REVIEW OF THE "SCIENCE PLAN FOR POTENTIAL 2008 EXPERIMENTAL HIGH FLOW AT GLEN CANYON DAM"

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BY GCD AMP SCIENCE ADVISORS

EXECUTIVE SUMMARY

The authors provide a convincing argument that high flow events in the CRE can mitigate some ongoing adverse effects of Glen Canyon Dam on sediment, and also benefit HBC, the aquatic food base, cultural resources, etc. The Plan also clarified goals and findings of previous high flow tests (1996/2004), explain how each differed, and identified inherent weaknesses and strengths. The summary review explains why additional tests are needed, and also what might be learned from this proposed high flow experiment. We find the overall plan acceptable for implementation, and provide the following input for improvements.

More explicit description of what is to be accomplished in this test would benefit from additional information. Some questions and comments from the SAs are:

- To complete the test of contrast to the 2004 test, having more sand distributed throughout the system is important. More sand is in the system, but is it distributed throughout the system?
- Impacts to the HBC may be avoided by a lack of movement of yoy out of the LCR. However, could winter storm events jeopardize this setting?
- Benefits to HBC are to be assessed from backwaters. However, it is unclear how benefits will be realized from this test in reviewing Table 1.A and the text. It seems realistic from current science that backwaters might offer beneficial habitat that might be used by chubs, but more information is needed to structure and test effective hypotheses in this high flow event.
- Documented impacts of high flow events on potential food base for RBT or HBC do not seem to be known well enough to develop good hypotheses for testing. As noted additional information will benefit hypotheses development.
- Sufficient knowledge seems to exist to test flow and sediment impacts on cultural resources. Yet, this is an area which appears to have separate rather than collaborate efforts to satisfy resource protection and learning in the AMP.

The science approach outlined does not mention BOR's efforts on protection, and the science approaches presented here are not referenced in the BOR effort.

The authors have listed the concerns of AMP members in Table 1.A and made these more specific in the strategic science questions (SSQ) in Table 1. However, when one tries to put all of these together it is not clearly apparent exactly what scientists currently know regarding potential expected impacts. It is not clear whether the scientific effort on a specific resource should be a test of a fully specified hypothesis, or should it be continued research or discovery to gain more knowledge to enable hypothesis testing in the future.

It would be helpful to clarify for each resource of concern, i.e. food base, HBC, cultural resources, vegetation, etc., those hypothesis tests the scientists feel they can fully articulate for the 2008 experiment, and what additional knowledge is required to allow pertinent hypothesis to be tested in the next high flow experiment.

Mention is made of socio-economic tradeoff assessments in the test, i.e. treatment of costs and benefits. However, no specific science activity is endorsed for this high flow event. The SAs have noted in prior reviews that significant benefits could be obtained for the AMP, most specifically the AMWG and TWG, if operable but simplistic Cost Benefit Analysis (CBA) models were developed for use in science and management program planning. As noted in SA comments, however, development of CBA capabilities for AMP managers might best be structured to respond to overall ongoing decision needs of the organization. In this regard, they should be designed and incorporated into an annual work plan where focus could be attached to the broader need. GCMRC has noted this effort is outside the scope of this project.

It is true that due to the complexity in determining overall and individual resource effects from high flow events, a longer term multi-event assessment is necessary. This does, of course, not obviate some interpretations from each event evaluated, such as the proposed 2008 event. GCMRC has noted, for example, some of the benefits or findings that might occur from the proposed 2008 event.

It is postulated that the GCD AMP will continue to complete its effort on the LTEP, part of which includes specification of the number and potential frequency of high

flow events. Although the SAs also agree that the AMP will accomplish this task, we feel it is likely this activity could be delayed for several years. Should similar conditions to 2008 develop in the next 3 year period; will another high flow event be proposed by the AMP and GCMRC? If so, design of some of its primary elements should be part of the outcome of the 2008 high flow assessments.

The AMP must balance its program of learning with its long-term pursuit to resolve 12 differing and often conflicting, resource goals that range from sand conservation to HBC enhancement to stable electric power generation. In the overall program direction, high flow events can contribute opportunity to resolve these multi-resource issues.

