Proposed

Two-Year Science Plan

for

Experimental Flow Treatments and Mechanical Removal Activities in WY's 2002-2004

PREPARED BY THE GRAND CANYON MONITORING AND RESEARCH CENTER

for

Glen Canyon Adaptive Management Program

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Proposed GCMRC Science Plan for Experimental Flow Treatments and Mechanical Removal Activities for WY 2002-2004

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Two-Year Science Plan for Experimental Flow Treatments and Mechanical Removal Activities in WY's 2002-2004

Introduction

This plan describes a conceptual framework, which identifies priority project areas for research and monitoring related to experimental flows and mechanical removal of non-naive fishes. It is not intended to provide highly detailed methodologies for accomplishing the research and monitoring. The plan assumes that normal core monitoring activities conducted by GCMRC as part of the Glen Canyon AMP will be completed and indeed may provide much of the necessary information to evaluate the effectiveness of the treatment scenarios.

In response to a motion passed by the Adaptive Management Work Group at their January 2002 meeting a series of treatment scenarios for WY2002-03 was developed by the Grand Canyon Monitoring and Research Center in conjunction with the Technical Work Group (GCMRC, 2002). At their April 24, 2002, meeting, the Adaptive Management Work Group reviewed these scenarios and made their recommendation for implementing Experimental Flows and Mechanical Removal of salmonids in the LCR reach of the Colorado River Ecosystem. The Bureau of Reclamation has forwarded the AMWG recommendation to the Secretary of the Interior via the Assistant Secretary for Water and Science. The Secretary's decision on that recommendation is expected during summer of 2002.

The treatments recommended by GCMRC and adopted by the AMWG for WY 2002 – 2004 are intended to: (1) decrease downstream export of tributary input sediment from Marble Canyon, (2) increase retention of sediment through High Flow Experiments (HFE), (3) improve survival and recruitment of HBC by reducing competition and predation from non-native fish (primarily rainbow trout) and (4) improve and maintain habitat for young native fish.

Within the recommended experimental flow scenario for WY 2002 – 2003, GCMRC is recommending a series of treatments, depending on the timing of and whether or not one gets significant sediment inputs, that combine low flows to reduce sediment export, HFEs to enhance sediment storage, and high fluctuating flows to disadvantage non-native fish. This latter flow pattern will potentially improve the growth of salmonids by reducing density in the Lees Ferry reach and reduce predation or competition by rainbow and brown trout on the endangered humpback chub in the LCR reach. Integrated science studies are also being designed to document relationships between terrestrial sand-bar dynamics and vegetation and impacts to cultural and recreational resources within Grand Canyon.

In addition, GCMRC has provided a first draft of a larger set of experimental flows that can serve as a starting point for working with the Science Advisors, the TWG, and other stakeholders to develop a longer term program of experimental flows. This long term implementation plan was part of the AMWG motion passed April 24, 2002.

The implementation of treatment activities could begin as early as September, 2002. GCMRC is undertaking preliminary work necessary to enable effective implementation of proposed treatments pending their approval by the Secretary. An essential element of that preparation is the development of a Science Plan which will identify necessary research and monitoring activities needed to evaluate the effects of proposed treatment actions. This document represents the proposed Science Plan and is intended to form the basis for implementation of the plan by the GCMRC. The Science Plan links the hypotheses to be tested with project descriptions which are in turn related to Goals and Management Objectives for the AMP.

Background

A detailed description of the experimental flow recommendations made to the Secretary and the rationale for those recommendations is contained in Version 4.0 of a document entitled "Treatment Scenarios for Water Year 2002-2003" developed by GCMRC in consultation with the TWG and presented to the AMWG on April 24, 2002. The general working hypotheses which resulted in the preferred treatment scenario recommendation from the AMWG are as follows:

Fine Sediment (Mass Balance and Sand Bar Dynamics**) -** Monitoring data indicate that tributary inputs of ***sand*** (sediment with grain sizes ranging from 63 to 2,000 microns) do not accumulate within the river channel over multi-year periods as predicted by the final EIS, and that such inputs are transported out of the Colorado River Ecosystem within less than one year under most ROD operations (Rubin et al., 2002; Rubin and Topping, 2001; Topping et al., 2000a; 2000b). On the basis of results from the summer 2000 flow experiment, as well as historical sediment-transport data, new inputs of sand should be retained more effectively within main channel storage sites during extended periods of dam releases at or below about 10,000 cfs (Rubin et al., 2002; Rubin and Topping, 2001; Topping et al., 2000a; 2000b). If such operations promote retention of sand (and finer sediment as well), then implementation of a HFE following such periods should greatly increase the effectiveness of such flows in restoring and maintaining terrestrial sand bars and related resources.

More efficient retention of fine sediment and silt prior to HFEs is hypothesized to result in more rapid rates of sand bar deposition, as well as sand bars with finer grain-size distributions. Finer-textured sand bars may be less prone to rapid erosion following bar building, as well as retain a higher level of nutrients contributed to the main channel by tributaries. Such improved bar characteristics may enhance the longevity of recreational camping areas, and improve chances for on-going in-situ preservation of cultural sites. Enhanced conservation of tributary sediment inputs in the channel should result in elevated suspended-sediment concentrations during HFEs, leading to rapid depositional rates during sandbar building. Elevated rates of sandbar deposition should reduce the required duration for HFEs, and hence will limit spill volumes. If sand bar deposition is significantly enhanced by implementing HFEs when the ecosystem's sediment supply is greatly enriched (resulting in sustainability of finer, more stable bars), then perhaps the

frequency for making such releases is simply linked to timing of tributary inputs, rather than strictly basin hydrology.

Coarse Sediment (Inputs, Impacts and Reworking) – Ongoing debris flows from drainages tributary to the Colorado River ecosystem continue depositing coarse sediment into the main channel. The direct and indirect impacts and influences on the ecosystem continue to be monitored annual with respect to aggradation of rapids and debris fans, as well as impacts to terrestrial and aquatic habitats. Efforts to better document the relationships between distribution and fate of trout redds and coarse bed-material transport will be studied during the flow experiments as a natural extension of the ongoing Advanced Conceptual Modeling project, being conducted as a collaboration between USGS and Ecometric Research. High flow experiments provide opportunities to document the degree to which these coarse-sediment deposits can be reworked by operations from Glen Canyon Dam. Limited studies of debris fan and rapid reworking are proposed in this science plan for the first, and possible the second years of experimental flows in WY 2002-04.

Native and Non-Native Fish - The Little Colorado River (LCR) population of humpback chub (HBC) has not demonstrated a positive response to the mainstem flow regimes under ROD operations. In contrast, the population of rainbow trout in Lees Ferry and the populations of rainbow and brown trout in the mainstem below the Paria River appear to have shown a positive response as reflected in increased abundance. Within the ROD, there is a need to implement experimental flows, which may improve survival and recruitment of HBC. The LCR population of HBC is comprised of fish resident in the LCR and in the mainstem near the LCR confluence. Therefore flows, which affect changes in HBC status in the mainstem, may positively influence the overall LCR HBC population.

Recent analyses of historical humpback chub (HBC) data suggest that the abundance of the Little Colorado River (LCR) population of HBC is in decline; Grand Canyon Monitoring and Research Center (GCMRC) unpublished analyses). These analyses utilized mark-recapture data in an open population model to construct estimates of the population recruitment (1989-1997 brood years) and sub-adult and adult abundance (>150 mm total length; 1991-1999). The decline in the abundance of sub-adult and adult fish appears to be the result of continued low recruitments beginning with the 1992 brood year. As these weak year classes have entered the sub-adult and adult portions of the population, the overall abundance of HBC has declined from a peak of 8,517 in 1993 to 3,388 in 1999. The overall trends in recruitment and abundance are supported by two additional analyses. First, the downward recruitment trend is supported by trends observed in the catch-rate (CPUE) of Age-1 and Age-2 HBC from hoopnet sampling in the LCR (GCMRC unpublished analyses). Second, a closed population mark-recapture experiment conducted in the LCR during the spring of 2001 indicated the population contained only 2,090 (95% C.I. 1611-2569; HBC >150 mm total length; USFWS *in prep*.). Combined, these three independent analyses provide sufficient evidence to conclude that the Little Colorado River population of HBC is in decline.

Of paramount importance in conserving this population of federally endangered humpback chub is determining the factors contributing to this population decline and implementing management actions designed to minimize the effect of those factors. Although it is still unclear all of the factors that may be responsible for the recruitment decline beginning in 1992, we have identified a list of likely factors that could be acting either singly or in combination. 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 LCR, and 4) predation by or competition with cold-water non-native salmonids within the Colorado River.

The body of evidence available to evaluate specific hypotheses varies among the postulated factors. For instance, beginning in August 1991 the operation of Glen Canyon Dam was changed to reflect the so-called "interim operating criteria." This hydrology, and the subsequent ROD flows that continue to present, can be generally characterized as having less severe daily flow fluctuations than the previous 28 years of load-following hydrology. Temporally, this major change in Colorado River hydrology correlates closely to the decline in HBC recruitment. Additionally, it is possible that the initial decline in HBC recruitment in 1992 was caused by the nearly continuous flooding in the LCR that occurred during the summer of 1992, particularly during the early summer time period when larval HBC emerge (Robinson et al. 1998). It is also possible that the high infestation rate of juvenile HBC by the introduced parasite Asian tapeworm is a causative factor. HBC infected with Asian tapeworm were first found during 1990, and infestation rates during 2001 have exceeded 90% (Anindo Choudury, pers. comm.). Finally, predation and competition by fishes either within the LCR or in the Colorado River may be driving the HBC recruitment trend. Although robust relative abundance data does not exist for non-native fishes within the LCR, there has been a large increase in the abundance of non-native salmonids in the Colorado River near the confluence of the LCR (LCR Inflow Reach RM 56.6-68.3; Gorman and Coggins, 2000).

While it is difficult to determine which factor is most responsible for the HBC recruitment decline, a likely significant factor is negative interactions (predation and competition) with non-native fish. Interaction with non-native fish is implicated in the decline and extinction of native fishes throughout the Colorado River basin (Tyus and Saunders, III 2000 and references therein). Indeed, after being presented with the recent analyses describing the decline in the LCR HBC population, the Glen Canyon Dam Adaptive Management Work Group (AMWG) passed motions to begin planning and to conduct feasibility studies to reduce non-native fish abundance in the Little Colorado River and Bright Angel Creek. Finally, it is plausible that the predation/competition hypothesis could overwhelm any benefits derived from management flow prescriptions intended to provide beneficial habitat conditions.

GCMRC believes the benefits to native fish will accrue indirectly through a reduction in predation/competition by non-native fish, primarily salmonids in the LCR reach. The model developed by Dave Speas and Carl Walters provides support for high fluctuating flows to reduce the number of RBT by interfering with and disrupting spawning activity

and/or reducing the recruitment of young fish. This model and data pertaining to the impacts of fluctuating flows are most relevant to the Lees Ferry reach where targeted reduction in trout numbers is also thought to be desirable. Unpublished and published (Maddux et al. 1987; McKinney et al., 1999) data from AGFD and GCMRC indicate that spawning is most frequent in January to March. In addition the amount of recruitment in the Lees Ferry rainbow trout population is most strongly correlated with fluctuating flows in this same period and the range of those fluctuating flows. The correlations are negative which means the lowest recruitment corresponds to fluctuating flows in these months. Similarly, the greater the degree of daily fluctuation, the lower the recruitment. It is reasonable to assume that these relationships are similar in the LCR reach although timing of spawning could be different.

