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MAY 03 2002

MEMORANDUM

To: Adaptive Management Work Group
Technical Work Group

From: Barry D. Gold, Chief

Subject: Science Advisors' Review and Assessment of Treatment Scenarios for WY2002-2003 (draft dated April 26, 2002)

As discussed at the April 24-25, 2002, AMWG meeting, I am pleased to transmit the draft report provided by the GCMRC Science Advisors on the experimental flows treatment scenarios.

As we continue to develop the details of the treatment scenarios and long-term experimental design, we anticipate further input and involvement from the Science Advisors.

DRAFT REPORT

A REVIEW AND ASSESSMENT OF THE GRAND CANYON MONITORING AND RESEARCH CENTER PROPOSAL: TREATMENT SCENARIOS FOR WY 2002-2003

BY

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APRIL 26, 2002

A REVIEW AND ASSESSMENT OF THE GCMRC PROPOSAL: TREATMENT SCENARIOS FOR WY 2002-2003

INTRODUCTIONS

The Grand Canyon Protection Act of 1992 called for operation of Glen Canyon Dam to "protect, mitigate adverse impacts to, and improve the values for which the Grand Canyon National Park and Glen Canyon National Recreational Area were established, including, but not limited to natural and cultural resources and visitor use." The Act called for development of an EIS, wherein the requirement was specified to establish an Adaptive Management Work Group to manage an Adaptive Management Program. Also a Science Center was to be established for research support and an Independent Review Panel was specified for science oversight.

In 2000, the Grand Canyon Monitoring and Research Center established an independent group of Science Advisors. The Science Advisors provide science review of various program planning documents, research findings, research needs, etc. In 2001, the Science Advisors reviewed the developed research needs of the Adaptive Management Work Group, providing requested recommendations.

THE CHARGE

On March 31, 2002, the Science Advisors received a proposal for "Treatment Scenarios for WY 2002-2003". The Science Advisors were requested to review the proposal on a research-based river trip scheduled for April 5-13, 2002. This draft report on the Science Advisors review represents a compilation of scientist observations on the treatment proposal. The charge to the scientists from GCMRC is to provide scientific evaluation of the treatments proposed, including:

1. Evaluation of research designs.
2. Assessment of experimental flow regime impacts on sediment.
3. Assessment of experimental flow regime impacts on humpback chub populations.
4. Assessment of mechanical shock treatments and experimental flows on rainbow trout populations.

The Science Advisors have provided input to the GCMRC staff and management team in extensive science discussion on the Colorado River science trip from April 5-13, 2002. At the end of the science trip, the science advisors provided a set of written recommendations to the GCMRC management team.

SUMMARY RECOMMENDATIONS

The Science Advisors' review of the GCMRC proposed Treatment Scenarios for WY 2002-2003 resulted in both a set of summary recommendations and this draft report. Following is the summary of recommendations.

1. The AMWG and GCMRC should create a sense of urgency regarding activities associated with protection of the HBC and its habitat. The entire experiment should use an adaptive management process.

2. AMWG and GCMRC should engage the USFWS and implement an assessment of the minimum viable population of the humpback chub.

3. GCMRC should maximize parameters in study designs that address control of trout populations, i.e., direct kill, flow regimes, TCD, etc. The specific analysis techniques should be presented, rather than example design or technique.

4. AMWG should pursue development of the TCD immediately.

5. AMWG should pursue development of a refugia population of HBC.

6. AMWG should pursue fluctuating flows in the treatments to effect reductions in the trout populations, i.e., strand fish, destroy spawn, increase adult predation, etc.

7. Treatments should evaluate the impacts of flow regimes on recreation, including both boating impacts and fishing impacts.

8. GCMRC and associates should continue ongoing sediment and hydrology monitoring using advanced technology.

9. AMWG should implement BHBF flows only in years with appreciable (high) tributary sediment input events.

10. The fluctuating flow events should include the normal monitoring of water, sediment, power, fish, etc., but also include additional monitoring in chub and exotic fish, recreation, cultural resources, etc.

11. Cultural resources are impacted by fluctuating flows by down-cutting, arroyo formation, river bank cutting and wind dune formation. Of the 328 critical cultural sites identified in the GC affected corridor, 15 to19 have been identified to have such significance and are under such threat of destruction that an immediate mitigation program is recommended over a ten-year period, with associated funding to resolve pending impacts.

12. American Indian involvement in the development of the experimental treatments program should be such that any reasonably foreseeable impacts to areas of traditional and/or cultural significance can be minimized.

13. Monitoring of anglers and river visitors (private and commercial) should be performed before, during and after any experimental flows. This can be accomplished by visitor intercept surveys with mail back at the take-outs: Lees Ferry for trout anglers, Whitmore Wash and Diamond Creek for rafters. During extended periods when no experimental flows or other treatments are planned, long term monitoring of rafters via NPS lists of private rafters and commercial passengers can be performed. Visitor intercept surveys can be accomplished for $50,000 a year for five years before, during, and after experimental flows. Regular non-event related monitoring can be accomplished for $35,000 via NPS private and commercial rafting lists.

ADAPTIVE MANAGEMENT

The Grand Canyon ecosystem is a complex social-ecological system, where unwanted ecosystem state shifts (species extirpation and endangerment, loss of habitat and biodiversity, transformation of temperature and turbidity) have resulted from large-scale water management projects. The social objectives or values in the system amount to attempts to restore lost ecosystem functions and resilience. These objectives are sought through an adaptive management program, where uncertainties about ecosystem dynamics are being confronted through the articulation of a set of competing hypotheses about what led to the loss of resilience, and what is needed to restore those lost ecosystem functions and services. Hypotheses are proposed for testing through a structured set of management actions, designed to sort among the alternative explanations and a comprehensive monitoring plan established through decades of research.