The LTEP selected in the 1996 ROD is the Moderate Low Fluctuating Flow (MLFF). It is apparent from AMP collaborative workshop efforts that both managers and scientists see potential marginal changes to the MLFF as offering capability over the next 5 years to enhance overall knowledge about sediment conservation. This issue is raised in the plan but not discussed.

It seems important to discuss how LTEP options might be best aligned to maintain the derived benefit of the high flow experiment. GCMRC should at least introduce this issue as a prologue to this plan. In this regard, science seems to point to some semblance of increased flow stability after implementation of a high flow event to gain greater assurance of conserving the sand that has been moved up and out of the channel to sand bars.

Extended low stable flows would create opportunity for conservation of sand but would also reduce the opportunity to maintain power supplies, one of the important goals of the AMP. A more marginal change under current 8.23 constraints would be to pursue a variant discussed in the Science Planning Group (SPG) that would establish equal monthly volumes and daily flows of lower variability, i.e. 7-13,000 CFS. These operations would be a slight modification of the MLLF that might reduce conflicts between power and environmental resources, and since they are within the ROD so they could be easily implemented. At the minimum, a discussion of the potential tradeoffs to this approach would seem a logical step to evaluate sand conservation after the high flow event.

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INTRODUCTION

The Science Advisors (SAs) reviewed the first draft of the current science plan in February 2007, and reported on that review to the GCMRC[1], TWG and AMWG. General and specific comments were contained in the review. The following general comments was provided by the Science Advisors:

- Presentation of background information from 1996 and 2004 high flow events were important.
- Detailed study information was important. More information on methods was requested. The riparian vegetation surveys are insufficiently supported by current literature.
- The Plan was generally well designed with good study linkage. Primary plan elements are covered.

[1] GCD AMP Science Advisors. 2007. A review of the Science Plan for Potential 2007 Beach Habitat Building Flow Experiment. Final review report on file at GCMRC, USGS, 2/12/07. 13 pages, Appendix.

- Greater documentation of HBC planned and ongoing science activity was needed. Some tracking was recommended on habitat change (backwater) and HBC.
- Additional documentation was needed of ongoing planned cultural resource programming.
- Vegetation study should be revised.
- Expand proposed Lake Powell assessment.

GCMRC committed to revise the draft plan based on recommendations from the SAs and other AMP members.

It was originally anticipated that a high flow experiment would be attempted in 2007, but due to several concerns it was delayed. Since then lower fluctuating flows during the remainder of 2007, and significant additional sand inputs from the Paria and Little Colorado River established even greater sand enrichment in the system for the winter and spring of 2008.

REVIEW OF REVISED PLAN

In late December 2007, GCMRC requested a review of the 2008 High Flow Experimental Science Plan. The plan had received significant changes since the SA review in February, 2007. New studies had been added, the text had approximately doubled to over 100 pages, and the total cost had increased over one million dollars.

Review Charge to SAs

A review charge and schedule was developed for the revised plan. The SAs and SA Executive Director selected a rapid review procedure that is to be finalized (final review report) with an executive summary forwarded to the GCMRC Chief by January 14 (Appendix A). The reason for the rapid review is that the Science Plan is scheduled as a topic of an AMWG conference call by the Secretary Designee January 17, 2008.

Structure of Review

This review is structured into two primary sections as follows:

- SA general comments on the high flow science plan
- SA specific comments on the high flow science plan

The SAs specific comments are indexed to page and paragraph of the text. Comments are also addressed to Appendix A and Appendix B.

SA GENERAL COMMENTS ON THE HIGH FLOW SCIENCE PLAN

This science plan responds in a very structured manner to implementation of a 2008 high flow event. It builds on both scientific knowledge and adaptive management approaches of the last decade, specifically information developed over the last three years. Significant advances in scientific findings and documentation have occurred from 2005-2008, including the following:

- Status of Knowledge
- Knowledge Assessment
- Science Planning Group and GCMRC assessments and proposals
- April 10-11, 2006 Scientist Workshop and Assessments
- HBC Age Structure Mark Recapture (ASMR) population assessments

Following are general comments of the SAs on overall plan elements and proposed studies included in the plan.