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

Proposed Treatment Scenarios (#1 and #2)

These scenarios provide for experimental flows aimed at both conserving sediment and benefiting native fishes. Treatments will be conducted during both WY's 2003 and 2004. Through August 2002, the dam follows normal ROD operations. Following significant[1] sediment inputs in the September - December 2002 period, and beginning as early as September 1, 2002, the dam would release alternative 2-week periods of constant 8,000 cfs and fluctuating 6,500 cfs to 9,000 cfs until January 2003. In January 2003, a HFE[2] of limited duration is conducted. This is followed by high experimental fluctuating flows with a daily range of 5,000 cfs to 20,000 cfs for the main portion of the non-native spawning and emergent/juvenile season (January through March). From April – September 2003, operations would follow monthly volumes under the ROD. Concurrent with the experimental flow treatment, mechanical removal of rainbow and brown trout in

[1] These are defined as inputs from the Paria River of at least 500,000 metric tons of sediment after July 1. Continuation of the Scenario 1 experiment past October 31 would be dependent on cumulative total Paria River sand inputs of at least 1.4 million metric tons. Implementation of a January HFE would require retention of at least 1,000,000 (+/- 20 percent, for measurement uncertainty) metric tons of sand in the reach above the Little Colorado River. For purposes of the HFE triggering decision, the start point for estimating total accumulated sand storage in Marble Canyon shall be September 1st.

[2] In every scenario where a HFE is proposed to be released in 2003 or 2004, the HFE should have a magnitude of at least 10,000 cfs above peak power-plant discharge or higher, depending on lake elevation.

the LCR reach (described below) would be implemented. This overall treatment (flows and mechanical removal) has the most potential to result in measurable responses, which improve the Lees Ferry trout fishery, reduce non-native predation/competition on native fish in the LCR reach, enhance native fish habitat, and increase sediment retention in the CRE.

The flow treatment related to testing fish hypotheses center around the notion of improving future humpback chub (HBC) recruitment by reducing the number of adult rainbow trout (RBT) and brown trout (BNT) residing in the system downstream of Lee's Ferry. Conceptually, this is to be accomplished primarily by reducing RBT and BNT recruitment by increasing the early life mortality rate of these fishes with highly fluctuating flows during their winter and spring spawning and rearing seasons. The other experimental treatment calls for the reduction of adult RBT and BNT abundance in the Colorado River mainstem (MCR) near the confluence of the Little Colorado River (LCR) via electrofishing and mechanical removal.

The LCR Inflow reach is recognized for having the highest abundance of adult and juvenile HBC in the Colorado River mainstem (Valdez and Ryel 1995). We have selected a sampling reach (56.2 RM - 65.7 RM) that encloses the majority of this population (see attached map). The proposed sampling effort will be uniformly distributed within this reach. The upstream and downstream endpoints are bounded by hydraulic and geomorphic control; however, it is not impermeable to system-wide fish movement (Stevens et al. 1997). We are proposing to conduct annually, three depletion trips in January-March and three depletion trips in July-September. The effort would also yield information regarding abundance of YOY HBC during this period and be complimentary to existing monitoring efforts.

Specific Proposed Action

The action proposed is an integrated ecosystem treatment that combines experimental flows to conserve sediment and improve native fish habitat with flows intended primarily to disadvantage non-native salmonid fishes in the CRE. The latter flow treatment is coupled with the mechanical removal of salmonids to reduce likely competition with and predation on native fish-particularly Humpback chub. Because this is an integrated ecosystem treatment aimed at learning more about conserving several key resources it involves tradeoffs when compared to a treatment which might optimize for a single resource, e.g. sediment.

Experimental Treatment Scenarios Project Overview

The Science Plan is intended to describe the suite of additional research and monitoring activities thought to be desirable, feasible, and necessary to interpret and understand the effects of the foregoing treatment scenarios on key resources in the CRE over an approximate two year period beginning in September (mechanical removal) or September

(sediment flows) 2002. The projects identified below are in addition to or represent an expansion of on-going research and monitoring activities already approved in GCMRC's FY02 and FY03 Work Plans. As such, these activities will require additional funding to complete. GCMRC is proposing to complete the following projects through increased activities of existing contractors and cooperators as well as through engagement of additional on-site contractors. Projects have been grouped to correspond with the elements of the annual treatment scenario as follows:

I. Primary Sediment Treatment (September through December flows)
II. Secondary Sediment Treatment (HFE contingent upon minimum sand inputs and accumulation within Marble Canyon, river miles 1-61)
III. Post-High flow experiment Treatment (January to April fluctuating flows)
IV. Non-Flow Treatment (mechanical removal of non-native fishes, primarily salmonids)

The experimental flows and mechanical removal treatments, described above and in more detail in other documents, are intended to be the first treatments in a longer series of management actions implemented experimentally. Many of the treatments and ultimately the overall multi-year experiment have hypotheses associated with their possible effects. In some cases these hypotheses may be testable almost immediately (e.g. sediment). However, in other cases, and particularly with regard to biological responses, testing these hypotheses may take several years owing to life cycles of fishes involved, sampling strategies, etc. Finally, some projects undertaken may only result in descriptive data which are not useful in the statistical sense of testing hypotheses but may yield valuable information regarding ecosystem responses.

The implementation of research and monitoring activities associated with the Experimental Treatment Scenarios over the next two years will represent a substantial undertaking by GCMRC, its cooperators and contractors. A summary of individual projects and their association with AMP goals and management objectives, as well as the projected cost of each project is provided in Table 1. The final column in this table ranks projects relative to GCMRC's perception of their importance in providing information critical to making management recommendations by AMWG. A synopsis of the hypotheses to be considered by each project is provided in Table 2. More detailed individual project descriptions are found in the following section of the science plan.

TABLE 1. BUDGET SUMMARY FOR EXPERIMENTAL FLOWS WITH SEDIMENT INPUTS

Project Titles, Funds Required, AMP Goals & MO's, & Funding Priority			Prog Mgr	FY-02	FY-03	FY-04	TOTAL	AMP GOAL	AMP MO's	Funding Priority
1	Fine-Sediment Mass Balance, Parts A-E		Melis	113,000	438,000	420,000	971,000	Goal 8	MO's 8.1-8.6	High
2	FIST (Parts A-D, fine-sediment storage within integrated reaches)		Melis	60,000	750,000	500,000	1,310,000	Goal 8	MO's 8.1-8.6	High
3	State of Primary Productivity, Carbon Flux & Alteration of Food Base		Gloss	125,000	30,000	25,000	180,000	Goal 1	MO 1.1, 1.2	Medium
4	Near Shore Temperatures & Habitat Use Monitoring During LSF		Gloss	0	50,000	200,000	250,000	Goal 2	MO 2.2	High
5	Sediment-Transport Modeling Measurements		Melis	0	0	62,000	62,000	Goal 8	MO's 8.1-8.6	Medium
6	Coarse-Sediment Monitoring (Inputs, Impacts, and Reworking)		Melis	0	0	49,000	49,000	Goal 8	MO's 8.1-8.6	Medium
7	Kanab Ambersnail Compliance Monitoring		Gloss	0	10,000	10,000	20,000	Goal 5	MO 5.1	High
8	Foodbase Impacts of HFE Flows in Glen Canyon Reach		Gloss	0	50,000	50,000	100,000	Goal 1	MO 1.1,1.2	Medium
9	Monitoring of Rainbow Trout Adult Stranding and Mortality		Gloss	24,000	50,000	0	74,000	Goal 4	MO 4.1	High
10	Distribution of Trout Redds & Mechanism Accounting for Reduced Recruitment		Gloss	0	132,000	225,000	357,000	Goal 4	MO 4.1	Medium
11	Food Base Impacts of Fluctuating Flows		Gloss	0	60,000	60,000	120.000	Goal 1	MO 1.1, 1.2	Medium
12	Mechanical Removal of Non-Native Salmonids		Gloss	95,000	651,000	610,000	1,356,000	Goals 2 & 4	MO 2.7, 4.2	High
13	Rainbow Trout Diet Analysis at the LCR Confluence		Gloss	32,000	164,000	123,000	319,000	Goal 2	MO 2.7	High
14	Incidence of Predation of Humpback Chub by Rainbow & Brown Trout…		Gloss	0	58,000	58,000	116,000	Goal 2	MO 2.7	High
15	Monitoring for Effects of the Test Flows at Archaeological Sites		Lambert	0	25,000	25,000	50,000	Goal 11	MO 11.1, 11.2	High
16	Economic Studies		Lambert	0	20,000	0	20,000	Goal 9	MO 9.1	Medium
17	Changes in Campable Beach Areas		Lambert	0	0	25,000	25,000	Goal 9	MO 9.2	Low
18	Administrative Services			2,000	25,500	40,000	67,500			
19	Technical Support									
	A.	Computer Support - .5 Student		0	23,500	21,000	44,500			
	B.	Survey Costs - Equipment		0	55.000	32,000	87,000			
	Total			451,000	2,592,000	2,535.000	5,578,000			

Table 2. Proposed Research and monitoring Projects, Hypotheses, Estimated Cost, and Funding Priority

PROJECT NAME	HYPOTHESES TESTED/CONSIDERED	PROJECT COST	PRIORITY
1. Fine-Sediment Balance, Parts A & B	H_o ¯ Sand-transport and silt-transport rates, are not significantly different under stable flows of 8,000 cfs versus low fluctuating flows ranging between 6,500 cfs and 9,000 cfs. H_o - Paria River sand inputs during July and August 2002, are not subject to high transport rates through Marble Canyon (significant export) under scheduled power-plant operations. H_o - Paria River silt/clay inputs during July and August 2002, are not subject to high transport rates through Marble Canyon (significant export) under scheduled power-plant operations. H_o - Paria River sand inputs during September through December 2002, are not subject to high transport rates through Marble Canyon (significant export) under experimental low-flow operations. H_o - Paria River silt/clay inputs during September through December 2002, are not subject to high transport rates through Marble Canyon (significant export) under experimental low-flow operations H_o - Paria River sand inputs during July through December 2003, are not sufficiently accumulated within Marble Canyon eddies to meet the December triggering criteria for implementation of a January HFE. H_o - Paria River silt/clay inputs during July through December 2003, are not significantly accumulated within Marble Canyon eddies and will not contribute substantially to bar restoration even if a January HFE is implemented.	$ 971,000 Total for Parts A-E	High
1. Fine-Sediment Balance Part C	H_o - With respect to its grain size and concentration, the sand supply within Marble Canyon is not significantly depleted during the HFE. H_o - With respect to concentration, the silt/clay supply within Marble Canyon is not significantly depleted during the HFE.		High
1. Fine-Sediment Balance Part D	H_o - With respect to concentration, the sand-transport rates are not decreased following the HFE. H_o - With respect to concentration, the silt/clay-transport rates are not		High

PROJECT NAME	HYPOTHESES TESTED/CONSIDERED	PROJECT COST	PRIORITY
	decreased following the HFE.		
2. Fine Integrated Sediment Team (FIST) - Parts A and B	H_o - Fine-Sediment storage above 8,000 cfs is not decreased during low stable or low fluctuating flows (either 8,000 cfs constant releases or 6,500 to 9,000 cfs fluctuations). H_o - Fine-Sediment storage below 8,000 cfs is not increased during low stable or low fluctuating flows (either 8,000 cfs constant releases or 6,500 to 9,000 cfs fluctuations). H_o - Fine-Sediment storage between 5,000 and 31,500 cfs is not increased during normal ROD operations in combination with peak power-plant releases that follow Paria River sediment inputs from July through October. H_o - Fine-Sediment storage below 8,000 cfs is not decreased during normal ROD operations in combination with peak power-plant releases that follow Paria River sediment inputs from July through October.	1,310,000 Total for Parts A-D	High
2. Fine Integrated Sediment Team (FIST) – Part C	H_o - Fine-Sediment storage above 8,000 cfs within Marble Canyon is not increased compared with conditions measured following the 1996 flood experiment. H_o - Fine-Sediment storage below 8,000 cfs is not decreased compared with conditions measured following the 1996 flood experiment. H_o - Fine-Sediment deposits above 8,000 cfs in Marble Canyon do not have finer grain-size distributions (with respect to sand-sizes) when compared with sand bars deposited by the 1996 controlled flood experiment. H_o - Fine-Sediment deposits above 8,000 cfs in Marble Canyon do not have higher contents of silt/clay when compared with sand bars deposited by the 1996 controlled flood experiment H_o - Fine-Sediment storage between 8,000 and 25,000 cfs within Marble Canyon is not decreased below conditions measured in September 1996, following the 1996 controlled flood experiment and one summer of ROD fluctuations. H_o - Fine-Sediment storage above 25,000 cfs within Marble Canyon is not decreased below conditions measured in September 1996, following the 1996 controlled flood experiment and one summer of ROD fluctuations.		