Unlike other large-scale ecosystems in the U.S. (Everglades, Columbia River basin, Cal Fed delta), the Grand Canyon appears to be at the forefront of adaptive management by cultivating institutional learning. For example, adaptive management in the Everglades has been trapped by special interest groups (agriculture and environmentalists) who seek to avoid learning. The Grand Canyon group, on the other hand, has developed an Adaptive Management Work Group, which uses planned management actions and subsequent monitoring data to test hypotheses, and build understanding of ecosystem dynamics. Such open institutions are essential for dealing with multiple objectives, uncertainty and the possibility of surprising outcomes.

The Grand Canyon Research and Monitoring Program is at the forefront of implementing adaptive management in the United States, because of the technical capacity to experiment in the system, the ability to monitor and detect changes in the system and the social institution to develop social capital necessary for adaptive management. But this does not mean that the process of adaptive management in the Canyon system is without issues or problems, as presented by the current round of proposed experiments by the AMWG.

GCMRC and AMWG have come a long way in the past decade in terms of understanding the ecosystem. This is most evident in the clear articulation of competing hypotheses about ecosystem function. Many cases of failure in adaptive ecosystem management can be traced to an inability to come to agreement about key hypotheses to be tested and the physical ability to confront those key hypotheses. Other failures can be traced to the lack of social capital or trust among stakeholders and managers that provides the willingness to experiment. Neither of these barriers to adaptive management appear to exist at this time in the Grand Canyon.

It is, therefore, strongly recommended that the AMWG proceed with implementation of the proposed multi-year experiments. Other sections of the report will address details and technical aspects of proposed alternatives, but the overall approach appears sound.

Following are recommended strategies for implementing more active adaptive management. Three strategic AMWG objectives appear important to meet management objectives and values; (1) actively experiment to accelerate learning, (2) design experiments that are "safe to fail," and (3) generate social capital. Each is expanded in the following paragraphs.

1. Actively experiment. GCMRC and AMWG have a decadal history of ecosystem experimentation, which should be moved into more active experimentation. Experimentation is key to accelerating the learning process. It is easy to move into a passive adaptive management mode, where variability in the system is monitored. The group should continue to propose more bold experiments. In these experiments, the proposed treatments should be of sufficient magnitude to produce a clear detectable response in the ecosystem. Treatments should be implemented for a sufficient period of time to generate information about responses. Long-term experimentation is necessary for learning! Where resources may not be available for experimentation, treatment design should be flexible to those types of changes. Sufficient resources should be assigned before, during and after experimentation to capture ecosystem responses and generate learning.

2. Design experiments that are safe. The property of ecological resilience is defined as the amount of disturbance that a system can absorb without changing state. Most of the priority management issues of the canyon (endangered species, invasion of non-natives, loss of sediment, cold water fisheries) indicate shifts in ecosystem state have already occurred. The approach in these cases is to actively manage the system in an attempt to return the system to a more desirable stability domain. Ecological resilience provides "insurance" within which managers can affordably fail and learn while applying policies and practices to "move" the system aggressively into desirable states. In issues such as endangered species, it is important that actions be developed to return resilience to these populations.

3. Develop social capital. In the Grand Canyon system, multiple stakeholders, multiple objectives, and a complicated ecosystem all contribute to lots of uncertainty. To probe uncertainties through management actions requires social capital. That social capital can also be described as trust or willingness to share in the costs of learning about the system.

OVERVIEW OF EXPERIMENTAL APPROACH

The challenges of managing the Grand Canyon system under current conditions result in four general recommendations from the science advisory team.

- View the environmental challenges from the top down. That is, look at the big picture and identify and deal first with the most pressing problem. From the perspective of the science advisory team, the demise of the hump-backed chub seems the most ominous situation. The chub, therefore, requires immediate attention to reduce the possibility of forced management of the entire system for only the chub.

- The experiment chosen should test potential effects of management options on environmental conditions that are of value to various resources and stakeholders. However, the chub resources should be given first priority.

- The experiment should be long term because components of the complex system may take several years to respond and several treatments should be evaluated in sequence.

- The experiment and changes in the experiment should be planned, to build upon knowledge and understanding as they develop. Such an adaptive experiment can deal with the confounding intricacies of the Grand Canyon and develop a means to manage for the key values of the system.

An overview of the Grand Canyon system shows that for the proposed experiment there are three main control processes that management can exercise to influence the main values of the system (Figure 1). The three proposed controls are flows of water from the dam, mechanical removal of the trout, and installing a temperature control device.

The prime values of the system are hydropower and water, cultural resources, recreation, and maintenance of rare species and their habitats. Cultural resources can be further divided into historic, prehistoric and spiritual aspects; and recreation including: non-native fishery, Lees Ferry trout guides, private and commercial boating, boat guides, and cultural sites.

Of all the potential impacts of controls on values, the biggest is the effect of flow from the dam on water and hydropower. Smaller impacts include: (1) flows affect sedimentation which affects cultural resources, beach building, and habitat of the native chub, (2) effects of the mechanical removal of the trout on recreation and the native fish, and (3) effects of the temperature control device on the trout and thus upon recreation and native chub. Several smaller impacts are possible such as: (1) flows affecting recreation, and (2) temperature changes influencing sedimentation, hydropower and water, cultural resources, and the chub directly or via altering conditions so they are more favorable for predaceous fish to move upstream from Lake Mead. Clearly it is a complex situation.

