THE GRAND CANYON MONITORING AND RESEARCH CENTER

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MONITORING AND RESEARCH WORK PLAN

by

THE GRAND CANYON MONITORING AND RESEARCH CENTER

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CHAPTER 1

THE GCMRC FY 2001 ANNUAL WORK PLAN

INTRODUCTION

The Fiscal Year 2001 (FY 2001) Grand Canyon Monitoring and Research Center (GCMRC) Annual Monitoring and Research Work Plan (Work Plan) describes the scientific activities planned by GCMRC for FY 2001.[1] The FY 2001 Work Plan is designed to implement the adaptive management and ecosystem science approaches called for in the 1992 Grand Canyon Protection Act (GCPA), the Glen Canyon Dam Environmental Impact Statement (GCDEIS, 1995) and the Record of Decision (ROD, 1996).

GEOGRAPHIC AND INSTITUTIONAL SCOPE

The geographic scope of GCMRC's activities is the Colorado River ecosystem within Glen Canyon National Recreation Area and Grand Canyon National Park (Figure 1.1). The Colorado River ecosystem[2] is defined as the Colorado River mainstem corridor and interacting resources in associated riparian and terrace zones, located primarily from the forebay of Glen Canyon Dam (GCD) to the western boundary of Grand Canyon National Park, a distance of approximately 293 river miles. The scope of GCMRC activities includes limited investigations into some tributaries (e.g., the Little Colorado and Paria Rivers). It also includes, in general, cultural resource impacts of dam operations for inundation levels associated primarily with flows

1 Current Management Objectives and Information Needs have been used by GCMRC as the basis for developing the FY 2001 Annual Plan.
2 "Colorado River ecosystem" will be used throughout this document as the standard definition of the monitoring and study area for GCMRC. This definition is consistent with that used in the FY 1997-2002 Strategic Plan.

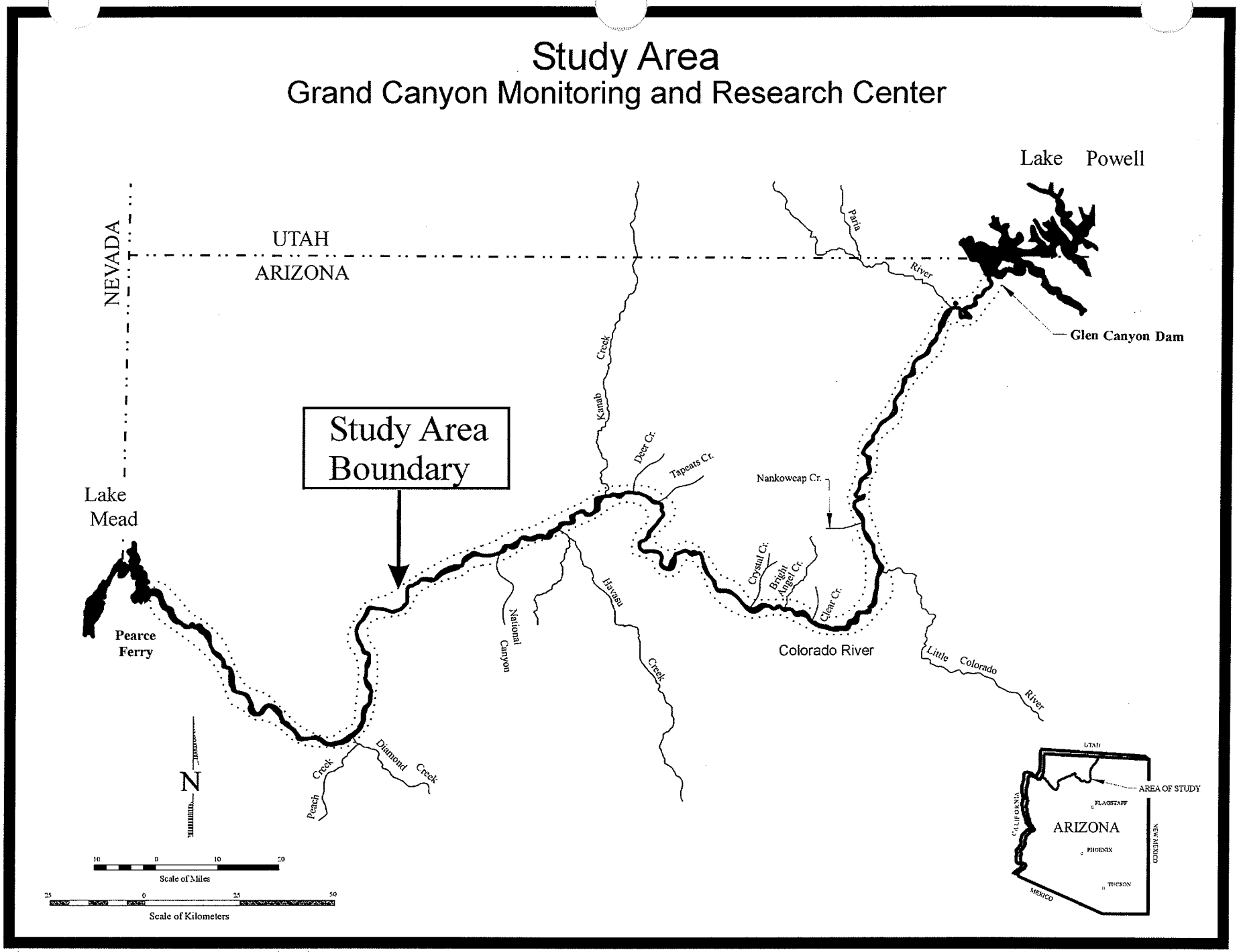

Figure 1.1 Grand Canyon Monitoring and Research Center study area boundary.

up to 256,000 cubic feet per second (cfs) as addressed in the Programmatic Agreement[3], and for physical, biological, recreational and other resources, impacts of dam operations for inundation levels associated primarily with flows up to 100,000 cfs. In between these levels, stakeholder concerns with respect to relict native vegetation, endangered species, and cultural resources may require activities by the GCMRC. All proposed projects relate to scientific activities intended to obtain information on "... the effects of the Secretary's actions[4]..." primarily on downstream resources located in the Colorado River ecosystem.