PROJECT NAME	HYPOTHESES TESTED/CONSIDERED	PROJECT COST	PRIORITY
2. FIST C (cont'd)	H_o - Fine-Sediment grain size of channel-bed material below 8,000 cfs is not coarser than conditions measured in January, immediately following the HFE test. H_o - Fine-Sediment grain size of sand bar deposits above 8,000 cfs is not coarser than conditions measured in January, immediately following the HFE test. H_o - Total fine-sediment storage within Marble Canyon study sites is not less than conditions measured immediately following the HFE test. H_o - Total fine-sediment storage above 25,000 cfs stage elevation within Upper Marble Canyon study sites is not greater than conditions measured immediately prior to the HFE test. H_o - Total fine-sediment storage within Upper Marble Canyon study sites is not greater than conditions measured immediately prior to the HFE test. H_o - Fine-sediment deposits created by the experimental HFE do not possess cohesive properties similar to pre-dam deposits. H_o - Fine-sediment deposits created by the experimental HFE do not possess cohesive properties similar to prior post-dam deposits. H_o - Fine-sediment deposits created by the experimental HFE are not significantly reworked by wind. H_o - Fine-sediment deposited by the experimental HFE are not transported by aeolian processes to areas where recent gully erosion has exposed cultural sites. NOTE: Also see Socio-Cultural Studies, Part A below.		
2. Fine Integrated Sediment Team (FIST) – Part D	H_o - Fine-Sediment storage between 8,000 and 25,000 cfs within Marble Canyon is not decreased below conditions measured in September 1996, following the 1996 controlled flood experiment and one summer of ROD fluctuations. H_o - Fine-Sediment storage above 25,000 cfs within Marble Canyon is not decreased below conditions measured in September 1996, following		

PROJECT NAME	HYPOTHESES TESTED/CONSIDERED	PROJECT COST	PRIORITY
2. FIST, Part D (cont'd)	the1996 controlled flood experiment and one summer of ROD fluctuations. H_o - Fine-Sediment grain size of channel-bed material below 8,000 cfs is not coarser than conditions measured in January, immediately following the HFE test. H_o - Fine-Sediment grain size of sand bar deposits above 8,000 cfs is not coarser than conditions measured in January, immediately following the HFE test. H_o - Total fine-sediment storage within Marble Canyon study sites is not less than conditions measured immediately following the HFE test H_o - Total fine-sediment storage above 25,000 cfs stage elevation within Upper Marble Canyon study sites is not greater than conditions measured immediately prior to the HFE test. H_o - Total fine-sediment storage within Upper Marble Canyon study sites is not greater than conditions measured immediately prior to the HFE test. H_o - Down-ramping rates of 2,500 cfs per hour do not result in increased seepage erosion rates in newly created sand bars when compared with down-ramping rates of 1,500 cfs per hour. H_o: There are no significant changes in aeolian sediment deposition at the study sites as a result of the high flows. H_o: There are no significant changes in aeolian deposition at the study sites following the fluctuating flows		
3. State of Primary Productivity, Carbon Flux and Alteration of Food Base	H_0 - Primary production as measured by algal biomass before and after low fall flows will not differ in the Glen Canyon reach H_0 - Dissolved and particulate organic drift will not increase in the CRE H_0 - NZMS density in the Glen Canyon reach will not change as a result of LFF.	180,000	Medium
4. Near Shore Temperature and Habitat Use Monitoring During Low Steady Flows	H_0 - There is no difference in near-shore habitat for steady 8,000 cfs releases and low fluctuations (6,500 to 9,000 cfs) in terms of temperatures, velocities, turbidity, and nutrients. (The strength of this hypothesis	250,000	High

PROJECT NAME	HYPOTHESES TESTED/CONSIDERED	PROJECT COST	PRIORITY
	increases with concurrent collection of fish information.) H_o - There is no difference between the alternative flow sequences of the fall flow period with respect to juvenile fish behavior. H_o - There is no difference between the alternative flow sequences of the fall flow period for native and non-native fish abundance in near-shore areas.		
5. Sediment-Transport Modeling Measurements	H_o - Sand-Bar depositional rates within study eddies are invariant throughout the duration or the HFE and do not verify model-simulations relative to suspended-sediment concentrations and grain-size conditions measured during the high flow. H_o - Evolution of fine-sediment supply with respect to concentration and grain size do not verify 1-Dimensional sand routing model simulations. H_o - Rapid sand-bar failures do not occur during the 2.5-day long HFE.	62,000	Medium
6. Coarse-Sediment Monitoring (Inputs, Impacts and Reworking) 6. Coarse-Sediment (cont'd)	H_o - Coarse-grained sediments recently deposited on debris fans and within rapids are not significantly reworked during the rising limb of the HFE, as previously measured during the 1996 flood experiment (41,000 cfs versus 45,000 cfs peak discharges). H_o - Boulders transported from newly aggraded debris fans at 41,000 cfs are not deposited within pools immediately below debris fans and constricted rapids. H_o - Fine gravel-sized sediment from newly aggraded debris fans at 41,000 cfs are not redistributed to downstream channel elements.	49,000	Medium
7. Kanab Ambersnail Population	H_o - KAS density in habitat below HFE flows will not change as a result of the HFE flows. H_o - Available KAS habitat will not change as a result of HFE flows. H_o - Pre-HFE population estimates will not differ from estimates derived during routine monitoring in the fall.	20,000	High
8. Foodbase Impacts of HFE Flows in Glen Canyon Reach	H_o – The phyto-benthic community will not change in response to the HFE flows.	100,000	Medium
9. Monitoring of Rainbow Trout Adult Stranding & Mortality	H_o – No difference in the abundance of stranded adult rainbow trout in selected areas of the Lees Ferry reach will occur between the low fall flows (Nov-Dec) and fluctuating flows from Jan-March.	74,000	High

PROJECT NAME	HYPOTHESES TESTED/CONSIDERED	PROJECT COST	PRIORITY
10. Distribution of Trout Redds & Mechanism Accounting for Reduced Recruitment	H_o - Location of spawning redds does not change in relation to season or dam releases. H_o - Distribution and abundance of spawning redds is unaffected by the presence of fine sediment on the channel bottom. H_o - No difference in abundance of YOY RBT results from fluctuating flows. H_o - No seasonal difference exists between survival of YOY RBT H_o - No difference in survival of YOY RBT occurs between fish with access to fluctuating flow regime versus fish restricted below 5-8,000cfs.	357,000	Medium
11. Food Base Impacts of Fluctuating Flows	H_o – The phyto-benthic community will not change in response to the HFE operations.	120,000	Low
12. Mechanical Removal of Non-Native Fishes (Primarily Salmonids) from the Colorado River Near the Confluence with the Little Colorado River 12. Mechanical Removal (cont'd)	H_o - Mechanical removal of RBT and BNT using electrofishing methods is an effective method of reducing adult RBT and BNT abundance in the LCR Inflow reach. H_o - Abundance of adult RBT and BNT in the LCR Inflow reach prior to each removal event is similar. H_o - No changes occur in adult RBT and BNT size composition in response to removal events. H_o - Trout immigration (Seasonal and Annual) into the LCR Inflow reach between removal events is undetectable.	1,356,000	High
13. Rainbow Trout Diet Analysis at the LCR Confluence and in Glen Canyon Reach	H_o: There are no seasonal differences in trout diet use. H_o: There are no spatial (upstream versus downstream) differences in trout diet use. H_o: There are no size-class differences in trout diet use. H_o: Determine if differences in feeding patterns are related to flow characteristics.	319,000	High
14. Incidence of Predation on Humpback Chub by Rainbow and	H_o - There is no incidence of predation by RBT and BNT on HBC in the LCR reach.	116,000	High

PROJECT NAME	HYPOTHESES TESTED/CONSIDERED	PROJECT COST	PRIORITY
Brown Trout at the Confluence of the Little Colorado River, Grand Canyon	H_o - Incidence of predation is unrelated to size-class and other meristic characteristics (e.g., gape-width, body-depth, length) of both the predator and prey. H_o - The incidence of predation by RBT and BNT does not changes(±) in response to predator abundance. H_o - Particular cohorts are more vulnerable to predation due to differences in size, relative prey abundance or relative predator abundance.		
15. Monitoring for Effects of the Test Flows at Archaeological Sites	H_o - There are no significant changes in sediment deposition or erosion at the study arroyo sites as a result of the high flows. H_o - There are no significant changes in sediment deposition or erosion at the study arroyo sites as a result of the fluctuating flows.	50,000	High
16. Economic Impacts to Whitewater & Angler Concessionaires & Private Boaters and Anglers	H_o - Economic impacts to whitewater and angling concessionaires will not differ significantly from economic impacts under normal daily operations. H_o - Economic impacts to private whitewater boaters and anglers will not differ significantly from economic impacts under normal daily operations.	20,000	Medium
17. Changes in Campable Beach Areas	H_o - Campable beach areas during the proposed experiment will not differ significantly from campable beach areas under normal daily operations.	25,000	Medium

Project Descriptions

I. PRIMARY SEDIMENT TREATMENT (Low Flows)
(September through December of 2002, and July through December 2003, low flow period in 2002 for Treatment #1, with Treatment #2 focused on peak power-plant tests in 2003)

Project 1. Fine-Sediment Mass Balance, Parts A and B

Treatment #1 - Sediment mass balance to ascertain triggering for low fall flows.

Part A. - July through October 2002 - Commence with annually scheduled daily sediment-transport sampling along main channel and monitoring of tributary inputs, July 1st through October 15th. Costs are currently covered by core monitoring for cableway sampling, but an additional amount will be required to expand use of instrumentation along four main channel locations to provide high-resolution, continuous sediment-transport data for improving mass-balance estimates. Comparison of sediment-transport rates under stable versus low fluctuating flows shall begin with two weeks of constant 8,000 cfs releases on September 1, 2002, if Paria inputs have already reached 500,000 metric tons, or immediately following this level of sand input should it occur after September 1st. Alternating two-week periods of stable versus low, fluctuating flows shall be released through at least October to evaluate which of these two operations conserve the most sand and silt/clay. The additional intensive sediment monitoring work that may be required after October 15, 2002, is proposed through modifications of existing agreements with USGS, plus 2 new procurements in summer/fall 2002.

Part B - November through December 2002 - On the basis of sediment-transport measurements made in September and October (assuming that the sediment supply of the channel has been significantly enriched, see above), sediment scientists shall recommend which of the two low-flow operations should be continued from November through December 2002, to conserve the greatest volume of the Paria River inputs. This recommendation shall be made on the basis of whether or not daily transport rates for sand and silt are significantly different (outside of the range of measurement uncertainty) for the two test-flow operations.

December 2002 – If during December, sediment-transport data indicate (within known levels of measurement uncertainty) that sufficient sand has accumulated within Marble Canyon, then a recommendation shall be made to decision makers to implement testing of the HFE in early January 2003.

Methods – Please refer to currently funded USGS work plan on file at the GCMRC.

<u>Null Hypothesis Related to Sand and Finer-Transport Rates:</u>
(Dam Operations and Export of Paria River fine-Sediment Inputs)

<u>Hypotheses to be tested/considered</u>:

H_o - Sand-transport and silt-transport rates, are not significantly different under stable flows of 8,000 cfs versus low fluctuating flows ranging between 6,500 cfs and 9,000 cfs.

Regarding Treatment #2 (Peak power-plant releases in response to Paria River sand inputs instead of low flows). The mass-balance project would follow the same protocol during July through December 2003, except that the measurements would be made for mostly normal ROD operations, with perhaps one to several peak power-plant releases made in response to significant sand inputs from the Paria River between July and November. A decision point would still occur in December 2003, on the basis of whether or not sufficient sand accumulation had occurred within Marble Canyon over the course of the sediment-input season. If the threshold of sand accumulation is met, then a HFE would be released in early January 2004.