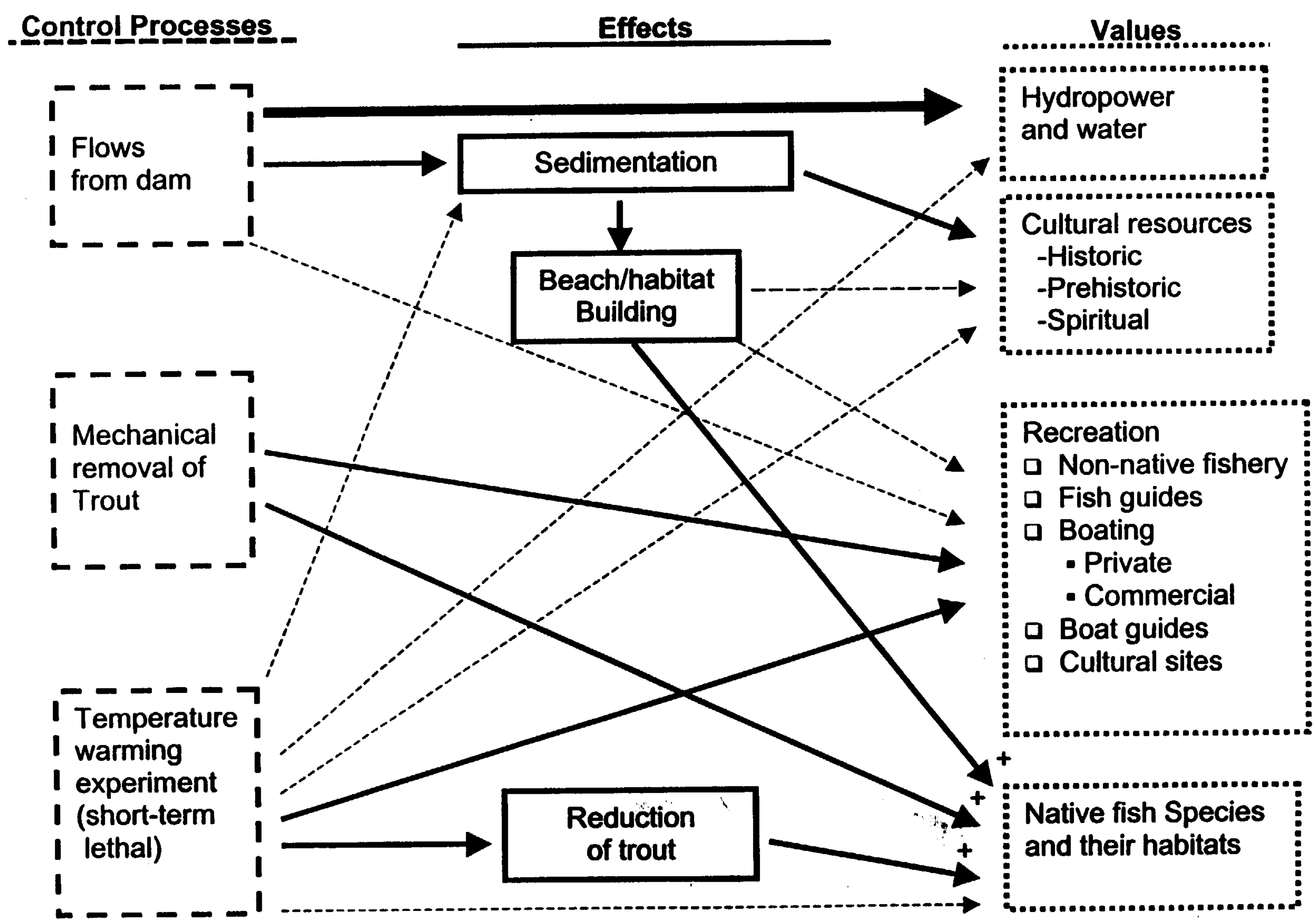
Because of these complexities, the advisory committee determined that it is important for the experiment be put in place for a long enough period to clearly define its effects. We also urge that the experiment be designed to best maximize confidence in the results. This usually relates to known opportunities for control. Therefore, we suggest the first and most aggressive treatment be one that reduces predation pressure on the chub when they first enter the Colorado River from the Little Colorado River (LCR). This reduction can be achieved by mechanical removal of both rainbow and brown trout in the reach near the LCR and by controlling flows to reduce the habitat available for successful reproduction of the trout. The success of the treatment can be monitored by both analyzing the stomach contents of the trout to determine if predation of the chub is ongoing and by estimating the number of mature chub. We realize that young chub are too difficult to handle without detriment to the fish so the experiment must be in place for a minimum of 5 years in order to be able to monitor two successive adult chub populations. At the same time, flow experiments should be implemented, especially if they are demonstrated to reduce the trout population.

Figure 1 illustrates aspects of the system that should be monitored as changes occur in the control processes. Any value that has an incoming arrow should be monitored by one or more means as the instigating control process is altered.

Some potential effects are not considered in the experiment and therefore, are absent from Figure 1. As the experiment proceeds they should receive consideration if they are expected to become significant impactors. They include:

- Tamarisk and other exotic riparian vegetation.
- Native riparian vegetation.
- Increases of other non-native fish species with warming of river flows.
- Neotropical migrants.
- Impacts of up-stream hydrology and reservoir dynamics, especially those relating to water quality.