- The Science Advisors feel the overall plan is acceptable for implementation. The SAs have reviewed the plan with the objective to identify areas for potential improvement.
- The plan overview of findings of the 1996 and 2004 high flow experiments are critical, as well as science information that has been developed to extend the knowledge gained from the high flow events. The high flow experiment has transitioned from focus of high flow impacts on sediment to the more complete array of Colorado River Ecosystem resources.
- The two merged AMP thrusts of resource enhancement and learning have been important to the interactive collaboration of scientists and managers on the 2008 high flow event. This focus permits one to put the high flow into proper perspective as relates to overall AMP goals.
- The **Executive Summary** is very good, especially they way it describes what makes this experiment different than 1996 and 2004. You may want to change the 1996 write up to bullets, and add something about effects on Lake Powell from proposed studies.
- One of the justifications given for a March experiment on p 8 (#2) is that life

history strategies of fish and other aquatic organisms have evolved with spring high flows from mountain snowmelt. That may be true, but we doubt the hydrograph historically peaked as early as March each year. The rising limb of the spring hydrograph may begin in the Grand Canyon in March, but would not have peaked until several months later. We question this particular justification for selection of the March date.

- **Studies 1 A-D:** The plan contains limited information about actual details of the methods to be used. This may reflect length constraints for the plan as a whole. We don't feel too uncomfortable with the overview, because GCMRC has consistently done a very good job in the past, but it would be nice to see more details on some of the new efforts in 1C in particular, such as exactly how they plan to measure aeolian transport, how long monitoring will continue after the BHBF, and details of the spatial sampling (number of gullies, resolution of surveys).

We are concerned by the lack of detail regarding the geomorphic aspects of 1D, the study of backwaters. It is very good to explicitly focus on backwaters. The summary comments (p. 43) indicate some integration among 1A-1D and geographically throughout the study area, but the integration of 1D with the other components of Study 1 does not appear to be well developed. Backwaters are fundamentally a reflection of channel-margin processes and thus must eventually be integrated into a quantitative sediment budget model and eddy-dynamics model. The lack of identification of investigators, and the emphasis on changes in form without any apparent link to process, makes it unclear how useful the measurements described in 1D will be related to 1B. 1D is a "pilot study", but it should be integrated as effectively as possible into the other geomorphic studies -- and use the BHBF as effectively as possible -- by providing evidence that the pre- and post-flood topographic surveys are the most useful information that can be gleaned from backwaters during the BHBF (or at least balance time/cost vs utility) for incorporation into linked hydraulic-sediment models of channel-margin areas (1B) and sediment budget models (1A).

Because of the enormous size and logistical challenges of the Colorado River ecosystem study area, the investigators take either a "black box" statistical approach where they track changes in geomorphic components (beaches, backwaters) throughout the canyon in relation to the BHBF, or take a more site-specific, mechanistic approach in

which they identify and measure processes responsible for geomorphic changes at a more limited subset of sites. Reading through the limited details provided on Study 1 (mainly parts 1C and 1D), it is not clear what balance GCMRC scientists are striking between these two endpoints. One of the goals of 1D is to determine where backwater habitats will develop, but isn't that really part of the goals of 1-B and 1-C. The "High-flow Science Questions" are proper things to examine, but most of the effects appear to be sediment moving questions. This leads to a bigger question: How do the high flow experiments fit into the bigger picture, i.e. LTEP? For example, how do you best conserve sand under normal flows?

