# GCMRC's Proposed Experimental Flow Options for the Colorado River Ecosystem in Water Year 2005 and Beyond

## [for Consideration and Discussion by the Glen Canyon Dam Technical Work Group]

## May 3, 2004

### INTRODUCTION

In December 2002, U.S. Secretary of Interior Norton approved an adaptive management experiment to be conducted in Grand Canyon National Park. This experiment, recommended by the Glen Canyon Dam Adaptive Management Program (AMP) and the Grand Canyon Monitoring and Research Center (GCMRC), began in January 2003 and consists of elements designed to provide a better and more integrated understanding of both sediment and fisheries resources. The GCMRC originally proposed a five-treatment experimental design that encompassed 16 years of experimentation (Table 1). The AMP recommended and Secretary Norton approved the first 2 years of this experimental design, and determined that the GCMRC and the AMP's Technical Work Group (TWG) would determine subsequent annual treatments towards attaining an effective long-term experimental design. Recent review of the original experimental design by the AMP's Science Advisors suggested that the design was perhaps unduly complicated and would benefit from some level of simplification. Therefore, GCMRC is responding to these suggestions by providing a simplified design contained in this document to form a foundation for discussions and experimental design planning with the TWG during their May 3-4, 2004 meeting and beyond.

### LONG TERM EXPERIMENTAL DESIGN

**Fisheries**

A number of factors are speculated to be responsible for the recent decadal decline in the survivorship and recruitment of the humpback chub population below Glen Canyon Dam. These factors include: 1) Colorado and Little Colorado River hydrology, 2) infestation of juvenile HBC by Asian tapeworm, 3) predation by or competition with warm-water native cyprinids and catastomids and non-native cyprinids and ictalurids within the Little Colorado River, 4) predation by or competition with cold-water non-native salmonids within the Colorado River mainstem, 5) near shore-line habitat alteration that includes back-waters, and 6) reduced growth rates associated with colder temperatures. Of the total number of factors identified, only a few can be effectively controlled for in a large-scale experimental manipulation. For this reason the scope of this experiment is focused on treatments applied in the Colorado River mainstem to address two prevailing hypotheses regarded as possible causal mechanisms responsible for the recent decadal decline in the survivorship and recruitment of the humpback:

1) predation/competition is contributing to the decline of humpback chub,

and

2) change in physical habitat (flows and temperature) is contributing to the decline of humpback chub.

These two factors are identified as affecting humpback chub in the U.S. Fish and Wildlife Services' biological opinion.

**Fine Sediment**

The fundamental sediment experiment is considered event driven based on uncontrolled hydrological factors that influence tributary sediment supply from the Paria River and export of such inputs relative to monthly release volumes from the dam. The underling strategy is to deposit available sediment at high elevations with a short-term high discharge under sediment enriched conditions. Because of current regulatory restrictions, this high discharge event can occur only during the months of January - July. However, sediment enriched conditions following Paria River inputs typically occur August – October. Therefore, the original experimental design contained operational elements to conserve fall sediment inputs until a January Beach Habitat Building

Flow (BHBF) could occur. Two different strategies have been identified to conserve sediment input during fall: 1) low stable flows that minimize sediment transport (sand conservation), and 2) short-duration, power-plant capacity releases immediately following Paria River inputs that are intended to load eddies with new sand under non-steady flows prior to a controlled flood greater than power plant capacity during the following January. Both of these tests (Scenarios #1 & 2) focus on the question of whether or not a solely operational strategy exists for restoring and maintaining sand habitats within the critical upper one-third of the Colorado River ecosystem? An additional strategy (Scenario #3) recommended by USGS sediment scientists consists of releasing a controlled flood greater than power plant capacity immediately following sand inputs from the Paria River. Under the currently approved design, a test of this strategy can only occur if such tributary floods occur during January through June.

**Modified Blocked Experimental Design**

Following development of the initial long-term experimental design, concerns were raised regarding confounding effects associated with the degree of complexity of testing multiple factors, as well as effects from uncontrolled factors. In an attempt to achieve greater simplicity in the design, the GCMRC staff proposes decoupling the fisheries portion of the integrated experiment from the sediment experiment while maintaining key element of the original 16-year blocked design (Table 2) including 2-fixed treatment effects and 2-random treatment effects (described below). The scheduled arrangement of the individual treatments allows for an analytical method to determine the effects of each factor alone or in combination with other factors on humpback chub recruitment and sediment response.

## PROPOSED EXPERIMENTAL TREATMENTS

**Flow Treatment, Fixed Effect (Jan – Mar, Aug – Dec)**

The GCMRC recommends that the flow treatment consist of two alternating flow regimes 1) high fluctuating flows, and 2) stable flows. These flow patterns are scheduled to occur in two-year alternating blocks, and are to be applied consistently over the duration of the 16-year experimental period.