Figure 1: Overview of Experimental Effects



THE PROPOSED RESEARCH DESIGN

To determine a way to improve the retention of sediment and benefit native fish populations, the GCMRC Research approach proposes annual experimental treatments spanning a multi-year time period. The advisory committee agrees that this experiment, if conducted in an appropriate manner, will enable the GCMRC to evaluate one or more experimental treatments (flow scenarios). However, the advisors provide the following observation and suggestions for improvement.

As stated in the plan, "An experiment fundamentally relies on three elements: control, treatment replication, and treatment evaluation." The plan for WY2002-2003 needs to be revised. First, the plan seems to rely on a 1-year experiment (although later in "Frequently Asked Questions," the plan proposes to repeat the experiment in future years, and a multi-year table is presented in the plan's Attachment 5 - Long-term Adaptive Management Experimental Design [see Appendix herein]). In discussions with GCMRC staff, the actual approach seems to be to adjust the long-term experiment as more information is attained. However, the GCMRC staff also noted that the scenarios presented in the plan's Attachment 5 are only a possible example of the long-term approach, and not the actual approach.

The Science Advisors propose that which ever scenario is chosen, the scenario should be implemented for a period long enough to evaluate, not only the short-term sediment dynamics, but also changes in the native and non-native fish populations. If sediment is the primary focus, several one-year experiments may be adequate. However, if native fish populations are also to be evaluated, we would suggest conducting the scenario most likely to provide positive effects for 7 or 8 years in a row (not 1-3 years). If a major year-class of native fish results, the AMWG might then operate the system even longer under the experimental conditions.

Conducting a given scenario for 7 or 8 years would enable the control of other factors that are changing annually and also permit treatment replication. In a multi-year study, a more explicit time frame should be described (more than just in an attachment).

Nothing is described in the plan on how to evaluate the treatment. We suggest adding a section on how the treatment will be evaluated (both sediment and fish), how resources will be monitored, and the data analyzed. References to potential impacts as indicated in Figure 1 may be useful.

In summary, the proposed plan suggests that the GCMRC plans to conduct a multi-year study, but as it is written, it appears more like a 1-year experiment. We think the document should be modified to demonstrate the long-term nature of the study. Also needed are more definitive sections on how the individual components will be evaluated (what data will be collected) and how the study may be modified if short-term sediment goals are not reached, or HBC populations reach critical thresholds.

AN ALTERNATIVE EXPERMENTAL DESIGN

In the research plan, a block-design experimental approach is proposed. The design will test multiple combinations of independent variables or factors to determine how various flow scenarios influence sand bar formation and determine whether or not biotic interactions such as predation and/or environmental alterations to habitat are limiting recruitment of humpback chub. In this plan, there are four types of independent variables: fluctuating flows (with various alternatives), mechanical removal of fish, fall flow regimes, and a temperature control device (TCD). However, the TCD contribution to the design is not clearly defined.

This approach is plausible if sufficient scenarios are tested for sufficient years. However, because of the number of independent variables, the cost of implementing various scenarios, and the complicating effects of other extraneous sources of variation, many years of data would be required (possibly many more than the 16 years proposed in the plan's Attachment 5) to isolate the effects of each variable.

An alternative experimental design would be to separate the experimental design for examining the effects on sediment deposition from the experimental design to examine the effects on Humpback Chubs. This alternative approach is briefly outlined in the following sections.

Sediment Deposition Experiment

A great deal of information is already known about how different flow regimes effect sediment deposition. In fact, a preliminary process-driven model has already been developed for this area. A more plausible experimental approach may be to use specific flow alteration experiments to further refine this model and then use the refined model to predict changes in sedimentation patterns and determine an optimal flow strategy to maximize sandbar formation. The following steps seem plausible.

Outlined approach:

1. Determine which coefficients/modules of the preliminary sediment deposition model need refinement (requires inputs from sediment modelers).
2. Develop specific flow scenarios to better calibrate coefficients and refine modules.
3. Perform specific flow tests.
4. Use measured flow and measured sediment movement to refine coefficients/modules.
5. Verify refined model with independent years of data and determine model accuracy (error bars for various physical characteristics).
6. Use refined model to simulate sedimentation patterns for various flow scenarios and determine optimal design to enhance sandbar formation.

This approach will reduce the time and costs associated with performing many individual flow scenarios. After an optimal flow regime is determined with the model, this flow regime can then be tested and implemented.

Adaptive Experimental Design for Humpback Chub

Over the past ten years, humpback chub populations have decreased significantly as trout populations have dramatically increased. It is not known specifically whether the trout are out competing the humpback chub or are being consumed by the trout. Humpback chub populations appear to be already very near (or below) critical thresholds. Because chubs are at high risk of loss, concern exists that insufficient time exists to conduct a 16-year block-design experimental approach to determine exactly what is causing the decrease in humpback chub populations. As an alternative, we encourage the GCMRC to immediately start reducing the trout populations below the Lees Ferry reach, by mechanical means (electroshocking and netting) and by structured flow impacts. In the Lees Ferry reach, the Arizona Game & Fish Department should increase the bag limit of fisherman. Annual surveys can be used to determine the success of this effort in reducing trout populations. In the process of mechanically removing the trout, stomach analyses should also be conducted to evaluate chub consumption. Trout bioenergetic models should be used to determine the overall impact of adult trout populations on humpback chubs.