<u>Null Hypotheses Relating to Mass Balance Parts A & B:</u>
(Accumulation of Paria River fine-Sediment Inputs)

Treatment #1, High Fluctuations in July & August, Low Flows in September through December (either stable at 8,000 cfs or fluctuations from 6,500 to 9,000 cfs)

<u>Hypotheses to be tested/considered</u>:

H_o - Paria River sand inputs during July and August 2002, **are not** subject to high transport rates through Marble Canyon (significant export) under scheduled power-plant operations.

H_o - Paria River silt/clay inputs during July and August 2002, are not subject to high transport rates through Marble Canyon (significant export) under scheduled power-plant operations.

H_o - Paria River sand inputs during September through December 2002, are not subject to high transport rates through Marble Canyon (significant export) under experimental low-flow operations.

H_o - Paria River silt/clay inputs during September through December 2002, are not subject to high transport rates through Marble Canyon (significant export) under experimental low-flow operations.

Treatment #2 - Normal Scheduled Fluctuations in July through December 2003, along with one to several peak power-plant releases that coincide or closely follow significant Paria River sediment inputs.

<u>Additional Mass-Balance Hypotheses to be tested/considered:</u>

H_o - Paria River sand inputs during July through December 2003, are not sufficiently accumulated within Marble Canyon eddies to meet the December triggering criteria for implementation of a January HFE.

H_o - Paria River silt/clay inputs during July through December 2003, are not significantly accumulated within Marble Canyon eddies and will not contribute substantially to bar restoration even if a January HFE is implemented.

<u>Notes</u>:

1) Assuming that significant Paria River sand inputs have occurred and that the low-flow testing has been conducted, reach-integrated fieldwork shall be conducted by the FIST (Fine Integrated Sediment Team, composed of researchers from USGS, Utah State University and Northern Arizona University, (see below for details) in early to mid-December, regardless of whether the HFE threshold is met or not. These December measurements will still provide extremely valuable data as to how Paria River sediment inputs were distributed and stored in the main channel throughout Marble Canyon (upper versus lower reaches of this critical management reach). These field measurements will be made primarily within existing study reaches in Marble Canyon, and exclusively in reaches upstream of Phantom Ranch (river mile 87).

2) Comparison of the sand conservation achieved by Treatments #1 and #2 assume that similar minimum volumes of sand are input from the Paria River during the ’02 versus ’03 sediment season. There is a high likelihood that this assumption will be violated during the next two years, making direct comparison of these two treatments impossible.

3) Experimental testing of HFE in January requires a minimum accumulation of 1,000,000 metric tons (+/- 20 percent) within Marble Canyon. Similar sand volumes input by the Paria River during January through July 2003, may result in testing of HFE immediately (see alternative described with the GCMRC Treatment Scenarios document).

4) Cooperating sediment scientists have recommended that the period for determining accumulation of sand in Marble Canyon, relative to HFE triggering threshold, begin on September 1, 2002.

Project 2. FIST - Parts A and B - Fine Integrated Sediment Team
(Pre-HFE Sampling to measure and estimate bar shape, grain-size distributions and volumes)

Part A. - October 2002 - Intensive, repeat measurements of selected sand-bars and camping area assessments (44 sites using standardized sand-storage change-detection protocols between Lees Ferry and Diamond Creek. This work is mostly funded as part of FY2002 CORE monitoring.

Part B. - December 2002 - Field measurements shall be collected within a subset of 5 FIST reaches (reaches 2-6) during December 2002, in the event that the January HFE test is implemented. These field measurements will be repeated again in January 2003, if the HFE test occurs.

Aerial Photography - shall be flown in December 2002, and again in January 2003, within reaches 1-11, in the event that the HFE test is implemented.

Daily Oblique Photography – of FIST long-term sandbars shall occur regardless of whether the HFE test is implemented. These daily photographic data shall be collected following the HFE test as a means of documenting bar conditions prior to implementation of the January to April fluctuating-flow treatment.

All of the Part B work proposed above shall be accomplished through modifications of existing agreements with USGS, NAU, USU. During FY 2002-2003, sediment inputs from the Paria River were not sufficient to initiate an HFE test in January 2003, however the fluctuating-flow test is being implemented. In this scenario, the FIST shall make only measurements of sand-storage above 8,000 cfs.

Methods – Please refer to currently funded FIST work plan on file at the GCMRC.

Null Hypotheses Relating to FIST Part A and B:

Treatment #1, Response of Sand-Storage Conditions within Marble Canyon Under Low-Flows during September through December.

Hypotheses to be tested/considered:

H_o - Fine-Sediment storage above 8,000 cfs is not decreased during low stable or low fluctuating flows (either 8,000 cfs constant releases or 6,500 to 9,000 cfs fluctuations).

H_o - Fine-Sediment storage below 8,000 cfs is not increased during low stable or low fluctuating flows (either 8,000 cfs constant releases or 6,500 to 9,000 cfs fluctuations).

Treatment #2, Response of Sand-Storage Conditions within Marble Canyon Under ROD fluctuations + Peak Power-Plant Releases coincident with Paria River Floods

> H_o - Fine-Sediment storage between 5,000 and 31,500 cfs is not increased during normal ROD operations in combination with peak power-plant releases that follow Paria River sediment inputs from July through October.
>
> H_o - Fine-Sediment storage below 8,000 cfs is not decreased during normal ROD operations in combination with peak power-plant releases that follow Paria River sediment inputs from July through October.

Project 3. State of Primary Productivity, Carbon Flux and Alteration of Food Base

> Evaluating the net productivity of the river is important to understanding potential impacts on the food base, particularly as it pertains to the Lees Ferry trout fishery. There is also potential for interaction between warming temperatures during this period and increases in abundance of the NZMS. This project will access and monitor the rate of primary productivity in the Glen Canyon reach as well as the rate of downstream export of organic carbon (drift and dissolved). An effort will also be made to examine changes in the composition and abundance of the invertebrate community, including the NZMS.

Assessment:

Algal and macroinvertebrate biomass (g/m2 AFDM) and density estimates will be determined at the sites corresponding to the 2000 LSSF for comparison. Riffles/cobble habitats will be assessed at each site. Sampling will be conducted along three transects, perpendicular to the shoreline, 30 m apart (n=6). Stage/discharge estimates from the GUI Model will be used to determine stage of collections, targeting < 5K cfs to reduce flow influence on cobble/riffle collections. Samples will be processed live within 48 h and sorted into five biotic categories: C. glomerata, Oscillatoria spp., detritus, miscellaneous algae and macrophytes, and macroinvertebrates which will also be numerated into Gammarus lacustris, chironomid larvae, simuliid larvae, and miscellaneous invertebrates. Distribution, density, size class and biomass of the New Zealand Mud Snail will be documented as a separate biotic category. Miscellaneous invertebrates will include lumbriculids, tubificids, physids, trichopterans, terrestrial insects and unidentifiable animals. Detritus is composed of both autochthonous (algal/bryophyte/macrophyte fragments) and allochthonous (tributary upland and riparian vegetation flotsum. Each biotic category will be oven-dried at 60°C and weighed to determine dry weight biomass. Samples will then be ashed (500°C for l h), and reweighed for ash-free dry mass estimates. Preservatives alter biomass estimates and accurate mass is required for building energetic models. Substratum type, microhabitat conditions, Secchi depth, water

velocity, depth, date, site, and time of day will be recorded at each sample site. Depth integrated light intensity data loggers will be deployed at each of the five sites.

Collection Dates: Mid-September, Late October, Early January

Data Analysis: These estimates will be compared past to past data collected during 1991-2001 for differences between sites, within sites and collection dates using multivariate analysis including, MANOVA and community analysis with Non Dimensional Multi-Scaling and Principal Components Analysis. Predictor variables include all abiotic data while response variables will include biomass and density biotic categories.

Organic drift (DOC, FPOM and CPOM) will be estimated at the sites corresponding to the 2000 LSSF for comparison. Protocols will the same as used by Benenati et al. (2001), Shannon et al. (1996), Blinn et al. (1999). Dissolved Organic Carbon (DOC) Samples (50 ml; n=3) will be collected at each site with a Millipore Swinex® system filtered through a glass fiber filter (Whatman® GF/A) and preserved with sulfuric acid (pH<2). Three 250 µml aliquots will be injected into a Rosemount/Dohrmann DC-180 from each sample or until the standard deviation is < 10%.

Coarse Particulate Organic Matter (CPOM). Nearshore surface drift samples (0- 0.5 m deep) will be collected at each site for CPOM during each collection trip (n=3). Collections will be taken in triplicate between 1000 h and 1500 h at each site to establish the affects of discharge on drift. Collections will be made with a circular tow net (48 cm diameter opening with 500 µm mesh) held in place behind a moored pontoon raft or secured to the river bank. Samples will be sorted and processed live for biota as outlined for the phyto-benthic collections above. Current velocity will be measured with a Marsh-McBirney electronic flow meter and collection duration will be measured for volumetric calculations (mass/m3/s). Fine Particulate Organic Matter (FPOM drift will be collected at the same time and with the same general protocol as CPOM (n = 3). The net has a 30 cm diameter opening with 0.5 µm mesh. Samples will be preserved in 70% EtOH and sorted in the lab with a dissecting scope into the following categories: Copepoda (Calanoida, Cyclopoida, Harpacticoida), Cladocera, Ostracoda, and miscellaneous zooplankton, which include small chironomids, Gammarus lacustris, planaria, hydra, etc. Large samples will be split with either 1 ml, 5 ml or 10 ml sub-samples sorted from a 100 ml dilution. Zooplankton densities of each category, general condition, reproductive status and presence of nauplii will be recorded. Samples will be processed for dry mass estimates and converted to ash-free dry mass using regression equations (Shannon et al. 1996). The remaining organic material will be filtered through a 1 mm sieve to remove CPOM and then filtered onto a glass fiber filter (Whatman® GF/A) with a Millipore Swinex® system. Filters will be dried at 60°C and combusted for 1 h at 500° C. Water volume collected will be calculated using a Marsh-McBireny electronic current meter and mass will be converted to mass/m3/s.

***Hypotheses to be tested/considered*:**

H_0 : Primary production as measured by algal biomass before and after low fall flows will not differ in the Glen Canyon reach

H_0 : Dissolved and particulate organic drift will not increase in the CRE

H_0 : NZMS density in the Glen Canyon reach will not change as a result of LFF.

Project 4. Near Shore Temperature and Habitat Use Monitoring During Low Steady Flows (GCMRC and contractor(s) to be determined)

The purpose of near shore temperature monitoring is to detect any near shore warming resulting from low steady flows. The approach will be to monitor the same sites as were monitored during the Low Summer Steady Flows of 2000, allowing for replication and thus a stronger correlation between steady flows and near shore warming. It will also enable the determination of seasonal effects, comparing 2000 summer measurements with 2002 fall measurements. The anticipated benefit will be to establish whether fall steady flows are potentially beneficial to native fish species by warming near shore habitat.

Methods will be similar to those used during the Low Summer Steady Flows of 2000; three separate thermistor strings will be extended perpendicular to a particular shore, with the thermistors measuring near surface temperatures at measured bottom depths. Air temperature will also be collected continuously at each site. Specific backwater sites near the LCR confluence will be monitored for fish use and abundance during alternating fall flow sequences to examine trends in use and abundance. These sites will also be measured with respect to habitat quality-depth, velocity, turbidity, etc.

***Hypotheses to be tested/considered*:**

H_0: There is no difference in near-shore habitat for steady 8,000 cfs releases and low fluctuations (6,500 to 9,000 cfs) in terms of temperatures, velocities, turbidity, and nutrients. (The strength of this hypothesis increases with concurrent collection of fish information.)

H_o: There is no difference between the alternative flow sequences of the fall flow period with respect to juvenile fish behavior.

H_o: There is no difference between the alternative flow sequences of the fall flow period for native and non-native fish abundance in near-shore areas.