GCMRC scientific activities are constrained to those probable effects on downstream resources associated with dam operations; for this reason upstream monitoring by GCMRC in Lake Powell, and downstream in tributaries, (i.e., Little Colorado River) are constrained by design. Participants in the Glen Canyon Dam Adaptive Management Program (GCDAMP) realize these to be constraints that inhibit understanding of the entire ecosystem and therefore accept that scientific information from programs outside the GCDAMP may be needed as a means of strengthening understanding of the entire Colorado River ecosystem. Nevertheless, the ultimate purpose of GCMRC monitoring and research activities is to develop information on changes in the Colorado River ecosystem related to "... the effects of the Secretary's actions..." primarily on "downstream resources."

3 The Programmatic Agreement, finalized in August 1994, is a legal agreement between federal and state agencies and tribal groups that specifies the responsibilities of the parties to comply with the National Historic Preservation Act (1996; 1992) and 36 CFR 800.
4 As specified in the 1992 GCPA and in the Record of Decision for the Glen Canyon Dam EIS (DOI 1996).

MISSION OF GCMRC[5]

The GCPA and GCDEIS direct the Secretary of the Interior, "To establish and implement long-term monitoring programs and activities that will ensure that Glen Canyon Dam is operated in a manner consistent with that of Section 1802..." of the GCPA. The mission of the GCMRC is:

> "To provide credible, objective scientific information to the GCDAMP on the effects of operating Glen Canyon Dam on the downstream resources of the Colorado River ecosystem, as well as other information needs specified by the AMWG, utilizing an ecosystem science approach. "

ENSURING OBJECTIVE, QUALITY SCIENCE

The GCMRC was established to provide objective, high quality scientific information to the Secretary of the Interior and to the Adaptive Management Work Group (AMWG). To accomplish these goals, specific protocols regarding science planning, competition, peer review, administration and publication have been established[6]. The quality and objectivity of GCMRC research findings is ensured through competition and independent external scientific peer review. All proposals, data, reports, etc., are reviewed by independent, external scientists as well as by the GCMRC science team.

GCMRC SCIENTIFIC ACTIVITIES

The FY 2001 Work Plan describes monitoring and research activities that address the management objectives (MOs) and prioritized information needs (INs)[7] of the GCDAMP. Long-term monitoring is designed to determine changes in resource attributes. Research is used to improve monitoring, interpret and explain trends observed from monitoring to determine cause-and-effect relationships and research associations, and to better define interrelationships among

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5 See Appendix 1 for the GCMRC Mission statement and Roles and Responsibilities.
6 Operating Protocols for GCMRC, June, 1996 and GCMRC Peer Review Guidelines, May 31, 1997.
7 The MOs and prioritized IN's adopted at the July 1998 AMWG meeting serve as the basis for the monitoring and research activities called for in the FY 2001 Work Plan. These can be found in Appendix 1.

physical, biological and social processes.

In addition to monitoring and research activities, the GCMRC operates an information technologies program to ensure information management (e.g., DBMS, GIS, Library), data analysis (e.g., GIS), and data dissemination to managers and stakeholders and science organizations (e.g., WWW), a surveying department to provide consistent, quality, cost-effective support to monitoring and research projects, and a logistics program to provide cost-effective support to monitoring and research field activities.

CURRENT KNOWLEDGE

Sediment and Water Resources – Since 1998, monitoring and research of sediment and water resources of the Colorado River ecosystem has continued under the GCRMC program as part of a "transition" from EIS activities initiated under the Glen Canyon Environmental Studies (GCES), toward implementation of long-term monitoring. Following are summaries of preliminary results of the current physical research and monitoring projects funded under FY 1998 through 2000 agreements with the U.S. Geological Survey - Water Resources Division, Utah State University (USU), Northern Arizona University (NAU) and Ecometric Research, Inc.

Main Channel and Gaged Tributary Streamflow and Sediment (USGS): Under the current agreement with the USGS-Arizona District, unit-values for streamflow continue to be acquired at four main-channel (river miles 0, 61, 87 and 225) and two tributary gaging locations (Paria River at Lees Ferry and Little Colorado River near Cameron) operated by the Water Resources Division. Daily mean discharges, 15-minute unit values, and data on several quality of water parameters for streamflow are currently available for these GCMRC-supported sites through either GCMRC or USGS web pages. Suspended-sediment and bed grain-size samples continue to be collected and analyzed on an intermittent basis to better document the fine-sediment budget below Glen Canyon Dam, and to support research aimed at documenting relationships between suspended-sediment transport rates and evolving bed grain-size distributions following tributary inputs of fine sediment (Rubin, Topping, Anima, and Hornewer). A theoretical, process-based conceptual model for sediment routing along the main

channel has also been developed under the current project (Wiele and others), and provides the basic strategy for development of a 1-dimensional fine-sediment routing model for tracking tributary inputs below Glen Canyon Dam.

Ungaged Tributary Sediment Inputs (USGS): Dr. Robert Webb of the USGS, has estimated ungaged tributary contributions for both fine and coarse sediments between Glen Canyon Dam and Upper Lake Mead. Preliminary results of this research are currently being externally reviewed, but indicate that as an average-annual minimum, inputs of sand from ungaged tributaries in Glen and Marble Canyons are approximately twenty percent of the Paria River's annual sand contribution. This is important information that further supports development of a fine-sediment budget for the ecosystem.

Sediment Input Models for Paria and Little Colorado Rivers (USGS): Between 1991 and present, Dr. David Topping of the USGS Water Resources Division's National Research Program, has developed geomorphically based flow and sediment-transport models for the major tributaries that contribute fine-sediment to the ecosystem. The Paria River model has been undergoing a verification process for flood inputs that occurred in Water Years 1997 through 1999, and to date has performed well in estimating sand and finer inputs to the main channel. A similar model for the Little Colorado River is still in the final phase of development, but is expected to be completed by the end of FY 2000. Long-term monitoring protocols have been established by Topping for tracking physical channel changes within each river's modeling reaches related to model assumptions and performance. The characteristics of the channel to be tracked through long-term monitoring are those related to key model parameters such as channel geometry and bed grain-size stability. Verification of both of these flow and sediment models will continue under USGS-Arizona District activities as future tributary floods occur. The main objective for developing these models is to provide accurate volumetric and grain-size estimates of fine-sediment loads (sand and silt/clay) that influence the main-channel sediment budget following tributary floods.