- **Study 1.C:** This study proposes to examine how high flows from the GCD and "normal" annual releases will: 1) Contribute to -- or subtract from -- the amount of sediments on sandbars, especially "campable" ones; and 2) Determine whether or not aeolian sands will be moved by Canyon winds up and over archaeological sites to protect them from the tourists and possibly fill in the erosion gullies currently decimating many of the sites, both of these will contribute to the well-being of the Grand Canyon. The Abstract for the study admits, however, that the high flow experiments of 1996 and 2004 did little to "increase campable areas at sandbars on a more sustainable basis" (p. 26). The immediate question is, why might the next one produce a more positive outcome? The Abstract goes on to ask, "Do sandbars deposited by high-flow experiments contribute to the preservation of archaeological sites in the river corridor?" The answer, at least as observed by those on the June 2007 SA river trip, is that sandbars, however derived, do not appear to contribute to the preservation of sites. The sites that were reviewed are melting away through water erosion, wind erosion, and trampling. The big sites we saw at the Palisades area would require many cubic meters of aeolian sand to fill existing gullies that run directly through the sites and then remain there. A relevant question is, assuming the sand did somehow get properly distributed, how would such loose deposits resist fast running water coming down through the existing gullies from cliffs and terraces above? The check dams previously built across the gullies at the Palisades sites were obviously of no avail. This is not sufficiently addressed in the study methods.

The general study of sediment transport and deposition on the Canyon sandbars, campable or not, is a legitimate scientific issue, one that is critical to the health of the Canyon. From what we can see, GCMRC has assembled an excellent team to do the general sediment parts of the study. Getting more sediment into the system to form more beaches seems to work.

The part of the study relating to the cultural sites does not appear to be a legitimate scientific matter, at least as stated in Section 1.C. It is, rather, an ethical archaeological issue (Fowler[2], Jolie and Salter 2008; Green 2008). Archaeological sites are containers of cultural and scientific data. When archaeological sites are threatened by natural actions, vandalism, or federally sanctioned activities, archaeologists are bound ethically, scientifically, and legally to insure that the data they contain are collected, preserved and made part of the public record.

Given all the data on the Grand Canyon sites contained in all the "stakeholder" archaeological studies, it is clear that most, if not all, of the archaeological sites on the lower terraces in close proximity to the river are endangered to greater or lesser degrees. Those melting away through erosion and trampling should be excavated as soon as possible. Is the proper course of action to wait several years to see if sediment, which may or may not be generated as a result of a number of high flow experiments, will blow over the sites and fill the ever deepening gullies running through them, thereby "conserving" them. The proposed "scientific approach" might in some locations be effective. However, in many locations it may only result in a loss of information valuable to the scientific community and cultural information valuable to the Indian tribes concerned with the Grand Canyon. The great concern with this approach is that it has significant risk that the solution may come to late, if it comes. The unspoken coda is we will lose some more of the cultural sites and the information they contain. That doesn't sound like either good archaeological science or good archaeological ethics. It would be

[2] Fowler, D.D., E.A. Jolie and M.W. Salter. 2008 Archaeological Ethics in Context and Practice, In *Handbook of Archaeological Theories,* edited by R.A. Bentley, H. Maschner and C. Chippindale, pp.409-422. AltaMira Press, Lanham, Md.

Green, T. J. 2008 Cultural Resource Management. In *Handbook of Archaeological Theories,* edited by R.A. Bentley, H. Maschner and C. Chippindale, pp.375-394. AltaMira Press, Lanham, Md.

most useful if many more specifics as to possible outcomes of the "experiment" in relation to the cultural sites could be provided. How specifically does, or might, aeolian sands get blown onto sites and what keeps them there? How, specifically, does, or might, aeolian sands get blown into erosion gullies across sites and what keeps them there? The questions are not meant to be facetious, but rather to say, "provide us with more information." As presently stated, the "experiment" does not read like a well designed inquiry into a difficult, possibly intractable, problem.

It is of interest that the Bureau of Reclamation has issued a request for proposals to excavate several sites that will be threatened by the proposed high flow experiment. This is an appropriate response given the relevant federal laws and guidelines relating to the mitigation of threatened cultural resources. It is of further interest, that none of the relevant archeological studies generated by other "stakeholder" agencies are cited or mentioned in the current BOR document, nor are any relevant archaeological studies from GCMRC. It would be very useful to know why this dichotomy exists in the GCD AMP.

- **Study 1.D:** This study has 2 goals, one of which is to determine use of backwaters by native and nonnative fishes. This relates to scientific questions posed by GCMRC (Table 1), specifically, the question of how important is backwaters and vegetated shoreline habitats to growth and survival of young native fish. Some confusion does exist as to what assessments in this study are really being accomplished with the high-flow, as versus the proposed longer term efforts.

