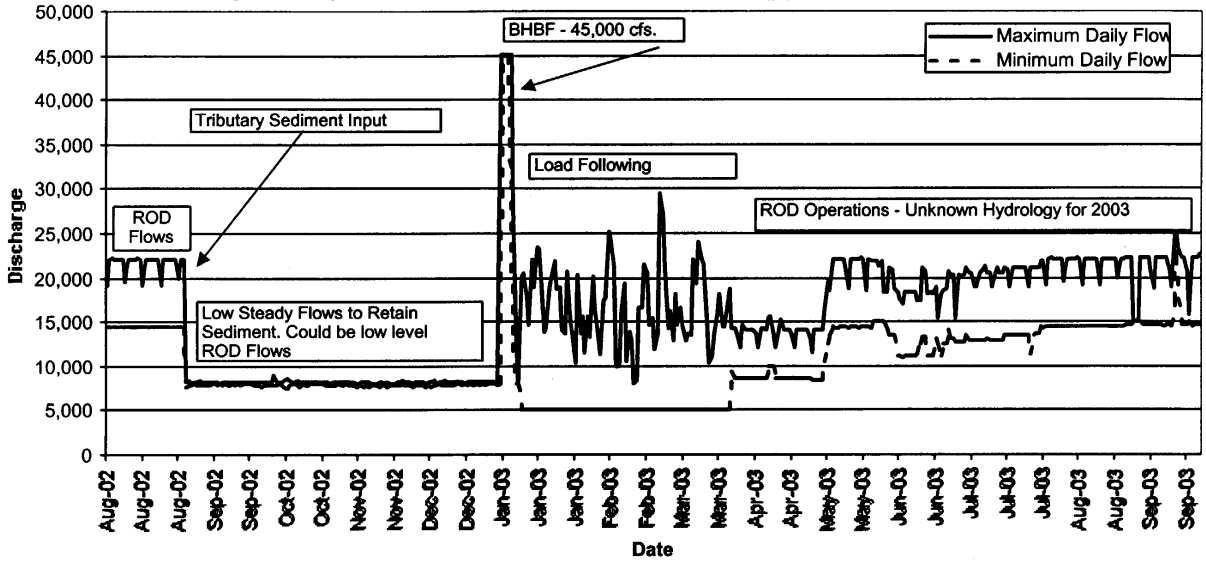

Figure 3. Proposed Water Year 2002-03 Experimental Flow *with* Winter/Spring Sediment Input

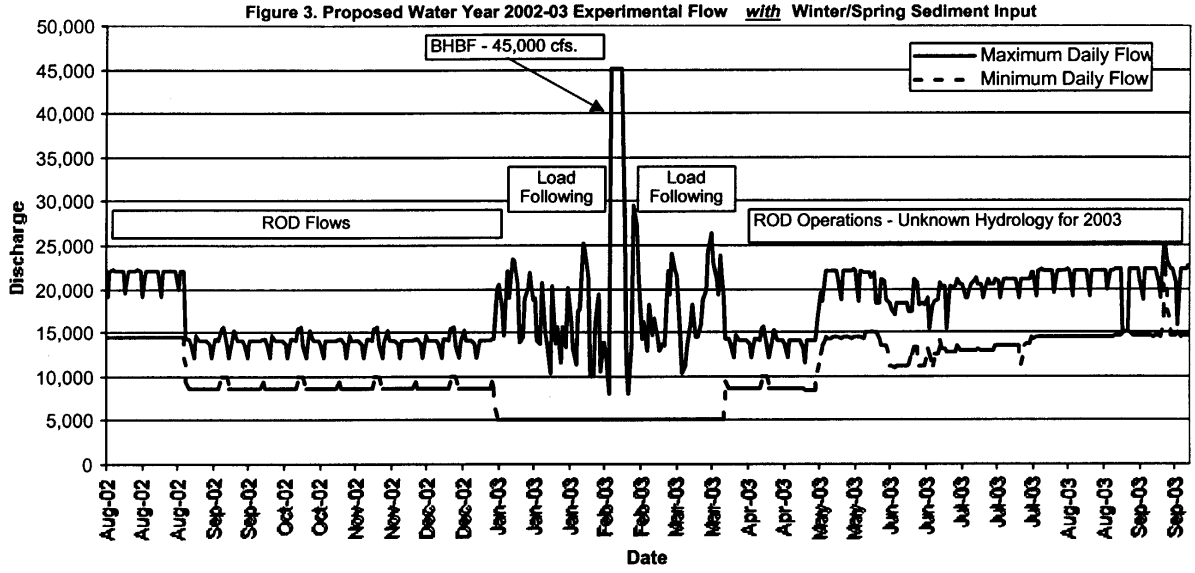

Table 1. Plausible causes of HBC decline and likelihood that the proposed experimental flow load-following scenarios would have no impact (0), possible impact (+), or probable impact (++).

Flow Scenarios Habitat limitations (1-6) Biological interactions (7-11)	Dry year, low storage, Sediment Inputs	Dry year, low storage, NO sediment	Wet year, high storage Sediment Inputs	Wet year, high storage NO Sediment
1. Water too cold for spawning	0	0	0	0
2. Water too cold for juvenile (70-150mm) growth	0	0	0	0
3. Foodbase limitation	?	?	?	?
4. Near shore stable habitat loss	+	?	?	?
5. LCR confluence habitat loss	?	?	?	?
6. Reduction in turbidity increasing predation/competition	+	0	?	0
7. Predation from RBT &BNT in mainstem (HBC<150mm)	++	++	++	++
8. Parasites & disease	0	0	0	0
9. Competition for habitat or food	+	+	+	+
10. Predation by Non-natives in LCR	0	0	0	0
11. Intraspecific predation	0	0	0	0