II. SECONDARY SEDIMENT TREATMENT *(High flow experiment)*

Project 1. Fine Sediment Mass Balance - Part C

Part C. - Continuation of intensive daily sediment-transport sampling along main channel and monitoring of tributary inputs. Sediment-transport monitoring sites include: Paria River near Lees Ferry, Paria River at Highway 89 bridge, Little Colorado River near Cameron, 30-Mile, 60-Mile, Grand Canyon near Phantom Ranch and Colorado River above the confluence with Diamond Creek. During the HFE, the network of suspended-sediment measurements will be expanded to include data collection at the Lees Ferry cableway as well. During the high flow, several measurements per day will be made at each of the main channel stations using conventional sampling protocols, while alternative technologies, such as LISST (*Laser In-Situ Scattering and Tranmissometry*) shall be used to collect data once every 15-minutes to an hour. This work is contingent upon the HFE test being implemented, and is proposed through modifications of existing agreements with USGS.

Null Hypotheses Relating to Mass Balance Part C
(Response of Fine-Sediment Supply in Marble Canyon to HFE)

Treatment #1 and Treatment #2 are the same relative the HFE of similar magnitude and duration released in January (41,000 to 45,000 cfs for 2.5 days)

Hypotheses to be tested/considered:

H_o - With respect to its grain size and concentration, the sand supply within Marble Canyon is not significantly depleted during the HFE.

H_o - With respect to concentration, the silt/clay supply within Marble Canyon is not significantly depleted during the HFE.

Project 5. Sediment-Transport Modeling Measurements

We will record intensive, repeated measurements of selected channel elements at 1-2 sites within Marble Canyon. This work will be accomplished through modifications of existing agreements with USGS, Johns Hopkins University, USU and possibly -- GCMRC staff, as well as FIST team members. The financial resources required to accomplish the FIST pre- versus post-HFE monitoring, plus the proposed timing of the HFE, currently make implementation of this research element uncertain.
Note: This HFE research element is contingent upon availability of personnel, equipment and funding resources, and requires additional planning and coordination between GCMRC and its physical-science cooperators.

Methods – Please refer to currently funded USGS work plan on file at the GCMRC.

Null Hypotheses Relating to Sediment Modeling
(Response of Sand-Bar Depositional Rates in Marble Canyon to HFE)

Treatment #1 and Treatment #2 are the same relative the EBF of similar magnitude and duration released in January (41,000 to 45,000 cfs for 2.5 days)

Hypotheses to be tested/considered:

H_o - Sand-Bar depositional rates within study eddies are invariant throughout the duration or the HFE and do not verify model-simulations relative to suspended-sediment concentrations and grain-size conditions measured during the high flow.

H_o - Evolution of fine-sediment supply with respect to concentration and grain size do not verify 1-Dimensional sand routing model simulations.

H_o - Rapid sand-bar failures do not occur during the 2.5-day long HFE.

Project 6. **Coarse-Sediment Monitoring (Inputs, Impacts and Reworking)**

Intensive monitoring of recently aggraded debris-fan deposits is proposed by the USGS just prior to, during and immediately following the January HFE, at river mile 67 (Comanche Rapid) and 93 (Granite Falls Rapid). This work shall only occur if the HFE is scheduled for implementation, and is proposed through modification of an existing agreement with the Water Resources Discipline of the USGS. The project requires some additional remote-sensing support for the study sites that can be completed as part of the FIST photogrammetry overflights. In addition, the coarse-sediment team is scheduled to collaborate with Ecometric Research in an expanded version of the work plan for the Advanced Conceptual Modeling project (coarse-sediment dynamics related to physical habitat used by trout in spawning and recruitment). This collaboration is intended to support efforts to map the distribution and documents the fate of trout redds in the Lees Ferry reach and lower Marble Canyon under experimental fluctuating flows.

Methods – Please refer to currently funded USGS work plan on file at the GCMRC.

Null Hypotheses Relating to Reworking on Newly Aggraded Debris Fans and Rapids
(Response of Recently Deposited Coarse Sediments at Comanche and Granite Falls Rapids)

Treatment #1 and Treatment #2 are the same relative the HFE of similar magnitude and duration released in January (41,000 to 45,000 cfs for 2.5 days)

Hypotheses to be tested/considered:

H_o - Coarse-grained sediments recently deposited on debris fans and within rapids are not significantly reworked during the rising limb of the HFE, as previously measured during the 1996 flood experiment (45,000 cfs peak discharges).

H_o - Boulders transported from newly aggraded debris fans under HFE are not deposited within pools immediately below debris fans and constricted rapids.

H_o - Fine gravel-sized sediment from newly aggraded debris fans at HFE are not redistributed to downstream channel elements.

Project 7. Kanab Ambersnail Compliance Monitoring (AGFD)

Kanab ambersnail is a federally listed endangered species occurring in one location in Grand Canyon: Vasey's Paradise. While the taxonomic ranking of this taxon is currently unresolved, it represents a taxon that is endemic to Vasey's Paradise. The snail and its habitat is a unique ecosystem determined to be of concern by stakeholders. The site is also a traditional cultural resource to all Native American stakeholders. The abundance and distribution of the snail and the quality of its habitat is influenced by operations of Glen Canyon Dam, as well as by springs located at Vasey's Paradise. Monitoring of quality, area and distribution occurs on a more detailed scale due to the limited nature of the habitat and surveys for animals are limited to snails. These surveys occur more than once per year. The relationships between operations from Glen Canyon Dam, habitat quality and its use by Kanab ambersnail at Vasey's Paradise are a management concern. Monitoring data on these ecosystem elements provide information on the effectiveness of the primary experimental flow treatment (Secretary's 1996 Record of Decision) relative to stated resource management objectives.

Monitoring of Kanab ambersnail densities, size classes and utilized habitat: (1) allows managers to assess the status of this endangered species; (2) provides data that allows identification and interpretation of linkages between physical and biological variables within the Colorado River ecosystem; (3) provides data on the effect of periodic management of sediment through high flows under the Record of Decision on the population dynamics and habitat interactions of this species.

Kanab ambersnail is a federally listed endangered species occurring in one location in Grand Canyon: Vasey's Paradise. While the taxonomic ranking of this taxon is currently unresolved, it represents a taxon that is endemic to Vasey's Paradise. The snail and its habitat is a unique ecosystem determined to be of concern by stakeholders. The site is also a traditional cultural resource to all Native American stakeholders. Monitoring of habitatquality, area and distribution occurs on a more detailed scale due to the limited nature of the habitat and surveys for animals are limited to snails. These surveys occur more than once per

year. The relationships between operations from Glen Canyon Dam, habitat quality and its use by Kanab ambersnail at Vasey's Paradise are a management concern. Monitoring data on these ecosystem elements provide information on the effectiveness of the primary experimental flow treatment (Secretary's 1996 Record of Decision) relative to stated resource management objectives.

Monitoring of Kanab ambersnail densities, size classes and utilized habitat: (1) allows managers to assess the status of this endangered species; (2) provides data that allows identification and interpretation of linkages between physical and biological variables within the Colorado River ecosystem; (3) provides data on the effect of periodic management of sediment through high flows under the Record of Decision on the population dynamics and habitat interactions of this species.

Objectives: To determine the abundance of Kanab ambersnails that inhabit the Vasey's Paradise Springs vegetation and to determine how snail densities change relative to the HFE flows and available habitat, as habitat is influenced by operations and discharge from the spring. Monitoring of Kanab ambersnail densities, size classes and utilized habitat: (1) allows managers to assess the status of this endangered species; (2) provides data that allows identification and interpretation of linkages between physical and biological variables within the Colorado River ecosystem; (3) provides data on the effect of periodic management of sediment through high flows under the Record of Decision on the population dynamics and habitat interactions of this species.

These data will be related to available habitat changes relative to HFE operations of Glen Canyon Dam and life history requirement of the species of concern. Kanab ambersnail monitoring data will be collected using primarily field-based survey methods for snail densities and available habitat. Habitat will be measured when possible using remotely sensed methods to minimize impact to the site. Available habitat values are used for biological opinion consultation associated with special high releases (e.g., HFE).

The work associated with before and after estimates of snail numbers and available habitat will also afford an opportunity to add additional knowledge to the program regarding overwinter mortality of KAS which is usually high based on routine monitoring. Specifically the project will allow quaintification of the number of KAS and available habitat up to 41,000 cfs or perhaps 45,000cfs in year 2. The project will also quantify available and lost habitat as well as conduct error test on selected habitat patches.

Hypotheses to be tested/considered:

H_o: KAS density in habitat below HFE flows will not change as a result of the HFE flows.

H_o: Available KAS habitat will not change as a result of HFE flows

H_o: Pre-HFE population estimates will not differ from estimates derived during routine monitoring in the fall.

Project 8. Food Base Impacts of HFE Flows in Glen Canyon Reach

Continuation of Project 4 described above.

***Hypothesis to be considered*:**

H_o: The phyto-benthic community will not change in response to the HFE flows.

Assessment:

Algal and macroinvertebrate biomass (g/m2 AFDM) and density estimates will be determined at the five sites corresponding to the 2000 LSSF for comparison (Shannon et al. 2002). Riffles/cobble habitats will be assessed at each site. Sampling will be conducted along three transects, perpendicular to the shoreline, 30 m apart (n=6). Stage/discharge estimates from the GUI Model will be used to determine stage of collections, targeting < 5K cfs to reduce flow influence on cobble/riffle collections. Samples will be processed live within 48 h and sorted into five biotic categories: C. glomerata, Oscillatoria spp., detritus, miscellaneous algae and macrophytes, and macroinvertebrates which will also be numerated into Gammarus lacustris, chironomid larvae, simuliid larvae, and miscellaneous invertebrates. Distribution, density, size class and biomass of the New Zealand Mud Snail will be documented as a separate biotic category. Miscellaneous invertebrates will include lumbriculids, tubificids, physids, trichopterans, terrestrial insects and unidentifiable animals. Detritus is composed of both autochthonous (algal/bryophyte/macrophyte fragments) and allochthonous (tributary upland and riparian vegetation flotsum. Each biotic category will be oven-dried at 60°C and weighed to determine dry weight biomass. Samples will then be ashed (500°C for l h), and reweighed for ash-free dry mass estimates. Preservatives alter biomass estimates and accurate mass is required for building energetic models. Substratum type, microhabitat conditions, Secchi depth, water velocity, depth, date, site, and time of day will be recorded at each sample site. Depth integrated light intensity data loggers will be deployed at each of the five sites.

Collection Dates: Early March, Early June.

Data Analysis: These estimates will be compared past to past data collected during 1991-2001 for differences between sites, within sites and collection dates using multivariate analysis including, MANOVA and community analysis with Non Dimensional Multi-Scaling and Principal Components Analysis. Predictor variables include all abiotic data while response variables will include biomass and density biotic categories.

III. POST HIGH FLOW EXPERIMENT TREATMENT *(January through April fluctuating flows)*

This aspect of the treatment is intended primarily to disadvantage non-native salmonids in the CRE, both above and below the Paria River. In the Lees Ferry reach there exists an overabundance of rainbow trout, thus reducing the population numbers through decreased recruitment should result in improved growth and condition of remaining trout. Downstream of Lees Ferry trout represent an unwanted non-native competitor and potential predator in consistent with AMP management goals. Reducing non-natives is thought to be desirable to improve the biological environment of the critical habitat for humpback chub.

However, this aspect of the treatment scenario for WY 2003 and 2004, also has potential to yield information relative to the rate of sediment loss and beach erosion compared to post 1996 HFE conditions and ROD operations over the past 5-7 years.

Much of the potential impact of fluctuating flows on salmonid recruitment and abundance will be obtained through routine on-going monitoring, which includes four regularly scheduled electrofishing efforts each year in the Lees Ferry reach where CPUE, length frequency, recruitment of YOY fish, condition factor, and spawning condition are all measured or estimated. The AGFD and GCMRC have over 12 years of data against which to compare results following implementation of fluctuating flows. Examples of this kind of data can be found in the attached trout discussion paper.

Downstream monitoring includes two regularly scheduled electrofishing trips which also provide similar (although less comprehensive sampling coverage) data for salmonids and other non-native fishes. Comparison of sampling locations within and outside of the mechanical removal reach around the LCR should enable detection of differences due to effects of mechanical removal versus fluctuating flows.