Synthesis of Historical Geomorphic and Hydrologic Data (USU and USGS): This synthesis research project for geomorphology, sediment-transport and streamflow is being conducted jointly by USGS (Topping) and Utah State University (Schmidt). The initial phase of

the synthesis (Lees Ferry to Phantom Ranch) is scheduled for completion by the end of calendar year 1999. The second phase of the research is focused on the Glen Canyon tailwaters reach, and is scheduled for completion under an FY 2000 modification. The study is designed to evaluate all streamflow and sediment-transport data for the Lees Ferry and Grand Canyon streamflow records relative to climate variability, onset of regulation, the Record of Decision, and historical 2-dimensional sand bar changes that have been recorded in aerial photographs between 1952 and the post 1996 Beach/Habitat-Building Flow (BHBF) Test, as well as 3-dimensional changes recorded through cross-section and sand bar surveys. Preliminary mapping results indicates that sand bar areas within some reaches of Marble Canyon were historically largest in 1984, following the 1983 flood flows, even compared with pre-dam eddy conditions. Further, existing time-series coverages for sand bars within existing GIS reaches below river mile 42 show no clear trends for sand bar erosion following closure of Glen Canyon Dam.

Historical pre- and post-dam sediment-transport data suggests that the likelihood for achieving multi-year storage of fine-sediment inputs from the Paria and Little Colorado Rivers along the main channel is small under Record of Decision flows. In fact, both pre- and post-regulated data suggest that significant aggradation of the main channel bed did not occur on more than a seasonal timeframe except for periods when flows were below about 8,000 cfs. Preliminary synthesis results also show that the major shift in the seasonal pattern of low versus high flows (relative to the fine-sediment input period), resulting from regulation, is a primary reason why multi-year storage potential in the main channel is limited. On the basis of these preliminary research findings, USGS sediment researchers have concluded that optimal fine-sediment conservation may only be achieved in upstream critical reaches by releasing BHBFs during or shortly following major tributary floods (late summer or fall). An alternative might be to keep dam releases at the lower end of the operations range during the fine-sediment input season (July through September) and into winter, until a controlled flood can be released under current hydrologic triggering criteria.

Sand Bar Monitoring (NAU): The annual monitoring of 35 sand bars and associated offshore channel-storage settings was continued after the 1996 BHBF-Test by the Geology Department of Northern Arizona University, with measurements having been made through

April 1999. These monitoring data indicate that high-elevation sand bars continued to erode slowly following the 1996 BHBF-Test, but that on average, terrestrial sand bar elevations are still slightly higher than they were before the 1996 BHBF. Low-elevation sand-storage environments (eddies and main channel) associated with the terrestrial sand bars appear to be filled with sand to about the same elevations they were just prior to the 1996 BHBF-Test. The exception to this is based on a single monitoring site in lower Glen Canyon, where the channel-bed elevations offshore from the terrestrial sand bar are higher than in early 1996; likely a result of ungaged tributary inputs of sand to the reach from 1997 through 1998. While it is still not clear what the long-term fate of this sub-sample of monitored sites will be relative to the system-wide sand budget, it is likely that partially eroded sand bars at higher elevations (between 25,000 and 45,000 cfs) would rebuild to higher elevations if another BHBF was released in FY 2000.

Conceptual Model (Ecometric Research, Inc.): Two conceptual modeling workshops and two other related science meetings were convened during 1998 to develop a conceptual physical sub-model. These meetings were attended by most of the cooperating physical scientists, as well as Timothy Randle of the Bureau of Reclamation and William Jackson of the National Park Service.

On the basis of discussions at these meetings and integration of existing data to develop the numerical conceptual model, several preliminary conclusions about sediment transport and the fine-sediment budget of the ecosystem were identified: (1) the dominant geomorphic setting throughout the main channel where fine-sediment storage occurs is within separation and reattachment sand bars and the lower elevations of eddies; (2) channel-margin sand bars may store large volumes of fine sediment, but existing monitoring cannot document how much this potential storage may be without additional data; (3) on the basis of current sediment transport theory, sand inputs from the Paria and Little Colorado Rivers should not be expected to aggrade the main channel (non-eddies) until discharges are at about 8,000 cfs or lower; (4) eddies are highly effective sediment traps with respect to main channel transport, but only when sediment concentrations are high in the main channel, grain-sizes are small and potential storage space is available within eddies; and (5) current knowledge about exchange rates between the main channel and eddies for fine sediment are mainly derived from empirical data sets, but can be

greatly improved through expanded use of sand bar evolution models using approaches similar to those developed by USGS for short study reaches below the confluence of the Little Colorado River.

Biological Resources –

Terrestrial Biological Resources - Since 1998, work associated with terrestrial biological resources has represented data collection efforts in support of eventual long-term monitoring programs. As with sediment resources, the emphasis for biological projects was in moving toward long-term monitoring while transitioning from EIS-related efforts associated with these resources. This transition has included attempts to maintain continuity among data sets that were collected prior to 1996. Little emphasis has been put on research associated with terrestrial biological resources. Current contracts are separated into vegetation (Kearsley, NAU), avifauna (Spence, GCRA), and Kanab ambersnail (Meretsky, SWCA). The following is information provided from these monitoring projects.