Fluctuation of flow at critical times of the year can also possibly reduce recruitment of trout and benefit the recruitment of humpback chub. Therefore, we also encourage the GCMRC to evaluate fluctuating flow experiments immediately as proposed. Fluctuating flows should be conducted when the majority of the trout population is thought to spawn. Annual fish surveys should be used to determine the success of this effort.

After the first two to three years of this effort, results of trout and chub fish surveys should be used to determine how best to proceed (adaptive experimental design). If fluctuating flows is not successful in reducing trout recruitment, this effort should be discontinued.

The rainbow trout fishery above Lees Ferry was for several years a trophy fishery however, with the rapid increase in trout populations the average length of trout and quality of fish has decreased. Reducing the number of trout should decrease competition for food and improve several life functions. The average length of the remaining fish and quality should increase. Increased trout could appease trout fishing stakeholders currently concerned about their fishery.

IMPLICATIONS OF EXPERIMENTS TO PREDATOR DENSITIES

Mechanical Removals

Lower reaches of the Little Colorado River appear to be the main or possibly sole spawning and nursery region of the humpback chub population. Predation is a major cause of mortality to larval and juvenile fishes. Juvenile chubs are known to appear in trout diets (although at low frequency) and the trout populations in the region of the LCR are increasing rapidly. Reducing predator populations is a proximate and immediate experimental management action that can be quickly implemented and tested. Accordingly, we strongly endorse the proposed program for removal of both rainbow trout and brown trout in the reaches of mainstem river associated with the LCR. We encourage immediate implementation of the program. There is urgency in this issue.

This management action is in keeping with the Adaptive Management philosophy in that it can be a direct manipulation focused on an important goal, protection and enhancement of the endangered humpback chub population. The technology exists and the merits of this approach will be quickly evident. A sequence of intensive removals over a 5-year period will test the initial adequacy of this management action. Catch rates of juvenile chubs may reveal early evidence of increased recruitment in proportion to removal rates. Recruitment to the age 3 cohort is the essential evidence required to fully assess the approach. Accordingly, the program will need to plan for a duration of at least the mean duration of two generations of chubs, or 8-12 years.

There is the risk of some mortality to juvenile or adult chubs during the removal. Experience in many analogous efforts reveals a handling mortality of 1-5%, with the average at the lower end. In this case, that is the unavoidable cost of attempts to protect and enhance the chub population. However, refusing to pursue this option because of the possible risk seems irresponsible. The chub population is declining and will continue to do so unless immediate, aggressive actions are pursued.

We encourage expansion of the proposed shocking effort to include as many sport boat shockers and working groups as can be assembled. They should be put to task in the season (summer) prior to chub spawning and the emigration of juveniles from the LCR. Modeling analyses based on previously collected trout diet data can be done to evaluate the reduction in predation mortality and its potential change in proportion to the reduction in predator populations. In addition, records of catch rates during the short-term sequence of removals will provide depletion rates required to estimate local predator densities. Inter-annual differences will reveal immigration rates from outside the managed region. If catch rates of trout do not decline as intended, the program can be suspended.

Fluctuating Flows

In the years when fluctuating flows were common, rainbow trout populations experienced variable and generally low recruitment, yet produced an abundance of very large trout and a world-class trophy fishery. Recent management has produced lower flow variability and has been accompanied by increased trout density, declining trout growth and condition (weight per unit length) and, most recently, possibly declining catch rates. These are symptoms of a trout population currently at or in excess its carrying capacity and moving toward a lower value as a recreational resource. Those trout are the focus of concern because the trophy fishery of the past is gone and because of the role of trout as potential predators for juvenile humpback chubs.

We endorse the proposal for re-establishing fluctuating flows during some periods of the year. In the Lees Ferry reach, this practice will reduce the excessive reproductive output by the current trout population and should re-establish greater growth rates and larger trout. In the LCR reach it should reduce the number of predators on chubs.

By fluctuating water levels during winter and spring, successful trout spawning will be confined to a lesser proportion of gravel habitat and juvenile trout will be removed from shallow water refugia. That makes them more available to predation by adults. When coupled with the predator removal program proximate to the LCR, these two management experiments will cause both a large-scale and local reduction in predators on juvenile chubs, which emerge from the LCR in autumn. In addition, the consequent reduction in trout density will encourage greater growth rates and re-establishment of the trophy fishery in the Lees Ferry reach.

Both the predator removal program at the LCR and the fluctuating flows practice would be best served by some attention to a public information effort for anglers in the Lees Ferry reach and boaters in reaches below Lees Ferry. This effort should explain and reinforce the importance of these management actions.

Providing Critically Needed Science and Management Options for the Chub

Immediate AMWG pursuit of planning and development of TCD: Virtually all biological rates are temperature dependent. A properly designed and operated Temperature Control Device has important potential as a management tool that can strongly regulate ecological processes downstream from the Glen Canyon dam. It should be pursued now so it can be a science and management option in 5 years. We strongly encourage the BOR to develop an expert panel convened in collaboration with GCMRC, then charged to evaluate the engineering alternatives and management applications that could be effected through wise use of this device. The panel should work with the BOR as it pursues an EA or EIS for establishment of the TCD.