The fluctuating flow regime is similar to the operational constraints that are identified for the High Fluctuating Flow (HFF) alternative in the EIS for operations of Glen Canyon Dam (BOR 1995). The GCMRC recommends that the TWG consider, as an alternative to the original design, that fluctuating flows occur seasonally during winter and early spring (January through April), followed again during the late summer and fall (August through December). Under this approach, daily and hourly operations would maximize the range in flow release (constrained only by annual forecasts and water deliveries), ramp rates for the ascending release are to be unrestricted, and the descending release is to range between 4,000 to 5,000 cfs. The daily maximum release would not to exceed 31,000 cfs, and the minimum release would not go below 5,000 cfs.

The stable flow regime would consist of a constant flow release based on monthly projected volumes. The GCMRC recommends high, stable flows during winter-early spring, and low, stable flows during the late summer–fall season. As Upper Basin hydrology will allow, the late summer–fall (August through December) is to remain at a low constant level of 8,000 cfs (± 1,000 cfs). This provides stability in near shoreline and backwater habitat and conditions for sediment conservation if tributary sand inputs occur. During the application of this stable treatment, differences in projected monthly flow volumes (low or high water years) are to be back-calculated and offset in preceding winter-early spring releases. A constraint to flow stability is to be maintained within but not among months during the winter-early spring period.

The GCMRC proposes that the summer operations (May through July) remain consistent through all treatments during both fluctuating and stable flow effects. Flow patterns are to follow existing flow guidelines identified in the Modified Low Fluctuating Flow alternative (MLFF) (BOR 1995). The overall flow treatment among all years provides for a combination of maximum load following during the application of the fluctuating treatment. Combinations of fluctuating and stable flows provide a means to determine how physical habitat influences reproduction and young-fish survivorship for both native and non-native fishes. Additionally, recreational use is not hampered during most of the summer period owing to MLFF being implemented consistently as a control.

**Mechanical Removal Treatment, Fixed Effect (Jan – Mar & Jul - Sept)**

The ongoing mechanical removal of non-native fish program will continue in 4 year blocks as originally proposed (Coggins *et al* 2002, Coggins and Yard *in Review*). This experimental manipulation has been

implemented in an attempt to better understand interactions between native and non-native fishes (see hypothesis above), particularly non-native coldwater salmonids and the Federally endangered humpback chub.

**Temperature Treatment, Random Effect**

As originally designed by the GCMRC in 2002, the temperature treatment was scheduled as two 8-year blocks. The thermal regime in the first 8-years was to have remained at normal conditions that represented cold, seasonally constant temperatures that were typical of this system. The latter block was to consist of temperatures that were seasonally warmed over the remaining portion of the experiment. This scheduled time lag for applying treatment effects allowed for development of the appropriate temperature control device (TCD) design, environmental compliance, construction, installation, and implementation. Currently, it remains uncertain when the entire TCD will be fully operational.

This is important because the effect of each treatment on the response of the experimental unit must be approximately the same from block to block. The consistency in treatment effect among blocks requires recognition and commitment by managers to avoid inconsistencies in the application of treatment effects throughout a long-term experiment. A departure from this invariably makes it more difficult to detect differences or to be able to separate out treatment effects among alternate treatments.

Unfortunately, in an ecological setting certain treatment effects are not entirely uncontrollable. This has been problematic owing to unexpected temperature increases in the Colorado River mainstem due to recent drought conditions, reduced inflows, and changes in the reservoir elevation. Additionally, the construction and initial testing of the TCD is currently recommended by the AMP Science Advisors to be incrementally scheduled and phased in over multiple years in the near future. For this reason, the TCD treatment should be considered more as a random variable in the first 8-years as an incremental titration.

**Beach Habitat Building Flow, Random Effect (January)**

Owing to the fact that there is no certainty as to which years the Colorado River ecosystem will be subject to sand inputs from the Paria River, it is impossible to implement the sand conservation tests under anything but a random fashion. While several key hypotheses remain to be tested with respect to sand bar restoration and maintenance, there is substantially less need for replication of the proposed treatments than exists for the fishery related treatments. The basic question to be answered regarding sand-based habitats is whether or not the desired objectives can be achieved under the highly limited sand supply conditions that exist below the dam.

## DISCUSSION

Although relevant sand-based issues may be mostly addressed within one to three flow-based scenarios, conducting a large scale-manipulation is hampered by two recurring problems: a lack of complete independence among the biological experimental units (e.g. recruitment response) to treatment effects, and a lack of a control. Relative to humpback chub recruitment, lack of independence is confounded by variability in growth among age-classes such that actual age must be estimated from pooled length-age relationships. There is then variability in the annual recruitment response because a particular age-class may be partially assigned to incorrect cohorts. Lastly, there is no secondary river system that can be used as an effective independent control to assess recruitment responses under reference conditions in absence of applied treatments.