Monitoring Vegetation Change along the Colorado River Mainstem - Dr. Michael Kearsley of Northern Arizona University has been involved in measuring vegetation change along the Colorado River corridor since 1993. Data collection efforts have changed from a focus on detailed compositional change that takes place on microhabitat scale (Stevens and Ayers, 1996) to characterizing change at the community or plant associated level. His work over the last two years has been to evaluate and incorporate structural components of vegetation, in addition to identifying changes in the species composition of plant communities. These structural components provide an index of vertical complexity, a variable that affects bird distribution and abundance. Measurements have also been done along shorelines to determine the relative availability of vegetated shoreline, a shoreline habitat utilized by young fish (Converse, et al., 1998). Preliminary results of this research have identified factors affecting availability of shoreline habitat to include discharge, magnitude of fluctuations, and time of year. Other results of this monitoring effort indicate that some community constituents have changed very little (e.g., tamarisk) in their representation and extent, while others are increasing in abundance

(arrowweed). These trends suggest that growth rates of arroweed may have implications associated with campable area over the long-term.

Monitoring Avifauna Abundance and Distribution along the Colorado River Mainstem – Dr. John Spence of the Glen Canyon National Recreation Area has been in charge of overseeing a project to monitor bird distribution and abundance along the Colorado River corridor. Included in this project is the monitoring of the endangered southwestern willow flycatcher. The project has determined that abundance and diversity changes in the avifaunal community along the Colorado River corridor is associated with vegetation densities and distance from the dam. Structurally complex vegetation patches like those found from river mile 42 to Cardenas and in the western Grand Canyon support more birds and more species of birds. Glen Canyon is also an area of waterfowl diversity, likely associated with the relatively rich benthic community and lower velocity waters found in this reach. The next year will be spent synthesizing the bird data and evaluating it to provide recommendations for long-term monitoring that can be integrated with habitat data.

Monitoring of Kanab ambersnail Populations and Habitat at Vaseys Paradise – Dr. Vicky Meretsky through SWCA Inc., has been the lead biologist involved with developing population estimates for the Kanab ambersnail (KAS) located at Vaseys Paradise in Grand Canyon. Both available habitat and snail numbers are determined for each trip throughout the year. Trips are conducted on a quarterly basis that coincide with the life history of the snail. Monitoring of the habitat indicate that primary habitat composed of Nasturtium is highly variable in terms of area covered. This plant species is an annual and its area cover is influenced by local climate effects. A warm winter may result in greater growth earlier in the season, while a summer storm event may result in scour of local patches. The variability in habitat is less likely to be observed with Mimulus (monkey flower) the other major plant species associated with KAS. This plant is a perennial species and the variability in area cover should be less than that of Nasturtium. Population estimates for KAS between years has not been shown to be significantly different. However, the confidence intervals around these estimates are great, due to overwintering

mortality that can result in high inter-annual variability. The life-history of KAS is characterized by starting with a small number of over-wintering adults. Population size increases throughout the season from recruitment. An associated KAS genetics project (Keim, Northern Arizona University) has provided preliminary indications that the KAS at Vaseys Paradise is genetically distinct from Utah populations also identified as KAS. What this distinction means in taxonomic terms is yet undetermined.

Aquatic Biological Resources - Since 1998, work associated with aquatic biological resources have represented data collection efforts in support of eventual long-term monitoring programs. As with terrestrial biological resources, the emphasis for biological projects is moving toward long-term monitoring while transitioning from EIS-related efforts associated with these resources. This transition has included attempts to maintain continuity among data sets that were collected prior to 1996. There has been a bit more emphasis put on research associated with aquatic resources when compared to terrestrial resource efforts to develop information that will be used in developing the long-term monitoring program. Current contracts are separated into aquatic foodbase (Blinn, NAU), Lees Ferry Trout (Persons, AGFD), and Native Fish Monitoring (Gorman, US FWS). The following is information provided from these monitoring projects.

Monitoring the Aquatic Foodbase in the Mainstem Colorado River and its Tributaries – Dr. Dean Blinn of Northern Arizona University has been studying aquatic biology of the Colorado River since the 1980s. Efforts since 1998 have focused on monitoring the productivity in the mainstem as influenced by dam operations and understanding the relationship and influence of tributary productivity on the mainstem. Results of these data collection efforts indicate that reducing fluctuations benefits productivity. Productivity is increased because areas available to colonize are stabilized. What is not known is if combinations of stability and short-term disturbance optimize productivity. Productivity increased following the 1996 BHBF, the subsequent flows in the summer of 1996 and in spring/summer 1997 that were high and relatively steady compared to operations in previous years and may have been a contributing factor in the measured productivity. Tributary

collections show that these streams are a source for benthic colonizers in the mainstem, but current mainstem conditions (constant cold temperatures) preclude their expansion into the mainstem. Some organisms found in tributaries need a range of temperatures as a growth cue. These cues are not available in the mainstem. Both of these pieces of information are important for managers trying to optimize mainstem productivity. Productivity might be limited by temperature (degree days) and other physical parameters, or by habitat instability (amount of fluctuations), or a combination of the two.

Monitoring the Lees Ferry Trout Fishery – Mr. Bill Persons of the Arizona Game and Fish Department has been overseeing the contract responsible for determining the effects of dam operations on rainbow trout in the Glen Canyon reach. This contract has included the collation of stocking and catch data since the 1960s and an examination of the effects of minimum flows on trout populations. Their analysis concludes that fluctuations conducted during the 1990 research flows caused a decline in the trout population in the Lees Ferry reach. Higher minimum and more stable releases appear to support greater standing stocks of trout than do lower minimum releases and releases with greater variability. These data support the findings associated with the aquatic foodbase. The full effect of stable releases is not fully realized for up to three years: densities of fish >304 mm declined until 1993. Small fish are more affected by physical factors, suggesting that recruitment is affected by operations. Larger-sized fish are more affected by biological factors (e.g., food availability) which may account for the lag in response to steadier releases by fish > 304 mm. Stock assessments for the Lees Ferry fishery suggest that the larger fish are food-limited. The trout fishery is considered self-sustaining and stocking currently is being suspended in this fishery.