In paragraph 3 of this plan it states that highest densities of humpback chub occur in vegetated shorelines and only 5% or less are captured in backwaters. This indicates that some shorelines (perhaps eddies or shallow runs) are important for the fish. However, "The relative value of backwaters for native fishes as compared to other habitats is not evaluated with this study." BHBF effects on vegetated shorelines in particular would appear to be of interest if that is where most of the humpback chub are in the mainstream Colorado River. The plan later notes that measurement difficulties make the assessment intractable.

Shorelines would be greatly affected by a BHBF and perhaps affect the fish in several ways. Humpback chub are insectivores, and some benefits would result from

flooding habitats and making terrestrial insects more available for food. Conversely, disruption in the aquatic habitats occurs with inundation and scouring of vegetated areas. Thus, the effects of BHBF on shoreline fish habitat, and the use of vegetated shorelines by native fishes (especially humpback chub) should be included in this study if feasible. GCMRC might consider some sampling of shorelines located in the vicinity of backwaters for fish abundance, water temperature, food base, etc.?

Methods (p.38) state that an effort will be made: "to assess as many backwaters as possible." This suggests that there may be more backwaters than there is time to sample all of them. In this case, it is important to consider just what constitutes a backwater that will be studied? Discussions on the river trip suggested that only very large and more permanent "backwaters" will be sampled– smaller alongshore embayments would not. If this is true, then sampling bias could be a problem. This is a concern because very large and more permanent backwaters in the upper basin tend to harbor some of the more aggressive nonnative fishes (e.g., centrarchids). If there may be more backwaters than can be sampled, then selection criteria are needed to guide sampling. In this case, a range of backwaters should be selected that would include more ephemeral as well as more permanent types. Finally, the study should address what attributes constitute the "best" target "backwaters"— is it area, depth, substrate, current, morphology, etc.

On page 39, it says that water temperatures will be taken in all backwaters sampled and in the mainstream. This should be extended to include temperatures of shallow shoreline eddies or runs. It would be instructional to find out how backwater and shoreline temperatures vary. On page 41, it states that one of the products would be to compare backwaters with "nearshore areas". This needs to be discussed more fully. How would such comparisons be made and how would nearshore areas be selected for food-base studies? How will these areas be characterized and would the impact of BHBF on vegetated shorelines be evaluated? Again this seems more appropriate for longer term assessments as well.

It seems that everyone has a different idea about what is a backwater. In a publication by Armantrout, N.B. (1998). Glossary of aquatic habitat inventory terminology American Fisheries Society, Bethesda, MD; six different definitions for the

term “backwater”were provided. Thus, the term needs to be defined more clearly up front and throughout the plan (e.g., p. vi).

Table 1, p. viii, We would like to see 1.D. (b) be changed to: “ how many fish use them” and a part (c) added to indicate: “why fish use them”.

Overall, **Study 1.D** is a good design, but why the emphasis solely on autochthonous production, particularly in backwaters. Many of the backwaters we have observed on river trips are surrounded by lush growth of riparian plants. Since chub are opportunistic feeders, and since we have still not yet seen a definitive report on how important autochthonous versus allochthonous production of organic matter is to the overall energy budget of the river, it seems this study should include estimates of riparian material inputs to backwaters and their potential importance for fish. Allochthonous inputs to backwaters may be important, and estimates could be done with ^{13}C isotopic analysis of sediment, or possibly even litter or sediment traps.

Table 4 (p. 40), does not include a schedule for ecological measurements of chlorophyll, NPP, phytoplankton, or zooplankton.