The blocked design provides a means to experimentally test multiple hypotheses using large-scale and long-term manipulations of the Colorado River mainstem. This is always problematic in an ecological setting because certain environmental factors are not entirely controllable (i.e., inter-annual differences in hydrology, sediment supply, and temperature in the mainstem). For this design to be effective, treatment factors must be applied consistently among and within scheduled blocks. This is important because the effect of each treatment on the response of the experimental unit must be approximately the same from block to block. Therefore, consistency in treatment effect among blocks requires recognition and commitment by managers to avoid inconsistencies in the application (time and intensity) of treatment throughout a long-term experiment. A departure from this implementation approach invariably makes it more difficult to detect differences or to be able to separate out treatment effects among other alternate treatments.

The proposed design elements address both sediment and fisheries resources. However, because the sediment treatments are event driven relative to enriched conditions following a tributary input and the treatments relative to fisheries follow a more structured design, the revised design outlined here decouples these treatments to some degree. The intersection of the fisheries and sediment experiments is during the fall when the

fisheries treatment may call for either stabilized flows or fluctuating flows depending on the year. During this same time period, the system may either be in an enriched sediment condition following significant Paria River input, or in a reduced sediment condition assuming no inputs. If sediment inputs occur during a scheduled stable flow year, sediment Scenario #1 (see above) would be pursued. Alternately, Scenario #2 would be pursued under enriched conditions during a scheduled fluctuating flow year. Scenario #3 would continue to be an option for testing in any year in which Paria River sand inputs meet or exceed the required triggering thresholds in the January through July timeframe.

## LITERATURE CITED


Coggins, L.G., M.D. Yard, and C. Paukert. 2002. Piscivory by non-native salmonids in the Colorado River and an evaluation of the efficacy of mechanical removal of non-native salmonids. USGS, Grand Canyon Monitoring and Research Center, Flagstaff, AZ.

Coggins, L.G., and M.D. Yard. *In Review*. Mechanical removal of non-native fishes in the Colorado River in Grand Canyon: Update of winter 2003 operations and findings. Grand Canyon Monitoring and Research Center. Flagstaff, Arizona. 69 pp.

U.S. Bureau of Reclamation. 1995. Operations of Glen Canyon Dam Colorado River Storage Project Act. Final Environmental Impact Statement. Department of the Interior, March 1995. 337 pp.

**Table 1.** Original experimental design with 4 fixed factors and 1 random factor (Beach Habitat Building Flow).

IMPLEMENT TREATMENT DO NOT IMPLEMENT TREATMENT

| Water Year | Increased Fluctuations In Daily Flows (Jan – Mar) | Mechanical Removal of Rainbow Trout in GC (Jan-Mar, Jul - Dec) | Stable-Low Flows in Fall (Aug – Dec) | Temperature Control Device (Future) | Beach Habitat Building Flow (Jan – Jul) |
|---|---|---|---|---|---|
| WY2002-03 | | | | | |
| WY2003-04 | | | | | |
| WY2004-05 | | | | | |
| WY2005-06 | | | | | |
| WY2006-07 | | | | | |
| WY2007-08 | | | | | |
| WY2008-09 | | | | | |
| WY2009-10 | | | | | |
| WY2010-11 | | | | | |
| WY2011-12 | | | | | |
| WY2012-13 | | | | | |
| WY2013-14 | | | | | |
| WY2014-15 | | | | | |
| WY2015-16 | | | | | |
| WY2016-17 | | | | | |
| WY2017-18 | | | | | |

**Table 2.** Proposed modified experimental design with two fixed factors (Flow Treatment and Mechanical Removal) and two random factors (TCD/Low Reservoir Releases and Beach Habitat Building Flow).

| Water Year | Flow Treatment (Jan – Apr, Aug– Dec) | Mechanical Removal of Rainbow Trout in GC (Jan-Mar, Jul - Dec) | Temperature Control Device/Low Reservoir Releases | Beach Habitat Building Flow (Jan – Jul) |
|---|---|---|---|---|
| WY2002-03 | Fluctuating | Remove Fish | Random | Event Driven |
| WY2003-04 | Fluctuating | Remove Fish | Random | Event Driven |
| WY2004-05 | Stable | Remove Fish | Random | Event Driven |
| WY2005-06 | Stable | Remove Fish | Random | Event Driven |
| WY2006-07 | Fluctuating | Do Not Remove Fish | Random | Event Driven |
| WY2007-08 | Fluctuating | Do Not Remove Fish | Random | Event Driven |
| WY2008-09 | Stable | Do Not Remove Fish | Random | Event Driven |
| WY2009-10 | Stable | Do Not Remove Fish | Random | Event Driven |
| WY2010-11 | Fluctuating | Remove Fish | Random | Event Driven |
| WY2011-12 | Fluctuating | Remove Fish | Random | Event Driven |
| WY2012-13 | Stable | Remove Fish | Random | Event Driven |
| WY2013-14 | Stable | Remove Fish | Random | Event Driven |
| WY2014-15 | Fluctuating | Do Not Remove Fish | Random | Event Driven |
| WY2015-16 | Fluctuating | Do Not Remove Fish | Random | Event Driven |
| WY2016-17 | Stable | Do Not Remove Fish | Random | Event Driven |
| WY2017-18 | Stable | Do Not Remove Fish | Random | Event Driven |