Immediate AMWG pursuit of planning and development of refugia population: If the LCR chub population continues to decline, the Biological Opinion's call for a second population may become a control criteria for the AMWG. Accordingly, we encourage a search for alternatives. One of those may rest with developing a partnership with one or more tribal groups willing to take on the task of developing a captured breeding population. Another may remain in the definition of distinction between the chub population in Grand Canyon and those remaining in the river above Lake Powell and the northern tributaries (e.g., the Yampa River) of the upper Colorado. These and related alternatives should be investigated as soon as possible. The chub population is currently at or near a minimum viable level and continues to decline. There is substantial urgency to pursue the issue now, to permit management options in the next decade.

IMPLICATIONS OF EXPERIMENTS TO EFFECT SEDIMENT, BEACHES, AND ASSOCIATED RESOURCES

Sediment and Beaches

Fine sediment, particularly in the sand sizes, is a critical resource along the Colorado River in the Grand Canyon (CRGC). This sediment supports most of the shoreline vegetation (tamarix, willow, grasses, sedges, etc.) and serves as camping sites for river trips. Most studies conducted within the first few years after the completion of Glen Canyon Dam (including the EIS) suggested that net accumulation of sand might be occurring in the upper canyon below the confluence with the Paria River. These conclusions were based upon simple, but uncertain, analyses of sediment influxes from tributaries and outputs through the Grand Canyon Gaging Station. However, these studies also recognized that the sandy "beaches" near post-dam high water had been undergoing net erosion. More recent analyses since 1995 paint a pessimistic scenario of extensive and continuing losses of fine sediment from the CRGC, particularly upstream from the junction of the Little Colorado River. These conclusions are based upon: (1) intensive monitoring of selected beaches and the river bed; (2) measurements of suspended sediment inputs and losses; (3) results of experimental flows; and (4) theoretical modeling of sediment transport. In fact, this scenario is sufficiently bleak that present strategies, including the experimental flows recommended by the GMCRC for the 2002-2003 WY and beyond, are directed at temporarily alleviating rather than reversing the net erosion trend.

The proposed experimental flow strategies are based upon utilizing sediment supplied by tributary floods (primarily from the Paria and Little Colorado Rivers) to rebuild beaches at elevations corresponding to river discharges between 10,000 cfs to 45,000 cfs (the level of proposed BHBF flows). Because of rapid winnowing and exporting of sediments introduced to the channel bed and lower eddies by tributary floods, BHBF flows should either occur immediately after (or during) such floods or after a waiting period characterized by low flow releases from GCD. Because tributary floods primarily occur during the summer and fall when operational constraints make BHBF flows unlikely, the recommended **Scenarios 1** suggests maintenance of low flows (below 15,000 cfs and preferably below 10,000 cfs) until a BHBF flow can occur. ***We support this scenario.*** **Scenario 2** also involves short peaks to ca. 33,000 cfs (within power plan capacity) during the summer or fall waiting period before the BHBF flow. These lower peaks will probably not store much sediment on beaches or in eddies and would export significant portions of the tributary inputs from the river. ***We do not favor this scenario.*** In certain years significant tributary sediment inputs can occur during the winter months. In this circumstance BHBF flows could occur immediately after tributary inputs (**Scenario 3**). ***We support this scenario for such circumstances.*** **Scenario** 4 concerns years with little sediment input from tributaries, so that no BHBF flows occur. ***We also favor this scenario for such circumstances.***

In general, BHBF flows should not be instituted unless sufficient sediment has been introduced from tributary floods to allow significant sediment deposition on beaches. This would probably be a flood with recurrence intervals longer than 2-3 years. However, for purposes of testing the treatment scenarios, an initial BHBF treatment could be conducted for more modest tributary inputs. BHBF flows should also not be instituted if significant periods of discharges greater than about 10,000 to 15,000 cfs have occurred between the tributary inputs and the possible BHBF flows.

Another component of the proposed flow scenarios is a period of highly fluctuating flows that is oriented toward interruption of trout spawning. These flows are highly desirable for this purpose, but they will probably induce increased erosion from beaches and eddies by flow erosion, groundwater sapping, and slumping. Therefore it is imperative that the monitoring of beach and channel bed elevations and sediment distribution in the sample river reaches be conducted before and after such flows; suspended sediment amounts also should be monitored during fluctuating flow periods.

The monitoring component of the GCMRC includes two major activities: (1) Monitoring of suspended sediment flux on the CRGC mainstem and tributaries, and (2) monitoring of topography and sediment characteristics in a number of representative river reaches. We view continuation of both of these efforts to be essential. Considerable progress has been made in reducing costs of the reach monitoring through advanced technologies (LIDAR and photographic/photogrammetric monitoring of beaches and fan complexes above water level, and multibeam depth measurements and bed photography), while at the same time increasing the total length of channel that is monitored. The investigation and refinement of reach measurement techniques should continue. Measurement of suspended sediment, however, presently involves laborious collection of suspended sediment samples at several cross-sections at frequent intervals by standard manual methods. Sediment concentration measurements are also essential, but costs could be reduced by automation, including measurements of sediment size and concentration using laser sensors as well as automated pump sampling, possibly in combination. These techniques would have to be tested and calibrated against direct sample collection by traditional means. In addition, periods of low, nearly constant flows exhibit little day-to-day variation in sediment size or concentration, and transport rates are so low that they have only a small influence on the overall sediment budget. Direct sample collection could be less frequent at such times. During high flows and during/immediately after sediment input from tributaries the monitoring frequency should be increased.

A new study to model the fine sediment transport through the Colorado River was initiated this year through GCMRC. Calibration and validation of this model require continuation and possibly augmentation of the monitoring activities discussed above. The results of this modeling activity should be taken into consideration in refining the experimental flows.