Study 2: The revisions in Study 2, riparian vegetation study, has improved the overall approach. It is a good study to conduct as part of an assessment of resource effects. Questions of the rate of recovery of flooded river banks and bars, or establishment on newly bare deposition surfaces relate back to questions of substrate stability, recreational uses, and potential allochthonous inputs of organic matter to the river and backwaters. We are not sure the theoretical discussion of invasibility of various sites based on species richness is very helpful, and there are a host of recent studies specifically on species composition of riparian ecosystems, including many in the Colorado River Ecosystem, that go uncited. Look at these papers and the references therein:

Adair, E.C., D. Binkley, D.C. Anderson 2004. Patterns of nitrogen accumulation and cycling in riparian floodplain ecosystems along the Green and Yampa rivers. Oecologia (2004) 139: 108–116. DOI 10.1007/s00442-004-1486-6

and

Uowolo, A.L., D. Binkley, and E. C. Adair 2005. Plant diversity in riparian forests in northwest Colorado: Effects of time and river regulation. Forest Ecology and Management 218:107-114 and references therein.

The working hypothesis for this effort is good, and can be answered with surveys of species composition. I do not think the alternative hypotheses, which are more complex and less robust, can be addressed well enough in the absence of better familiarity of current literature and with the proposed study design. The riparian study is a good example of why there is need for a broad ecosystem approach to understanding river physical and ecological dynamics.

The study design has not been cross-fertilized by other investigative efforts going on now or in the past. One unpublished report by Kearsley is cited for methods, location, and sample design. Where is the justification from the literature for attempting to link species establishment to grain size, soil C and soil N? And how does that relate specifically to the paragraph on species richness? A reference from prior studies of buried organic matter that might be helpful is: Parnell, R.A., Jr., Bennett, J., and Stevens, L., 1999, Mineralization of riparian vegetation buried by the 1996 controlled flood, *in* Webb, R.H., Schmidt, J.C., Marzolf, G.R., and Valdez, R.A., eds., The Controlled Flood in the Grand Canyon: Washington, D.C., American Geophysical Union, Geophysical Monograph Series, v. 110, p. 225–240. Personal communication with Dr. Jennifer Tank, who is a participant in the ongoing food base study, notes river water N concentrations are unexpectedly high from Lake Powell all the way down to Lake Mead, suggesting that a nuanced approach toward addressing the links between soil nutrients, flooding, and species establishment could provide interesting results. However, that should be developed with more care and understanding of riparian species-biogeochemical linkages.

SA SPECIFIC COMMENTS RELATED TO SECTIONS OF THE PLAN

Following are developed comments that relate to specific sections of the plan. As such, these comments are indexed to page and paragraph of the text.

P1 P3: The text might lead one to conclude that Appendix A and Table A.1 provides information on costs and benefits associated with the high flow event.

Appendix A does provide general treatment of issues identified by stakeholders which is helpful. Cost Benefit Analysis (CBA) information, however, is not provided. The SAs note that provision of some science effort to develop a simplistic CBA tool for tradeoff analysis would be beneficial for evaluations necessary for effective adaptive management.

P2 P1: It needs to be stressed that the study area is only part of the Colorado River ecosystem, and the text and table should be revised to indicate that this is only a part of the greater ecosystem — not the entire ecosystem. Political boundaries defeat the purpose of viewing the entire Colorado River ecosystem as a functional whole.

P5 P3: It refers to Figure 3 as evidence that humpback chub populations increased in the period 1994 to 2000. However, this figure shows overlapping confidence intervals at the 95% level. Thus, the statement doesn't seem very credible. If the CIs shown are correct, then tests of significance would show that there may be no difference among those years. The text should tell us at what level we would be willing to "not accept" the null hypothesis (no difference).

P5 P 2-3: Although it is not inaccurate to make the statement here that tracking increased levels of HBC adults and juveniles through use of ASMR would indicate no impacts of high flow events (1996, 2004), it is good that it is treated more as a hypothesis statement for testing than a test result.

P8 P2: March dam releases may simulate spring flow levels, but not the 17º C elevated temperatures.

P8 P5: Will the food base and trout assessments test the hypothesis relating to algae response from "cropping".

P9 P2: The authors do not say that "sufficient sand" has been transported into lower Marble and Grand Canyon to produce an effective test. Is the longer time period of 5-19 months at MLFF "assumed" or "not assumed" to have transported sufficient sand downstream? #1 a P8 P1 implies that the sand is still in Marble Canyon. P9 P3 seems to imply that the sand is more evenly distributed through the canyon. At this time, February 2008, what is the confidence level that sufficient sand exists throughout Grand Canyon to conduct the test?