Monitoring of Native and Other Fish in the Mainstem Colorado River and its Tributaries– Dr. Owen Gorman, formerly of the U.S. Fish and Wildlife Service, has been the principal investigator responsible for native fish monitoring in the mainstem since 1998. Work in this project has included mainstem data collection and tributary data collection. The emphasis has been on evaluating recruitment in the tributaries, primarily the Little Colorado River, and

characterizing relative abundance of species in the mainstem. The intensity of sampling in the mainstem may not have equaled historic levels, but gear-types are comparable. Data from these monitoring trips indicate that Rainbow Trout is the most common fish, followed by Speckled Dace and Humpback chub in the mainstem. The addition of mini-hoopnet to the sampling regime has resulted in the capture of an increased number of smaller Humpback chub in the mainstem. This result suggests that either gear types are biased against this size fish, that recruitment and survivorship has increased in this size class, or that new habitats are being sampled that were previously not sampled. The latter is not a likely explanation for this data. Included in this contract was research associated with juvenile growth and temperature. Preliminary results indicate that young fish provided unlimited food that are in 12°C water do not grow over a 6-month time period and lose body mass over time. Fish in 18°C and 24°C tanks showed changes in growth rates after the first month–with those fish in the warmest water growing the greatest. These data have direct application for Temperature Control Device (TCD) operations. A question that still needs to be addressed is if the small but now older fish are moved from the 12°C tanks to warmer tanks will they respond in a similar fashion to temperature increases.

Native Fish Syntheses - Additional synthesis and modeling work on native fish has been conducted by SWCA (data integration report), Duncan Patten (compilation of GCES Phase II aquatic biology studies) and Walters, et al. (modeling abundance trends in native fish). Population estimates for Humpback chub in the LCR have been published by Douglas for 1991-1993 and additional estimates for 1993-1995 are in press. In addition, modeling work by Walters, et al. (in preparation), suggests that populations of Humpback chub in the LCR are stable or possibly declining slightly over the period 1991-1996. The work of SWCA highlights the importance of life history parameters on the survival of Humpback chub and points to the potential of predator-prey interactions in addition to temperature as a key factor affecting Humpback chub abundance and distribution in the mainstem. The reviews of GCES Phase II Humpback chub monitoring and research activities by Brunkow (in Patten) will be useful in designing the long-term monitoring program for native fish.

Socio-Cultural –

Cultural Resources – The current information concerning cultural resources is based on a number of previous and ongoing investigations within the Colorado river corridor in the Glen and Grand Canyons conducted by the NPS, Tribal groups, and GCMRC investigators. Cultural resources along the Colorado River corridor include archaeological sites and traditional cultural resources such as springs, landforms, sediment and mineral deposits, and traditional plant locations and animals. The goal of the cultural resource efforts is *in-situ* preservation with minimal impact to the integrity of the resources, and when preservation is not possible, treatment efforts as appropriate. Monitoring activities include site visits, photography, and remedial activities and tribal assessments of traditional cultural resources and the general health of the ecosystem through traditional perspectives.

Cultural resources are monitored regularly and during high flow events. Many of the archaeological resources along the river corridor are contained in the sediment deposits which form the alluvial terraces. Since the completion of Glen Canyon Dam, the sediment resource has declined, and the alluvial terraces have eroded. A system-wide method for regenerating the river terraces and redistributing sediment is generally considered an essential component to maintaining integrity for cultural resources.

Previous Investigations. The 1996 BHBF presented an opportunity to study the effects of high flow discharge from Glen Canyon Dam on alluvial terraces and margin deposits along the river corridor. The flow was expected to provide system-wide mitigation to most cultural sites in the Colorado River corridor through the accumulation of additional sediment and the overall findings of the cultural resources studies strongly suggest that the 45,000 cfs BHBF flow had either no effect, no adverse effect, or a beneficial effect on cultural resources. These findings support the original contention that habitat building flows can offer a system-wide mitigation for cultural resources. Some locations, especially in the Glen Canyon reach, did experience loss of sediments or re-deposition of sediments in a way that, in the long run, could be detrimental to cultural resources.

Ongoing Investigations. Current resource monitoring of archaeological and traditional resources suggests that archaeological resources continue to be impacted by physical impacts such as surface erosion and gullying in both the Grand and Glen Canyon areas. While some surface erosion is due to natural processes that are unrelated to dam operations, sediment loss from erosional processes believed to be related to dam operations and mainstem water levels, and head cutting arroyos appear to impact archaeological sites at specific locations. Visitor impacts such as trailing and collection of artifacts have also been noted at archaeological sites and locations of traditional importance (Leap, et al., 1999). Generally, plant resources seem to be in good condition with some physical and visitor impacts noted at some locations.

Ongoing GCMRC projects will provide additional information that complements previously collected data. These projects include a synthesis of data collected by the NPS and Tribal groups, mainstem flow and deposition modeling, and testing of a geomorphic erosional hypothesis. The data synthesis will help identify data gaps in previously collected data. A stage flow and deposition modeling project will provide information on estimated sediment deposition at selected archaeological resource locations that may result from flow regimes associated with dam operations. These data can then be used to analyze available information on pre-dam processes that affected cultural site preservation. An ongoing geomorphic project is attempting to identify erosional processes that are related to dam operations versus naturally-occurring processes. Results of these studies will be helpful in distinguishing resource impacts that are related to dam operations. Draft reports for the data synthesis and geomorphic projects have been submitted and are being reviewed. An interim report on the flow and deposition modeling is due later in FY 2000. Ongoing tribal projects include an ethnobotanical project to evaluate traditional plant resources and a public outreach project to disseminate information on traditional tribal resources. Project reports with recommendations are due in FY 2000.

Recreational Resources – Beaches and sand bars serve as campsites for rafting groups and are highly valued based on size, boat mooring quality, wind protection, access to side canyon hikes, scenery, and shade. Historically, these beaches were replenished annually by sand and silt transported by the river during spring runoff. Since this sediment now settles out in Lake

Powell, the beaches downstream are eroding due to the river's clear, sediment-free flows (Kearsley, et. al., 1994). Most pre-dam beaches are now considerably smaller, and some have disappeared completely. Camping beaches are also being eroded through gullying induced by monsoon rainstorm runoff, a phenomenon believed to be related to the lowered mainstem base levels as degraded beaches are not replenished by annual flooding.