Hypotheses to be tested/considered include:

Lees Ferry

H_o: Recruitment of YOY rainbow trout in the Lees Ferry reach is not different than during MLFF years

H_o: Growth and condition of rainbow trout in the Lees Ferry reach is not different than during MLFF years

H_o: CPUE of all size classes of rainbow trout in the Lees Ferry reach is not different than MLFF years.

Downstream

H_o: Recruitment of YOY RBT and BNT is not different than during previous two MLFF years

H_o: CPUE for RBT and BNT of all size classes is not different from preceding two MLFF years

H_o: CPUE for RBT and BNT of all size classes is not different in areas subject to mechanical removal of salmonids

Project 9. Monitoring of Rainbow Trout Adult Stranding and Mortality (EcoPlan Associates, Inc.)

A significant concern to the angling and guiding community who utilize the Lees Ferry fishery is the notion that the January–March fluctuating flows may impose substantial mortality on the spawning (adult) portion of the RBT population in the Lees Ferry reach. During the 1990-1991 research flows, the Arizona Game and Fish Department documented so called stranding pools in the Lees Ferry reach. These pools were locations that tended to capture adult rainbow trout following flow reductions and impose varying degrees of mortality due to reduced water quality and dewatering. The January-March fluctuating flows **could** be designed to minimize stranding, as the purpose of the fluctuating flows is to impact recruitment for the 2003 and 2004 year class of RBT rather than adult abundance. However, it is likely that some stranding will still occur and the locations of known stranding pools will be periodically monitored to evaluate mortality due to stranding. We will estimate the daily number of adult fish stranded in known stranding pool locations in the Lees Ferry reach and the mortality rate of fish in known stranding pools in the Lees Ferry reach. If fluctuations are to be done every day of the week, surveys will need to be conducted during nighttime hours. If fluctuations are limited to Monday-Saturday, surveys can be conducted during daylight hours on Sundays.

Hypotheses to be tested/considered:

H_0: No difference in the abundance of stranded adult rainbow trout in selected areas of the Lees Ferry reach will occur between the low fall flows (Nov-Dec) and fluctuating flows from Jan-March.

Project 10. Distribution of Trout and Mechanism Accounting for Reduced Recruitment

This project would map, using snorkeling and/or SCUBA observations, the elevational and longitudinal distribution of spawning redds in the Lees Ferry reach using transect corresponding to the snorkeling surveys conducted during

routine monitoring. Transect would be mapped once per month from November through May. Observations of redd location would be related to flow regime to see whether fluctuating flows induced spawning at higher elevations (>cfs flow rates). Additional transects in selected reaches below the Paria will be mapped in an effort to determine whether sediment inputs and deposition/retention in the channel affects the distribution or abundance of salmonid spawning redds.

Hypothesis to be considered:

H_o: Location of spawning redds does not change in relation to season or dam releases.

H_o: Distribution and abundance of spawning redds is unaffected by the presence of fine sediment on the channel bottom.

Part 2 of this project would attempt to gather information pertaining to the causal mechanism and life stage accounting for reduced recruitment (if any) of rainbow trout in the Lees Ferry reach during periods of fluctuating flows from Jan-March. A series of Rainbow trout populations in the Colorado River downstream of GCD were likely enhanced by reductions in flow fluctuations that began in the early 1990's (McKinney et al. 2001). Recent stock assessment and mark recapture analysis for native fish indicate a declining trend in humpback chub (HBC) recruitment (L. Coggins, GCMRC, Flagstaff, AZ., pers. comm.). Increased predation and competition from the large rainbow trout population in the vicinity of the Little Colorado River is considered one of the potential causes for this decline and is the motivation behind the fluctuating flow and exotic mechanical removal experiments.

Increased flow fluctuations are thought to effect rainbow trout abundance through two mechanisms. Variation in river stage would lead to exposure and temporary dessication of redds which in turn could lead to a reduction in egg and alevin survival rates. A number of studies have shown that egg stages are relatively insensitive to short-term dessication events but that eleutheroembryos and pre-emergent alevins are very sensitive to dessication (e.g., Becker et al. 1982). Variation in river stage would also destabilize shoreline habitats forcing fry and parr to move from protective shoreline cover and increase their predation risks and energetic costs, ultimately leading to reduced survival and growth. McKinney et al. (2001) hypothesized that this was the most likely mechanism explaining the increase in the abundance of small rainbow trout observed following reduced flow fluctuations from GCD.

In theory, monitoring the abundance of adults would provide an assessment of the effects of increased flow fluctuations on rainbow trout populations in Grand Canyon. In practice, this approach is complicated by a number of factors: 1) it may be institutionally difficult to implement a sound experimental design where the treatment is held constant for sufficient time for its effects to become

observable in the adult population that is monitored. Recruitment pulses generated from single-year experiments may be swamped by the presence of multiple year-classes in the adult population; 2) the effects of flow changes on the adult rainbow trout population may be confounded by other management actions such as mechanical removal of trout in the vicinity of the LCR; 3) there will be a considerable lag (3+ yrs) between the time that recruitment of juvenile trout is changed and the time it takes for this change to be potentially noticeable in the adult population; and 4) high interannual variation in index sampling and mark-recapture programs for trout in Grand Canyon may make modest changes in early life stage survival resulting from flow changes potentially difficult to detect.

Considering these challenges, it is reasonable to investigate other monitoring alternatives that are more amenable to detecting the effects of short-term (i.e., single year) experiments with minimal lag time. This proposal outlines an approach for developing an early life stage-survival monitoring program for rainbow trout in Glen and Marble Canyon reaches. The program would provide indices of incubation and early fry survival rates that could be compared across various treatments (e.g., more stable vs. more fluctuating flows). Data from such an assessment would be useful to assess the efficacy of reducing rainbow trout abundance through increased flow variation from GCD, and in designing more effective trout-limiting flow alternatives for future experiments.

Hypotheses to be tested/considered:

H_o: No difference in abundance of YOY RBT results during fluctuating flows.

H_o: No seasonal difference exists between survival of YOY RBT

H_o: No difference in survival of YOY RBT occurs between fish with access to fluctuating flow regime versus fish restricted below 5-8,000cfs.

Project 11. **Food Base Impacts of Fluctuating Flows (NAU)**

Algal and macroinvertebrate biomass (g/m2 AFDM) and density estimates will be determined at the sites corresponding to the Foodbase Monitoring sites for comparison. Riffles/cobble habitats will be assessed at each site.

Sampling will be conducted along three transects, perpendicular to the shoreline, 10 m apart (n=18). Stage/discharge estimates from the GUI Model will be used to determine stage of collections, targeting < 5K cfs to reduce flow influence on cobble/riffle collections Samples will be processed live within 48 h and sorted into five biotic categories: C. glomerata, Oscillatoria spp., detritus, miscellaneous algae and macrophytes, and macroinvertebrates which will also be numerated into Gammarus lacustris, chironomid larvae, simuliid larvae, and miscellaneous invertebrates. Distribution, density, size class and biomass of the New Zealand

Mud Snail will be documented as a separate biotic category. Miscellaneous invertebrates will include lumbriculids, tubificids, physids, trichopterans, terrestrial insects and unidentifiable animals. Detritus is composed of both autochthonous (algal/bryophyte/macrophyte fragments) and allochthonous (tributary upland and riparian vegetation flotsum. Each biotic category will be oven-dried at 60°C and weighed to determine dry weight biomass. Samples will then be ashed (500°C for l h), and reweighed for ash-free dry mass estimates.

Preservatives alter biomass estimates and accurate mass is required for building energetic models. Substratum type, microhabitat conditions, Secchi depth, water velocity, depth, date, site, and time of day will be recorded at each sample site. Depth integrated light intensity data loggers will be deployed at each of the five sites.

Collection Dates: December, January, February, March, June.

Data Analysis: These estimates will be compared past to past data collected during 1991-2001 for differences between sites, within sites and collection dates using multivariate analysis including, MANOVA and community analysis with Non Dimensional Multi-Scaling and Principal Components Analysis. Predictor variables include all abiotic data while response variables will include biomass and density biotic categories.

Hypothesis to be tested/considered:

H_o: The phyto-benthic community will not change in response to the HFE flows.

Project 1. Fine Sediment Mass Balance – Part D.

Part D. – Following the HFE, continued daily sediment-transport sampling at the four primary main channel stations (30-Mile, 60-Mile, 87-Mile and 226-Mile), as well as flood-event monitoring of tributary inputs at existing stations on the Paria and Little Colorado Rivers will be conducted. Conventional and alternative methods for sampling suspended-sediment transport shall be used during this period and into summer 2003, following termination of the fluctuating–flow treatment. This work is beyond the normal scope of annual monitoring and is proposed through modifications of existing agreements with the USGS.

Null Hypotheses Relating to Mass Balance Part D
(Post-HFE Suspended-Sediment Transport Rates)

Treatment #1 and Treatment #2 are the same relative the HFE of similar magnitude and duration released in January (41,000 to 45,000 for 2-3 days)

Hypotheses to be tested/considered:

H_o - With respect to concentration, the sand-transport rates **are not** decreased following the HFE.

H_o - With respect to concentration, the silt/clay-transport rates **are not** decreased following the HFE.

Project 2. FIST - Part C.
(Post-High flow experiment sampling to measure and estimate bar shape, grain-size distributions and volumes within integrated monitoring reaches, as well as at selected sites where cultural resource preservation within sand deposits is of critical concern.)

Part C. – January and March 2003 - Field measurements shall be collected within a subset of 5 FIST reaches during January and March 2003, contingent upon whether or not the HFE test is implemented. Studies of aeolian transport of sand shall also occur on a March 2003, river trip, if the HFE is implemented, so as to better document the fate of wind-reworked sand bars in the proximity of recently eroded cultural sites. Additional fieldwork related to the fate of sand bars in the vicinity of cultural resources shall be undertaken within Part D of the FIST (see below).

Aerial Photography - shall be flown in January 2002.

Daily Oblique Photography - of FIST long-term sandbars shall only continue if the HFE test is implemented. These daily photographic data will be collected as a means of documenting bar conditions prior to implementation of the January to April fluctuating-flow treatment.

Null Hypotheses Relating to FIST Part C

Treatment #1 and Treatment #2 are Assumed to have the Same Magnitude and Duration of HFE and Similar Antecedent Fine-Sediment Supply Conditions
(Response of Sand-Storage Conditions within Marble Canyon in Response to HFE)

Hypotheses to be tested/considered:

H_o - Fine-Sediment storage above 8,000 cfs within Marble Canyon is not increased compared with conditions measured following the 1996 flood experiment.

H_o - Fine-Sediment storage below 8,000 cfs is not decreased compared with conditions measured following the 1996 flood experiment.

H_o - Fine-Sediment deposits above 8,000 cfs in Marble Canyon do not have finer grain-size distributions (with respect to sand-sizes) when compared with sand bars deposited by the 1996 controlled flood experiment.

H_o - Fine-Sediment deposits above 8,000 cfs in Marble Canyon do not have higher contents of silt/clay when compared with sand bars deposited by the 1996 controlled flood experiment.

H_o - Fine-Sediment storage between 8,000 and 25,000 cfs within Marble Canyon is not decreased below conditions measured in September 1996, following the 1996 controlled flood experiment and one summer of ROD fluctuations.

H_o - Fine-Sediment storage above 25,000 cfs within Marble Canyon <u>is not</u> decreased below conditions measured in September 1996, following the 1996 controlled flood experiment and one summer of ROD fluctuations.

H_o - Fine-Sediment grain size of channel-bed material below 8,000 cfs **is not** coarser than conditions measured in January, immediately following the HFE test.

H_o - Fine-Sediment grain size of sand bar deposits above 8,000 cfs is not coarser than conditions measured in January, immediately following the HFE test.

H_o - Total fine-sediment storage within Marble Canyon study sites <u>is not</u> less than conditions measured immediately following the HFE test.

H_o- Total fine-sediment storage above 25,000 cfs stage elevation within Upper Marble Canyon study sites is not greater than conditions measured immediately prior to the HFE test.