P11 Table 1: Can the question be answered by just this one test? Or are you saying that if deposits are at some optimum level "the test result" could surely be represented at some pre-assigned confidence level?

P11, Q 1.D on HBC: What assumed criteria or "quality backwater factors" are established that are assumed to benefit HBC? Will a combination of these positive factors be used to rank backwaters from "better" to "worse"? Or, is "quality" determined by presence or absence of HBC? Not sure if the question is properly specified.

P11, Q1.C: The question appears to be clearly specified to permit measurement and test. However, can assessments be made in reasonable times to protect resources?

P12, Q-4. A & B, RBT: The question about RBT movement to Marble and Grand Canyon might not be appropriate specification. That is, movement may not normally occur at all under lower flows. However, high flows could cause the young and old life phases to be swept downstream. Or, is the test directed at determining which life stage is most vulnerable to movement by high flows?

P 12 Q-3: Food base effects. Greater insight exists on this question by reading the section on study 3. The primary initial factors affecting food base is water flow velocities. Over the longer run water quality and its effects on primary productivity seems critical.

P12 Q-5 Lake Powell Water Quality: Changes in Lake Powell during drawdown should be predictable and able to be simulated with a dynamic model. The research question should look more at how imposed currents will react with the lakes thermal structure during drawdown.

P12 Q-6 Cultural Resources: The issue of direct high flow water and sediment impacts to cultural sites would seem predictable by site location, and presence or absence of vegetation. It seems we are trying to use the tests to develop hypotheses rather than test hypotheses.

P12 Q-2 Vegetation: Is it assumed that this will be the tested hypothesis?

P12 P1-2: These paragraphs seem to defend the position that much of the 2008 test would be directed at formulating hypotheses to test in the future, rather than testing hypotheses already developed. The position taken appears to be one in which more study

is needed to accurately formulate good hypotheses about food base and backwaters that can be tested in a later high flow event.

P13 P1-3: This section provides a good overview of what of the science of CRE hydrology, sedimentology and geomorphology is most effectively known i.e. can be used to accurately predict other events, and what areas still need more extensive learning.

P19 P4: It is unclear what is meant by, "based on the findings of a future high flow within 12-24 months of the next high flow."

P35 P1: It is difficult to determine how the research will relate "occupation" and "physical site characteristics". Correlation methods are assumed such as principal component analysis, but it is not specified. It does not appear that the hypothesis test is fully specified at this time. Instead it appears that developed data will help with this process, as well as define a potential future hypothesis test.

P36 P1: It is stated that this study will not evaluate the relative value of backwaters and other habitats for native fish; but instead evaluate 1) their development 2) food availability 3) and presence or absence of native fish. And, these evaluations will be used to develop more comprehensive studies to evaluate HBC use of backwaters and other habitats.

P36 P4: Given the more constrained planned accomplishments, will the researchers be able to answer the last two strategic questions listed?

P39 P1: Is the second question meant to apply to aquatic food production in the entire CRE, or just backwaters? We assume backwaters, but it is not clear.

P50 P2: The researchers note that measurements have been taken on previous high flow, but they have not been linked to whole system carbon budgets. As such will none of the previous assessments be used in this experiment to confirm sampling procedures and/or other assumed characteristics of the food base?

P53 P3: The study of contrasts; i.e. MLFF monitoring data contrasted to high flow data should also provide input on sensitivity of results from measurement techniques to differing disturbance regimes, i.e. very high flow event. Will this be evaluated?

P56 P2: Under study goals the term "compensatory survival response" is mentioned as a mitigating factor for juvenile RBT survival. A similar term "strong

compensatory mechanisms" after emergence (P57 P5) is used in hypothesis 2. What are these mechanisms, i.e. how are they measured and documented?

P57 P3: Strategic Science Question. Earlier it is proposed that methods developed in studies 4A and 4B could possibly be transferred to native fish interpretations. What elements are being considered besides the sonic tracking method?