Effects of BHBF flows, fluctuating flows for trout reduction, and changes in release patterns from GCD upon sediment within the CRGC should be continued to be evaluated and the experimental program adjusted in response to new findings during the proposed long-term adaptive management cycle.

We suggest that the monitoring and research program also address the following issues during the proposed adaptive management program:

1. Are tributary floods supplying large quantities of granules and fine gravel to the river bed that are accumulating under present flow regimes and providing spawning habitat to trout?

2. Are appreciable quantities of fine sediment supplied from tributary floods being protected from erosion from the bed by armoring of coarse sand and fine gravels? If they are, can BHBF flows remobilize the fine sediment?

3. Does exposure of underlying gravel or tributary fan debris on eroding beaches significantly slow further sand erosion? Does establishment of dense vegetation play a similar role? Conversely, is new beach sediment supplied by BHBF flows so rapidly eroded that it is of limited value? Are there unobtrusive methods of beach stabilization (e.g., through encouragement of vegetation growth)?

4. What is the magnitude of wind erosion of beach sands?

5. Should vegetation be managed on prime camping sites along the river? What would be the impact of vegetation control and incidental human activities on wind and water erosion of campsites?

EXPERIMENTAL FLOWS AND CULTURAL RESOURCES

Introduction

Cultural resources in the Grand Canyon corridor include historic and prehistoric sites, museum collections that have originated from these sites and tribally identified spiritual locations. These materials and locations, relate to the human use of Grand Canyon and along with natural and recreational resources are specified for safeguarding under the Grand Canyon Protection Act of 1992.

While the Endangered Species Act is intended to protect threatened animals, the National Historic (and prehistoric) Preservation Act is designed to protect cultural resources. The Grand Canyon Monitoring and Research Center, Grand Canyon National Park and the Bureau of Reclamation are all pledged to abide by these laws and their intended purposes including the protection of and data recovery from threatened cultural sites.

Cultural Resources Within the Grand Canyon Corridor

In the course of work on the Environmental Impact Statement, and at the request of the BOR, 336 archaeological and historic sites were located and reported along the Grand Canyon corridor. A comprehensive review by the State Historic Preservation Officer concluded that 328 of these sites were of sufficient cultural significance that they were eligible for the National

Register of Historic Places. Yet, only nineteen of the 328 sites were considered to be both of sufficient significance and under such threat by river impact from higher fluctuating flows, to warrant immediate excavation to protect the important information they contained. Eighteen of these sites are in locations directly affected by arroyo cutting due to lowered river levels and one is in a side canyon drainage affected location.

These significant and threatened sites can be classified into seven categories: two important pueblo settlements; three small structures; two structures with several adjacent roasting pits; two locations containing several roasting pits; two locations with a single roasting pit; four sites with fire cracked rocks; and four artifact scatters.

Research at these nineteen threatened locations would protect the information they contain before they are destroyed by direct river or indirect erosive action and thus would fulfill obligations under the law incumbent upon the agencies involved. This work also would add important new information to our understanding of the prehistoric and historical record of American Indian life within Grand Canyon.

Proposed Plan for Research at the Nineteen Vulnerable Sites

An inclusive plan and program for research on the endangered sites would includes a series of interlocked steps. The steps should be pursued immediately, considering increased impact from experimental flows. Each of these is briefly introduced below.

Prior to the beginning of work on the vulnerable sites an agreement must be in place allocating research funds of $200,000 a year for a ten-year period. This funding would allow for consultation, planning, testing and all other required research and publication relating to these sites. Following the first year of testing this amount should be reevaluated on the basis of more complete information concerning the nature of the threatened sites.

A small panel of active, academic archaeologists should then be formed to review the nineteen sites, set up a priority ranking and consult on an initial testing program. This panel should also be convened yearly to review the programs progress and serve as a source of recommendations on the evolving research design.

To insure the highest quality research effort, throughout the full length of the program, a relationship should be created with archaeologists from two different university departments. These should be archaeologists who have a background in Southwestern archaeology and understanding the advantage, for all involved, of being part of a long-term program of collaborative Grand Canyon archaeology. One group of archaeologists might be asked to focus on the two major pueblo sites, while the other could work on the remaining seventeen sites, although the exact division of labor between these sites should be negotiated. This division would create a parallel series of archaeological research projects where each would benefit by the work and insights of the other and together they would provide the related agencies with a broader base of expertise.

As soon as feasible, preferably within the next year, each university group should be given funds to test their assigned sites to determine their boundaries and other information necessary to construct a full multi-year research design.

While this testing is proceeding the Grand Canyon Historic Preservation Plan and Research Design should be completed and agreed upon with the BOR. The outside archaeological panel could also be asked to review these documents.

Reports on the initial testing should be completed expeditiously and reviewed by the panel a few months following the completion of the fieldwork. The report on the testing should also contain an updated research design for each site. After obtaining the panel's suggestions the reports could be edited and posted on Grand Canyon National Parks web site to make them immediately available to other archaeologists for comment.

Comprehensive archaeological fieldwork should then begin the following fiscal year and continue until all the necessary excavation and related research is completed. Yearly progress reports should be submitted by the researchers and be reviewed by the peer panel. There should be a regular series of interactions and communication of results and ideas between the two research groups, and the cultural resource officers of the Park, GCMRC, BOR, SHPO, and others who might be helpful in the interpretation of the research results and the evolution of the research design.

With the completion of all fieldwork the final report should be written and circulated both internally and written for peer reviewed journals and as academic and monographs.