H_o - Total fine-sediment storage within Upper Marble Canyon study sites is not greater than conditions measured immediately prior to the HFE test.

H_o- Fine-sediment deposits created by the experimental HFE do not possess cohesive properties similar to pre-dam deposits.

H_o - Fine-sediment deposits created by the experimental HFE do not possess cohesive properties similar to prior post-dam deposits.
H_o - Fine-sediment deposits created by the experimental HFE are not significantly reworked by wind.

H_o - Fine-sediment deposited by the experimental HFE are not transported by aeolian processes to areas where recent gully erosion has exposed cultural sites.

All of the Part C, work proposed above shall be accomplished through modifications of existing agreements with USGS, NAU, USU.

IV. NON-FLOW TREATMENT *(Mechanical Removal of Salmonids)*

Project 12. Mechanical Removal of Non-Native Fishes (Primarily Salmonids) from the Colorado River Near the Confluence with the Little Colorado River

While it is difficult to determine which factor is most responsible for the HBC recruitment decline documented in recent years, a likely significant factor is negative interactions (predation and competition) with non-native fish. Interaction with non-native fish is implicated in the decline and extinction of native fishes throughout the Colorado River basin. This project is the initiation of a multi-objective study to evaluate the potential effect of RBT and BNT predation on HBC recruitment and the efficacy of mechanical removal of RBT and BNT from the LCR Inflow reach.

The LCR Inflow reach is recognized for having the highest abundance of adult and juvenile HBC in the Colorado River mainstem. We have selected a sampling reach (56.2 RM - 65.7 RM) that encloses the majority of this population. The proposed sampling effort will be uniformly distributed within this reach. The upstream and downstream endpoints are bounded by hydraulic and geomorphic control; however, it is not impermeable to system-wide fish movement. For this reason, we are proposing to conduct a depletion effort that is both spatially discrete, and repeated seasonally over a period of 4 years. We are proposing to conduct annually, three depletion trips in January-March and three depletion trips in July-September. The sampling efforts are scheduled to precede the major periods of LCR flooding events (spring runoff and monsoonal storms) that are correlated with juvenile HBC immigration to the mainstem Colorado River. Due to the logistical obstacles associated with beginning this program, only 1 trip will be conducted during 2002 (September). All captured species and individuals not native to the CRE will be removed and destroyed during the mechanical removal sampling process.

Hypotheses to be tested/considered:

H_o: Mechanical removal of RBT and BNT using electrofishing methods is an effective method of reducing adult RBT and BNT abundance in the LCR Inflow reach.

H_o: Abundance of adult RBT and BNT in the LCR Inflow reach prior to each removal event is similar.

H_o: No changes occur in adult RBT and BNT size composition in response to removal events.

H_o: Trout immigration (Seasonal and Annual) into the LCR Inflow reach between removal events is undetectable.

Methods

A series of five, single-pass depletion efforts will be conducted in fishable habitat using four electrofishing boats that concurrently sample the river on opposing sides. Two boats will sample upstream of the LCR confluence and two downstream. Sampling equipment, methods and electrical configuration used will be consistent with the established GCMRC fish handling and sampling protocols. The sampling time required to complete each single depletion pass has been estimated at 2 days, with an initial estimated catch of approximately 1500 fish for the first depletion pass. Using a depletion method, the catch-rates of single depletions passes are regressed against the cumulative catch for the trip to determine an initial population estimate. This depletion effort will be repeated four years, for a total of 24 times, to determine how removal of fish using a series of depletion passes in a discrete designated area will influence the relative abundance of the remaining fish stock. Since we will be unable to control for migration, recruitment and mortality occurring at a local level, comparisons among trip population estimates and trip catchability coefficients (Q) are to be analyzed in order to evaluate if mechanical removal methods are an effective means to control for undesirable fish species. Additionally, electrofishing catch-rate will be used to measure juvenile HBC relative abundance.

Hoop-net sampling: In conjunction with trout depletion efforts, an estimate of juvenile HBC relative abundance (CPUE) will be determined using a combination of gear types (electrofishing and hoop-nets). Owing to the established NPS non-motor season (16 September to 15 December; NPS 2001) additional electrofishing sampling is unrealistic. For this reason, a total of 30 hoop-nets (24"x 36") will be fished for a 4-day period at pre-established transects that are presently used as part of the long-term monitoring program, and checked at 24-hr intervals (Gorman and Coggins 2000). In addition to this annual netting effort (mid-September and January depletion trips), USFWS has proposed (VanHaverbeke 2002) to resample these same transects using hoop-nets on an annual basis during November. This supplemental netting effort will provide an additional CPUE datum to determine relative abundance of this vulnerable size-class during a period of motor use restrictions and will comply with NPS regulations. Following Valdez and Ryel (1995), these CPUE data will be used to construct survival/retention rates of juvenile HBC in the LCR Inflow reach.

Data Analysis

During the course of this study, long term monitoring activities will continue to track the recruitment of HBC into the LCR population. Specifically, program SUPERTAG will be updated annually to produce continuing estimates of annual recruitment and abundance. Long term monitoring data will also be used to estimate: instantaneous abundance of HBC >150 mm total length residing in the LCR during the spring spawning season; abundance of age-1 fish (recruitment) residing in the LCR during the fall; and

survival/retention rate of juvenile HBC within the LCR Inflow reach. With these data sets in hand, we will eventually be able to examine the relationship between adult RBT and BNT abundance in the LCR Inflow reach and survival/retention rates of juvenile HBC in the LCR Inflow reach. We will also have the ability to examine the relationship between adult RBT and BNT abundance in the LCR Inflow reach and concurrent brood year specific recruitment to the LCR HBC population.

Project 13. **Rainbow Trout Diet Analysis at the LCR Confluence and in Glen Canyon Reach**

Predation by non-native fishes is considered to be one of the most likely hypotheses explaining HBC recruitment trend. In the last eight years, trout have responded positively at a system-wide scale to modifications in flow operations at Glen Canyon dam. Trout abundance levels have had a 2.5 to 8 fold increase system-wide. Additionally, the phytobenthic community has corresponded similarly to these flow modifications.

We have proposed a multi-year study to evaluate the potential effect of rainbow trout (RBT) and brown trout (BNT) predation on HBC recruitment. Concerns exist regarding how rainbow trout (RBT) will respond to a set of prescribed manipulations consisting of experimental flows (system-wide effect) and mechanical removal (localized effect) during a multi-year experiment. Proposed high flow fluctuations scheduled between January-March and are timed to disadvantage RBT spawning activities as well as destabilize near shoreline habitat for emergent fry. The underlying purpose of these flows is intended to target recruitment mechanisms for this non-native species. These fluctuating flows may influence the phytobenthic community by changing the standing biomass, community composition, production (primary and secondary), and drift characteristics

A popular RBT fishery located in a 25-km tail-water section of Glen Canyon has responded to modified operations at Glen Canyon. Although, this local population demonstrates high abundance, recent trends have indicated shifts in reduced angling catch rates and reduced condition that are perhaps in response to population dynamics and carrying capacity constraints in the system. Concerns have arisen regarding issues of trout response (i.e., habitat partitioning, cannibalism, dispersal) to changes in food base composition and availability owing to changes in flow operations. The primary questions of this project are: 1) Are there spatial (upstream versus downstream) and seasonal (winter versus summer) differences in trout diet? 2) Does trout diet vary in response to changes in seasonal flow patterns at Glen Canyon Dam? 3) Does trout diet vary in response to changes in trout abundance? The scope of work specific to the trout diet analysis will require an integrated approach by combining activities with other studies collecting information. The objectives listed below are specific to addressing the dietary use patterns of RBT. Other species are unlikely to occur in

large numbers in electro-fishing samples (exception may be carp). However all species collected will be sampled for diet analysis in relation to their prevalence in samples.

Hypotheses to be tested/considered:

H_o: There are no seasonal differences in trout diet use.

H_o: There are no spatial (upstream versus downstream) differences in trout diet use.

H_o: There are no size-class differences in trout diet use.

H_o: Determine if differences in feeding patterns are related to flow characteristics.

Sampling Method: The scheduling of data collection activities for assessing differences in dietary use patterns is to be coordinated with ongoing monitoring and research efforts. These include quarterly sampling in the Lees Ferry/Glen Canyon Section, and biannual sampling in the Little Colorado River reach, and downstream regions of Grand Canyon. Electrofishing will be the primary mode of capture.

Dietary Analysis: Gut contents are to be analyzed from a set of sub-samples that are randomly selected and stratified by fish size. The dietary analysis is to quantify ingested phytobenthic and macroinvertebrates using a combination of analytical methods (volumetric, weight, and numeric counts) taxonomically identified. Seasonal and inter-annual differences in the availability of the aquatic food base (standing biomass and drift) are to be linked to fish feeding habits and electivity preferences. Additionally **all trout** collected from the LCR inflow, are to be assessed for the presence or absence of fish in the gut. Dietary analysis is problematic, owing to differential rates of digestion and the difficulties associated with recognizing and identifying accurately specific items from partially digested material. To evaluate for fish presence/absence and distinguishing taxonomic characteristics of macroinvertebrates a series of voucher specimens will be developed from previously assessed samples, as well as accumulating from the gross field assessment a comparative library of anatomical characters and traits. All collected specimens and data sheets are to be assessed for completion, accuracy, and data entry errors, and sample specimens are to be cataloged, organized and stored for later transport. All data will be entered following trips consistent with GCMRC format structures.

Project 14. Incidence of Predation on Humpback Chub by Rainbow and Brown Trout at the Confluence of the Little Colorado River, Grand Canyon

Predation by non-native fishes is considered to be one of the most likely hypotheses explaining HBC recruitment trend. Additionally, it is one of the more testable hypotheses. There are two hydrological time periods (Spring and Summer

monsoons) that increase the frequency of YOY fish dispersed into the LCR. Displaced YOY originate from different brood years owing to the timing of the hydrological displacement periods. Therefore, size and abundance of this potential prey will vary because of differences in life history schedule. The variation in abundance and size should influence prey vulnerability levels. The primary questions of this scope of work are: 1) Do trout prey on HBC? 2) If predation occurs, does the incidence of predation change (±) in response to changes in predator or prey abundance?

We are proposing to conduct annually, three depletion trips in January-March and three depletion trips in June-September. The sampling efforts are scheduled to coincide with seasonal HBC-YOY dispersal from the LCR to the Colorado River Mainstem (August-September), followed again by early winter sampling. The scope of work specific to the stomach analysis will be an integrated effort with other studies collecting information on sampling efficacy, trout and HBC abundance, immigration rates, and diet analysis. The objectives listed below are specific to addressing the incidence of predation.

Hypotheses to be tested/considered:

H_o: There is no incidence of predation by RBT and BNT on HBC in the LCR reach.

H_o: Incidence of predation is unrelated to size-class and other meristic characteristics (e.g., gape-width, body-depth, length) of both the predator and prey.

H_o: The incidence of predation by RBT and BNT does not changes(±) in response to predator abundance.

H_o: Particular cohorts are more vulnerable to predation due to differences in size, relative prey abundance or relative predator abundance.

Design and Analysis: Owing to the passive dispersal of young-of-year HBC the availability of this prey to trout is disproportionately distributed in the downstream reach. For comparative purposes the trout population ($\mu_1 = \mu_2$) in the upper extent will serve as the spatio/temporal control. Comparisons in the incidence of predation will be made between the two separate trout populations to compare predation response relative to differences in prey availability. Comparisons between years will provide an understanding of how incidence of predation changes as a function of changes in trout abundance owing to multiple years of depletion (μ_{2a}, μ_{2b}, μ_{2c}, μ_{2d}). Comparisons made among seasons and within years will provide information on whether or not particular cohorts are more vulnerable to predation due to differences in size, relative prey abundance or relative predator abundance.

The stomachs are scheduled to be collected annually during the March and September trips when there is a high likelihood that HBC have been dispersed into the Colorado River mainstem. For all captured trout, stomach samples will be collected and analyzed for the presence or absence of fish or fish remains. Special dye markers will be used with preservatives to discriminate for bones and cartilage contained in the gut contents. Where possible, bones will be used for reconstructing and identifying prey taxa. Samples are to be assessed in the laboratory and not the field location.