P62 P2: Occupancy assessments and sonic technology are proposed as the most reasonable methods to study RBT migration into Marble and Grand Canyon. Are these methods suited to HBC application?

P63 P2: Will sampling for relative abundance assessments also use the same three river strata?

P66 P4: Why would the MPS be needed at the ring outlets? Mixing would not have been accomplished here. Could additional benefit be derived from measurement during ramp up and ramp down of the event; i.e. assessment of any critical threshold values? You might consider changing the emphasis of this section to first the lake and second downstream. Leading these discussions with the downstream changes does not follow the title and is a backward way of assessment. You could add a modeling component to the study. It would provide more learning and future predictability.

P69 P1: Compliance monitoring. The text references a 2006-07 high flow experiment. Change to 2008.

P71-73: Synthesis of Knowledge. The proposed integrated synthesis report is an excellent approach to providing a more comprehensive look and assessment of the series of high flow experiments. Dedicating this specific assessment to evaluate interactive processes, linkages, integrated impacts etc, will realize important additional benefit from the assessments. Scheduling writing and assessment workshops will provide emphasis to the project activity.

P75 & 76; Table 6: The text and table are confusing as they present differing information on the same trips. We recommend the section be reevaluated by science and logistic staff and differences corrected.

REFERENCE SECTION

The references have been screened to provide primarily information related to high flows or supporting information to specific conclusions, hypothesis or other

statements in the text. Some references, however, have been eclipsed by more current research. Some have limited relevance. For example, although use of Darwin (1859) to contrast theories of invasive species provides emphasis, recent work contrasting these positions provide greater clarity of differences.

APPENDIX A: GCMRC RESPONSE TO ISSUES RAISED BY GCD AMP MEMBERS

Issue 1. Table A.1: The table is a good representation of issues presented by members at the AMWG meeting and by TWG representatives. The documentation is an important part of the process.

Issue 2: Although many questions are implied in Table A.1, they are not specified fully as questions.

Issue 4: Table A.2 provides sufficient information to focus on the primary differences in the two regimes.

Issue 6: Appendix B does clarify the difficulty in determining HBC associated impacts with high flows.

Issue 7: Will the proposed food base studies provide the comparative data to define a "net benefit" or "net loss" to the food base from flow impacts?

Issue 8: A question exists as to why a simplistic socio-economic impact assessment tool could not be developed with this or one of the past high flow tests. Significant benefit could be derived from, for example, a simple cost benefit analysis (CBA) model that captures the primary factors that can significantly shift costs or benefits. The tool could be used by AMWG in the future for looking at tradeoffs among options, i.e. time of application, length of event, size, etc. As noted in other comments, development of this tool might better be attached to GCMRC's annual work plan where emphasis could be adjusted to overall AMP needs. However, it is important to recognize the need.

Issue 9: Although impacts to upper Lake Mead from this one high flow event may not be significant, the impact to a cultural site in Glen Canyon will be significant. However, planned actions for the necessary mitigation are being developed by BOR.

APPENDIX B: FACTORS INFLUENCING DESIGN OF HIGH FLOW EXPERIMENTS

P 97: This Appendix does highlight the difficulties to determine impacts of a high flow event on the HBC. The reference to continued monitoring activities does provide insight into possible identification of significant departures should they occur. However, finding reference points for this single event may not be possible, due to variance in the system. Again this points to a need to provide more reference of how the high-flow outcomes will link to the LTEP. Perhaps a prologue should be developed to discuss sediment conservation. GCMRC has discussed the merit of testing equal monthly volumes under 8.23 constraints. With lower fluctuating flows, i.e. 7-13,000 cfs, minimum compliance would sum to be required for the test.

Table B.1: Please note the second March trip must be an August trip due to location in list, and it is noted as "autumn."

P99-104: This discussion of testing new methods for evaluating HBC abundance, movement, use of habitat etc, is an appreciated response to the SAs concerns over HBC assessments in the first science plan draft. Discussion and proposed attempts at new methods, i.e. sonic tag assessments and occupancy assessments are encouraged. Although probable success is limited in isolating direct flow impacts to HBC population, tracking movements could benefit other assessments relating to competition and habitat change.