With this work completed the legal obligations relating to the EIS will have been completed by Grand Canyon National Park, BOR and the GCMRC. These units would then be in a position to revaluate their responsibilities as regards future American Indian related discoveries.

Summary

The proposed experimental flows program have in past flow regimes had demonstrated impact on cultural sites. Nineteen sites are considered at high risk. These significant, threatened cultural resources that have been located thus far along the Grand Canyon corridor can be responsibly dealt with through an agreement between all related parties that a systematic series of planning events and research stages would satisfy all current legal obligation. This work could be supported by a $200,000 a year funding obligation over a ten-year period. This on-going archaeological work, and its evolving results, would also provide a continuous flow of results useful for river guides, Park interpreters and the scholarly community. This project would also be a strong illustration to the general public and congressional staffers about the positive results that are being derived from just one of the several research areas for which the BOR, the Park, and the GCMRC are responsible.

EXPERIMENTAL FLOWS AND RECREATION

Benefits of Recreation Monitoring

It is important to understand how the visitor experience is positively or negatively affected by experimental flows, beach-building flows, fluctuating flows, archeological restoration and protection efforts, trout fishery management (changes in total abundance, size of catch, catch limits, upstream river access at different flows).

Many private rafters have waited 10-15 years for a permit. This is a once in a lifetime experience for many of these private boaters and nearly 80% of commercial passengers. Their trip experiences can be adversely affected or enhanced by flow experiments. Since the purpose of Grand Canyon National Park is to preserve resources for the enjoyment of current and future generations, knowing how well the agencies are doing is important feedback to Park managers.

River Flow or Other Experimental Event Related Recreation Monitoring for Experimental Flows or Other Significant Treatments Such as Mechanical Trout Removal, Temperature Control Devices, etc.

Monitoring of river rafters and anglers economic benefits and experiences in the Grand Canyon and Glen Canyon reaches, respectively, should be accomplished: (a) prior to commencing changes in flows or other treatments or management manipulations to establish baseline visitor benefits; (b) during experimental flow releases or management manipulations; (c) after experimental flows or management manipulations.

METHODS

Sampling of Rafters: Commercial passengers could be intercepted at Whitmore Wash takeout, Diamond Creek and South Cover.

Sampling of Anglers: At Lees Ferry as they take out. Visitors would be handed a mail-back questionnaire with a postage paid return envelope. Their names and addresses recorded to apply follow up mailings. Using this approach 65-70% response rates have been obtained on the Snake River through Jackson Hole, Rocky Mountain National Park, and Mono Lake.

Survey Content: Important Attributes of Trip. Using a five point Likert Scale, questions on archeology, geology, wildlife, fisheries, beaches, rapids, side canyons, water flow levels, crowds, etc.

Trip Satisfaction: Using a standardized and long-used 10 point scale for visitors. Their trip expenditures for travel, film, guide fees, food, etc., would be recorded. They would be asked to rate their "trip experience."

Trip Expenditures: Willingness to pay question would be asked on a current trip they have taken, plus alternative trip scenarios using either contingent valuation method or cojoint trip profiles so as to obtain values of trip attributes.

Two Samples: One of anglers in the Glen Canyon Research and one on rafters in the Grand Canyon.

Time Line: This would take place over a five-year period. The first year would be survey development and pre-testing, and then one sampling prior to beginning experimental flows, the year of the fluctuating flows, and two years following the fluctuating or experimental flows.

Cost: $50,000 a year, for five year, for a total of $250,000.

Long Term Monitoring of River Rafting Recreation Demand in Grand Canyon

In cooperation with Grand Canyon National Park, private and commercial names and addresses could be provided to sample: (a) people that have taken trips; (b) privates on the waiting list. Those that have taken trips would be asked to fill out the same type of survey as those that were intercepted at the take out points. This would allow continuous monitoring of privates and commercials. The names and addresses of commercial passengers are provided by the companies as part of the lawsuit settlement over the private rafting permits. Privates that have not received a permit will be surveyed to understand the motivations for applying for a permit, what their expectations are regarding a trip, and their willingness to pay for a permit.

Time Frame: Annual, routine monitoring during non-experimental flow periods would be continuous, as monitoring is required by the Grand Canyon Protection Act.

Cost: $ 35,000 a year for survey printing, mailing, data entry and analysis.

APPENDIX

EXPERIMENTAL DESIGN, LONG-TERM SEQUENCE OF TREATMENTS

Water Year	**Fluctuating Flows (Jan – Mar)**	**Mechanical Removal (Aug – Dec)**	**Stable Fall Flows (Aug – Dec)**	**TCD (Future)**	**BHBF (Jan – Jul)**
WY2002-03	Yes	Yes	Yes	No	?
WY2003-04	Yes	Yes	No	No	?
WY2004-05	No	Yes	Yes	No	?
WY2005-06	No	Yes	No	No	?
WY2006-07	No	No	Yes	No	?
WY2007-08	No	No	No	No	?
WY2008-09	Yes	No	Yes	No	?
WY2009-10	Yes	No	No	No	?
WY2010-11	Yes	Yes	Yes	Yes	?
WY2011-12	Yes	Yes	No	Yes	?
WY2012-13	No	Yes	Yes	Yes	?
WY2013-14	No	Yes	No	Yes	?
WY2014-15	No	No	Yes	Yes	?
WY2015-16	No	No	No	Yes	?
WY2016-17	Yes	No	Yes	Yes	?
WY2017-18	Yes	No	No	Yes	?