Previous Investigations. In 1994, change in campable area was analyzed from an inventory of campsites using past aerial photographs (Kearsley, et al., 1994). The effects of the 1996 controlled flood on campsites were evaluated and it was found that the increase in the number and size of campsites was of short of short duration. These data suggest that floods temporarily increase campsite number and size but then campsites will continue to erode slowly. The flood effects to campsites seem temporary but they appear to be the only feasible means of depositing sediment above normal fluctuations (Kearsley, et al., 1999.)

Ongoing Investigations. Ongoing GCMRC studies address campsite assessment and monitoring through quantitative beach and sand bar measurements to detect area and volume change. The results of this work will be available later in FY 2000. An additional recreational study is assessing recreational preferences relative to experiences. This study includes recreational preferences for camping beaches and activities such as white water rafting, day-use rafting in Glen Canyon, and fishing and recreation experiences. Data on beach use frequency is currently being collected by an NPS study and will be available in FY 2001 for use in future studies investigating human impacts to beach sites. Recreational fishing data will be assessed in FY 2000 as part of a protocol assessment that will be conducted in tandem with other trout study assessments. These data will be available in later in FY 2000.

Information Technologies Program (ITP) -

Data Base Management System (DBMS) - Development of the DBMS has been on hold since the resignation of GCMRC's DBMS Coordinator in August 1998. The Oracle DBMS software has been selected as the data base engine and Windows NT has been selected as the platform. The Oracle DBMS software has been obtained and installed and the installation procedure documented. We have recently filled the DBMS Coordinator position and anticipate

moving forward with DBMS development in the very near future.

Geographic Information System (GIS) – Development of the GIS was on hold since the resignation of GCMRC's GIS coordinator in June 1998. A new GIS Coordinator was hired in April 1999. Since then much effort has been dedicated towards remote sensing evaluation and cataloging, and making available legacy-GIS data obtained by GCMRC's predecessor, the GCES program. Much of this data is now available to GCMRC staff and investigators, AMWG/TWG members, and the public through our FTP server at ftp.gcmrc.gov. The FTP server contains spatial coverages of non-sensitive, project-specific data; topographic, geologic, and hydrologic base data at established GIS sites; and remotely-sensed imagery including LIDAR and digital orthophotos. Additional effort has been dedicated toward assembling basin-wide GIS data sets, developing GIS data and metadata standards, preparing for a possible BHBF during the summer of 1999, providing GIS support and training to GCMRC scientists and investigators, and coordinating remote sensing activities.

Library – The GCES made great strides in the establishment of the library in 1993 when a research librarian was hired to organize and maintain it. However, the librarian resigned in May 1997 during the transition from GCES to GCMRC and the position was not immediately backfilled. There have been valid concerns about the condition of the library since that time. New holdings have been stacked on shelves, desks, or placed in boxes for safekeeping. There was no formal monitoring of the library or checkout process to track the whereabouts of library materials. Fortunately, that situation has since been corrected and significant progress has been made in making the library a functional entity within the GCMRC.

A library committee was assembled in October 1998 to decide what actions should be taken to update and maintain the library. Over several months, the committee produced a strategic plan with recommendations for the restoration of the library. The library contents and strategic plan were reviewed by two outside consultants who each produced written comments and recommendations. Since that time, a student has been hired from Northern Arizona University to oversee the day-to-day operations of the library and reorganize its contents. Library automation software has also been obtained and the library contents are being indexed

using this software on a time-available basis.

Surveying - Surveying has been an integral part of science monitoring and research in the Grand Canyon since 1993, starting with the former GCES. In addition to providing general survey support to GCMRC scientists and investigators for spatially-referencing data collected in the field, the survey function provides survey and mapping infrastructure in the form of terrestrial base maps, hydrographic base maps, and control.

Terrestrial base maps - Terrestrial mapping in the Grand Canyon on the Colorado River corridor is required for spatial monitoring of physical, biological, and cultural resources. Terrestrial mapping usually produces a digital terrain model (DTM) in combination with the XYZ position of features and artifacts. Periodic mapping of the same areas can be used for change detection of resources. This data is usually displayed in the form of a contour map.

The two types of terrestrial mapping currently done are field surveys and remotely-sensed data (photogrammetry, LIDAR). Field surveys can yield a very high precision DTM with a contour resolution of 10 centimeters (cm). The accuracy is dependent on the control. Photogrammetry data, as in our GIS sites, are sub-meter precision and are displayed at one half-meter contour. There are a few sites with high-resolution photogrammetry at 20 cm resolution.

It is an objective of GCMRC to establish a sub-meter accuracy terrestrial topographic base map of the entire river corridor to support long-term monitoring. This is only feasible using remotely-sensed data such as photogrammetry or LIDAR.

We currently have sub-meter accuracy terrestrial topographic coverage of approximately 80 miles of the ecosystem in 17 areas of concentrated scientific effort that we refer to as GIS sites (Figure 1.2). We also have similar topography from GCD to Badger Rapid near river mile (RM) 8 and in the Phantom Ranch area derived from our LIDAR evaluation. In 1999, the GCMRC participated in a cooperative project with the USGS and the National Geodetic Survey to collect geo-referenced stereo photography of the entire Colorado River ecosystem with the objective of evaluating a new procedure for producing sub-meter accuracy terrestrial topographic base maps without the need for ground control. A 25-mile test section of the ecosystem will be mapped as part of the evaluation. The processing costs for the remainder of the ecosystem have yet to be allocated. In addition to sub-meter terrestrial base maps described above, we have high-