Project 1. Fine Sediment Mass Balance - Part E.

Part E. – Continuation of intensive suspended-sediment measurements during fluctuating flows treatment and afterwards through June 2003. This component of intensive daily monitoring would conclude the sediment portion of Treatment #1, and would immediately precede implementation of Treatment #2.

Null Hypotheses Relating to Mass Balance Part E
(Post-HFE Suspended-Sediment Transport Rates under Non-ROD Fluctuating-Flows)

Treatment #1 and Treatment #2 are the same relative the fluctuating-flow treatment

Hypotheses to be tested/considered:

H_o - With respect to concentration, the sand-transport rates are not increased during Non-ROD fluctuations relative to ROD operations following the 1996 HFE.

H_o - With respect to concentration, the silt/clay-transport rates are not increased during Non-ROD fluctuations relative to ROD operations following the 1996 HFE.

Project 2. FIST - Part D.
(Post-HFE Fluctuating Flows, sampling to measure and estimate bar shape, grain-size distributions and volumes)

Part D. – April 2003 - Field measurements shall be collected within a subset of all 11 FIST reaches during May 2003, contingent upon whether or not the HFE test is implemented. In the event that the January 2003 HFE is not implemented, only measurements of bar area and volume change above 8,000 cfs will be collected using on-the-ground and airborne methods.

Aerial Photography - shall be flown in April-May 2003 (this system-wide photography is part of core monitoring and is included in the FY03 work plan). Additional aerial photography and related photogrammetry shall also be flown within each of the 11 FIST reaches. This additional component of the May 2003

over-flight is not part of the FY 2003 annual remote-sensing protocol, and would not be flown until May 2004 under normal FIST biennial monitoring.

Daily Oblique Photography - of FIST long-term sandbars shall continue only if the HFE test is implemented. These daily photographic data will be continued as a means of documenting bar conditions following implementation of the January to April fluctuating-flow treatment.

All of the Part D, work proposed above shall be accomplished through modifications of existing agreements with USGS, NAU, USU. Following, are tentative FIST trip schedules required to support Treatments #1 and #2.

Null Hypotheses Relating to FIST Part D

Treatment #1 and Treatment #2 are Assumed to have the Same Magnitude and Duration of HFE and Similar Antecendent Fine-Sediment Supply Conditions
(Response of Sand-Storage Conditions within Marble Canyon in Response to Non-ROD Fluctuating Flows during winter/spring)

Hypotheses to be tested/considered:

H_o - Fine-Sediment storage between 8,000 and 25,000 cfs within Marble Canyon is not decreased below conditions measured in September 1996, following the 1996 controlled flood experiment and one summer of ROD fluctuations.

H_o - Fine-Sediment storage above 25,000 cfs within Marble Canyon is not decreased below conditions measured in September 1996, following the 1996 controlled flood experiment and one summer of ROD fluctuations.

H_o - Fine-Sediment grain size of channel-bed material below 8,000 cfs is not coarser than conditions measured in January, immediately following the HFE test.

H_o - Fine-Sediment grain size of sand bar deposits above 8,000 cfs is not coarser than conditions measured in January, immediately following the HFE test.

H_o - Total fine-sediment storage within Marble Canyon study sites is not less than conditions measured immediately following the HFE test

H_o - Total fine-sediment storage above 25,000 cfs stage elevation within Upper Marble Canyon study sites is not greater than conditions measured immediately prior to the HFE test.

H_o - Total fine-sediment storage within Upper Marble Canyon study sites is not greater than conditions measured immediately prior to the HFE test.

H_o - Down-ramping rates of 2,500 cfs per hour do not result in increased seepage erosion rates in newly created sand bars when compared with down-ramping rates of 1,500 cfs per hour (full study implemented only in the event that the January HFE is released so that this non-ROD operational change can be studied most effectively on newly deposited sand bars).

Monitoring of Aeolian Sediment Transport at Archaeological Sites

This sub-project of the FIST will assess, quantify, and monitor aeolian sediments that are derived from HFE deposits in selected archaeological locations. The study will investigate transport characteristics of the sediments, including their condition and the rates of change. Monitoring will occur prior to and after the proposed HFE and following the fluctuating flows. Stage elevation of study locations relative to aeolian transport and the depositional source (e.g. aeolian or fluvial) of sediments will be studied. This project will coordinate with Project 15 (described above) to investigate aeolian deposits in arroyos at or near archaeological sites, as these are locations where aeolian and fluvial deposits are likely to occur. Study personnel will include geologists and geoarchaeologists.

Hypotheses to be tested/considered:

H_o: There are no significant changes in aeolian sediment deposition at the study sites as a result of the high flows.

H_o: There are no significant changes in aeolian deposition at the study sites following the fluctuating flows.

V. Socio-Cultural Studies

Project 15. Monitoring for Effects of the Test Flows at Archaeological Sites

These monitoring efforts are currently on-going by the NPS under a cultural resource program administered by Reclamation to record change at archaeological sites. These activities will encompass assessments of the test flow affects on archaeological sites during scheduled monitoring trips. Regular monitoring trips will be scheduled to allow assessments of site conditions prior to and after the proposed high flow and after the fluctuating flows. Trip schedules to be determined by the NPS and Reclamation.

This project will monitor the deposition of high flow (HFE) sediments in arroyos mouths at or near archaeological sites. Sediment deposition in arroyos has the potential to reduce gully erosion through archaeological sites. Locations will be selected from FIST reaches where a comprehensive study has been proposed to record deposition of sediment at sand bars and recreational camping beaches. As feasible, selection criteria will include geomorphic data obtained in earlier work that studied erosion/deposition and geomorphic settings. Study locations will be monitored for the amount and type of sediment deposited (e.g., grain size), and the retention of sediments deposited from the high flows and the possible loss of sediments from erosion. To the extent possible, study sites will be tied to arroyo locations studied in 1996 under that experimental flow. Study location data will be collected prior to and following the high flows and following the fluctuating flows to determine the retention of the arroyo deposits. Where feasible, monitoring data will be integrated with the proposed aeolian sediment transport study described below.

Hypotheses to be tested/considered:

$H_{o:}$ There are no significant changes in sediment deposition or erosion at the study arroyo sites as a result of the HFE test.

H_o: There are no significant changes in sediment deposition or erosion at the study arroyo sites as a result of the fluctuating flows (full study implemented only if HFE is released).

$H_{o:}$ There are no significant changes in the condition of the archaeological sites as a result of the high flows.

H_o: There are no significant changes in the condition of the archaeological sites as a result of the fluctuating flows.

Project 16. Economic Impacts to Whitewater and Angler Concessionaires and Private Boaters and Anglers.

The proposed hydrograph may have economic impacts to recreationalists. The high flow periods may affect fishing opportunities in the Lees Ferry reach, and other recreationalists and create economic impacts to fishermen, river runners, and guides. This study will investigate the affects of the experiment on these groups relative to the proposed high flow and the subsequent fluctuation flows.

Using existing records supplemented with direct interview, compare and contrast the number of guided fishing trips during the proposed project with comparable previous periods to study the economic impacts to angling within the area of the Dam to Lees Ferry and below in the Colorado River. Possible sources of impact due to flows include changes in the frequency of guided trips, numbers of

fishermen, and possible motor and equipment damage due to flows. Using this information, develop estimates of the economic impacts to commercial fishing guides and the local community.

Impacts to whitewater boating within the Lees Ferry reach (day use boating) and downstream (multi-day) will be studied to determine the economic impacts to these groups. Areas of possible economic impacts include adjusted boating schedules due to the proposed flows and incidences of motor, equipment and raft damage due to flows. In addition, economic impacts to rafting operations launching at Diamond Creek (on the Hualapai Reservation at River Mile 226) may be affected. Where possible and feasible, similar data may be obtained through direct interview. Using available data and direct interviews estimate economic impacts to these groups.

Hypotheses to be tested/considered:

H_o: Economic impacts to whitewater and angling concessionaires will not differ significantly from economic impacts under normal daily operations.
H_o: Economic impacts to private whitewater boaters and anglers will not differ significantly from economic impacts under normal daily operations.

Project 17. Changes in Campable Beach Areas.

The availability of camping beaches is of concern to recreationalists within the Grand Canyon. This study proposes to use aerial data collected during pre-experiment and post experiment to determine the change in camping beach area at selected beaches. Specific study areas will include: 1) sediment deposition relative to camping beaches during each stage of the experiment; 2) sediment deposition at camping beaches in critical reaches; 3) sediment retention at camping beaches; and 4) differences in sediment retention at camping beaches, based on grain size. Following these experimental flows, these data will be analyzed and evaluated against campable areas known to exist under normal (ROD) operations. The on-going efforts of the Adopt-A-Beach project of the Grand Canyon River Guides will be coordinated with this effort to monitor the affects of the experiment on the camping beaches.

Hypotheses to be tested/considered:

H_o: Campable beach areas during the proposed experiment will not differ significantly from campable beach areas under normal daily operations.

Relationship of Proposed Projects to Existing Monitoring Programs

Core monitoring efforts conducted by GCMRC have become increasingly robust over recent years for some resources. These monitoring efforts will provide much

of the data necessary to evaluate effects of the experimental treatment flows and mechanical removal activities. For example, although the principal fisheries treatment is to reduce non-native salmonids in the LCR reach of the CRE, the anticipated consequence of this treatment is an increase in recruitment rate of HBC as non-natives are reduced.

Hypothesis to be considered

H_o: Humpback chub in the LCR population will show no change in recruitment as non-native fish abundance declines

Data will be gathered to test this hypothesis through the routine monitoring programs in place.

A brief summary of the core monitoring program for fisheries in the CRE is as follows:

Lees Ferry Trout

4 annual monitoring trips to estimate electrofishing CPUE, abundance, size distribution, and PSD.

***Downstream Non-native Fish* (primarily Salmonids and Carp)**

2 annual monitoring trips to estimate electrofishing CPUE, abundance, size distribution, and condition. Detect presence and distribution of all non-native species.

LCR Humpback chub

4 annual trips to estimate spring and fall abundance, spring spawning abundance, fall recruitment form previous year class, open population model to estimate recruitment and abundance using 1989-present PIT tag database.

LCR Flannelmouth Sucker

Open population model to estimate trends in recruitment and abundance using 1989-present PIT tag database.

Downstream Native Fish Monitoring

2 annual trips to estimate relative abundance (CPUE), size distribution, condition (HBC, FMS, BHS). Look for HBC recruitment (changes in size distribution and mark rate).

Note: The following additional sections will be added to this science plan document.

REMOTELY SENSED DATA COLLECTION (AERIAL PHOTOGRAPHY AND TOPOGRAPHIC CHANNEL MAPPING)

1. Photogrammetrically derived topography data within FIST reaches in December 2002 (only in the event of January HFE), January 2003 (only if HFE), May 2003 (even if no HFE, but Fluctuating flow test implemented during Treatment #1), and December 2003 (with HFE), January 2004 (with HFE) and May 2004 (even if no HFE, but Fluctuating flow test implemented during Treatment #2).
2. Multi-beam hydrography within the first five FIST reaches in Marble Canyon in December 2002, and January 2003 (only if HFE).
3. Multi-beam hydrography within all 11 FIST reaches in May 2003 (only if HFE is released as described in Treatment #1), with elements of 4 and 5 repeated in support of Treatment #2 in 2003 and 2004. If no HFE is released, then FIST only makes measurements of sand-storage changes within the 11 integrated reaches above 8,000 cfs, using on-the-ground and airborne methods.

Survey Support

1. Installation and removal of photogrammetric panels within FIST reaches in December 2002 (only if HFE), and January (only if HFE) and May 2003 (even without HFE, but with fluctuating-flow test).
2. GCMRC assistance in terrestrial survey elements related to FIST activities in December 2002, and January and May 2003. Level of required support will depend upon whether or not HFE is implemented.

Logistics

Logistical costs support the Treatment #1 and Treatment #2 Experimental Scenarios, and not components of the studies that are already scheduled under CORE monitoring.

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