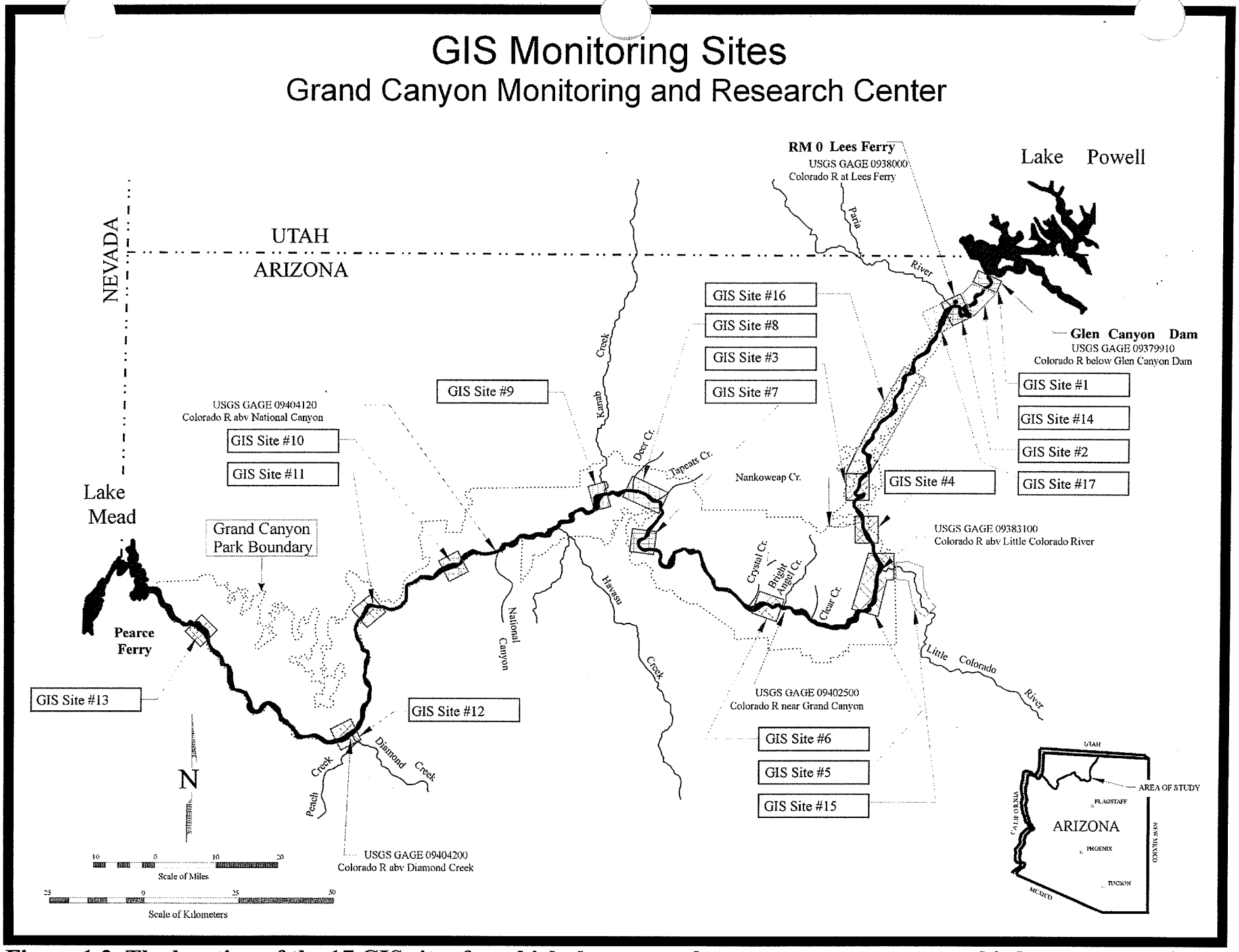

Figure 1.2 The location of the 17 GIS sites for which there are sub-meter accuracy topographic base maps available.

resolution field surveys of 35 sand bar sites that have been repeated at varying intervals since 1991. We also have numerous field surveys of vegetation, cultural, and KAS surveys. Additional sub-meter accuracy terrestrial topographic coverage needs to be obtained for the remainder of the ecosystem.

Hydrographic base maps - The Hydrographic mapping program was established for the purpose of obtaining a sub-aqueous channel map of the Colorado River within the ecosystem and measure changes in morphology and volume to monitor sediment. Another important emerging hydrographic technology is the monitoring of grain-size movement and distribution.

The hydrographic single beam system prior to 1999 had an XYZ spatial accuracy of about 25 cm 90 percent of the time. The use of a robotic tracker and motion compensation improved the single beam accuracy to about 5 cm. Using the single beam system, a 10 meter square grid generally yields a reliable 0.5 meter contour resolution and 0.25 meter contour resolution using the new system. A pilot study on a multi-beam hydrographic system, which produces 100 percent coverage of the bottom, yielded a 5 cm contour resolution. Furthermore, the productivity of the multi-beam demonstrated the only feasible method of completing a channel map in a reasonable amount of time.

It is an objective of GCMRC to acquire an in-house multi-beam system to complete a channel map of the entire system. The system would also be used to collect event-driven hydrographic data as well as sediment monitoring. We would also like to incorporate side-scan sonar or bottom classification technology to monitor grain-size distribution and bottom geomorphology.

We currently have low resolution (20 meter transects) single beam base data from GDC to Badger Rapid, and GIS Site 7. We currently have high resolution (10 meter square) single beam data in 35 NAU sand bar sites (repeated since 1993), repeated surveys from Paria (RM 1) to Cathedral Wash (RM 3), 4 large pool sites in Site 5 (Wiele, 1998), 5 repeated surveys in GIS Sites 4 and 5 to monitor the 1996 flood, and a pre and post flood survey on the Lake Mead Delta. We also have extremely high resolution (multi-beam) surveys in the pools from RM 60 to RM 68. Additional channel mapping of all the GIS reaches and the remaining river channel

needs to be obtained as control is established.

Canyon control – Survey control in the Colorado River ecosystem is required to meet the demands of any spatial measurements for scientific monitoring and research. Survey control also supports the spatial positioning of hydrographic and bathymetric channel mapping as well as ground control for aerial mapping or remote sensing applications.

The control framework is established with static differential GPS. The desired accuracy for this GPS is centimeter accuracy with millimeter precision. The interconnecting conventional traverse surveying allows for continuous line-of-site point availability as well as network adjustment capability. The desired accuracy for primary conventional control is 10 cm with 1 cm precision. The objective is one primary control point every 500 meters.

We currently have approximately 20 first order GPS grade base stations set on the rim of the Grand Canyon in support of Static Differential GPS. This base station network is currently in good order to complete the control in the Canyon. We additionally have continuous traverse control (point-to-point line of sight) from GDC to RM 72. Downstream from RM 72 there is continuous traverse control in all existing GIS sites. In addition there is continuous traverse control from the LCR confluence to Blue Springs, approximately 14 miles upstream which encompasses GIS Site 15.

There are approximately 50 sites throughout the system that exist outside of GIS areas that use locally-established control points. These sites must be tied in as we bring control into these areas. The list includes NAU sand bar monitoring sites, vegetation monitoring sites, and cultural sites. All the USGS transect bolts have been tied in from GDC to RM 72. Downstream USGS bolts in GIS Sites have also been tied in. USGS bolts that require surveying are at Phantom (RM 90), and National Canyon (RM 160). The GCMRC Survey department objective is to complete the continuous control network in the Canyon in the next three years.

Systems Administration – Systems Administration encompasses the entire computing and networking environment at the GCMRC. The GCMRC computing environment has been substantially upgraded during the past two years with improved intra- and inter-net infrastructure and standardized computer hardware and software. The core computing environment is now, for the most part, stable with the majority of malfunctions attributable to typical glitches associated

with all computer environments of similar complexity. One part-time student employee, in conjunction with the IT program manager, currently acts as our systems administrator.

Remote Sensing – There are currently two aspects to GCMRC remote sensing: (1) remotely sensed data collection, and (2) the remote sensing initiative entitled "*Evaluating ground-based and airborne remote sensing technologies*." Remotely-sensed data collection currently consists of annual aerial photography collected during the Labor Day weekend. Black-and-white stereo aerial photography is collected over the entire Colorado River ecosystem and natural color is additionally collected in areas critical to vegetation studies. The GCMRC intends to continue the annual acquisition of aerial photography until other remotely-sensed data sets are identified and implemented into the monitoring program.

The GCMRC remote sensing initiative is currently on hold since the resignation of the GCMRC staff member coordinating the activity in February 1999. The remote sensing initiative formally begins in FY 2000. However, planning and informal activity have been taking place since spring of 1998. In May 1998, a remote sensing protocols evaluation panel (PEP) met to review the remotely-sensed monitoring and research methodology currently used by the GCMRC. The panel recommended alternative remotely-sensed technologies that might better meet science program information needs. The panel's report recommended a number of ground-based and airborne remote sensing technologies that had potential in the Canyon, but the panel did not provide any prioritization of these technologies. It is anticipated that most of these technologies will be evaluated as part of the remote sensing initiative. Some technologies have been evaluated on an accelerated schedule due to related projects funded prior to the remote sensing initiative, pressing needs for technological development in specific monitoring areas, or opportunistic circumstances.

Remote sensing technologies recommended by the PEP and their evaluations initiated in FYs 1998-1999 are:

- Investigating cultural terrace erosion using photogrammetry
- Three-dimensional sand bar measurement using vertical photogrammetry
- Three-dimensional sand bar measurement using oblique photogrammetry
- Bathymetric channel mapping using multibeam sonar

- Channel bed classification using QTCview
- Terrestrial mapping using LIDAR
- GPS comparison to total station as a means of setting control (preliminary)
- Multi-resource monitoring using HYDICE hyperspectral imaging (data collection only)
- Vegetation monitoring using color infrared (data collection only)
- Biomass measurement using LIDAR
- Turbidity using passive optical sensors
- Radiant temperature measurement
- Radiotagging of boulders

Interim products from these pilot tests include:

- Three-dimensional model and DEM of the Glen Canyon reach from Lees Ferry to Badger Rapids produced from LIDAR
- Geo-referenced, ortho-rectified color infrared photography of the Glen Canyon reach which can be used for rectifying additional annual photography and evaluate color infrared as a means of vegetation monitoring
- Cultural terrace maps which can be used for identifying areas of erosion and calculating volumetric changes
- Three-dimensional sand bar maps from which to compute volume changes
- Geo-referenced channel maps of portions of the Lees Ferry reach which can be used for volumetric sediment transport measurements
- Single-beam channel bed classification for portions of the Lees Ferry reach which can be used to classify channel bed material
- Surface-water temperature maps of the Colorado River

These products will be useful to the program whether or not the evaluation yields information suggesting we should implement a given technology in an operational mode as part of GCMRC's

long-term monitoring and research. GCMRC is currently evaluating how best to proceed with coordinating the remote sensing initiative. Staffing arrangements under consideration are: (1) utilizing a term appointment to last the three year duration of the initiative within GCMRC, (2) utilizing a cooperative agreement with experienced personnel from another agency within the Federal government, and (3) contracting the evaluation to an external third party.

PROGRAM INTEGRATION

All GCMRC monitoring and research programs utilize ecosystem science approaches that require integrated studies (Figure 1.3) that conform to the appropriate spatial and temporal scales of the issues at hand. As the report of the Ecological Society of America Committee on the Scientific Basis of Ecosystem Management (ESA, 1995) indicates, the incorporation of good science into management decisions at a landscape level is an essential component of ecosystem management. An ecosystem approach will serve to advance both scientific understanding and management capabilities, while supporting protection, management, and use of natural resources.

MANAGEMENT OBJECTIVES AND INFORMATION NEEDS

The monitoring and research activities proposed in the FY 2001 Work Plan are intended to address the management objectives and prioritized information needs recommended by the AMWG to the Secretary and approved by the Secretary for use in developing priorities for monitoring and research activities for the Colorado River ecosystem. MOs and INs are specified in nine different resource areas including hydropower, water, sediment, fish and aquatic biology, riparian vegetation, threatened and endangered species, terrestrial wildlife, cultural, and recreational resources. Within each of the above resource areas specific MOs and INs have been developed by the Technical Work Group (TWG) and adopted by the AMWG (see Appendix 2.) The specific MOs and INs addressed by the monitoring and research activities proposed in this plan are listed in Chapter 2 in table format, and referenced in the project descriptions.

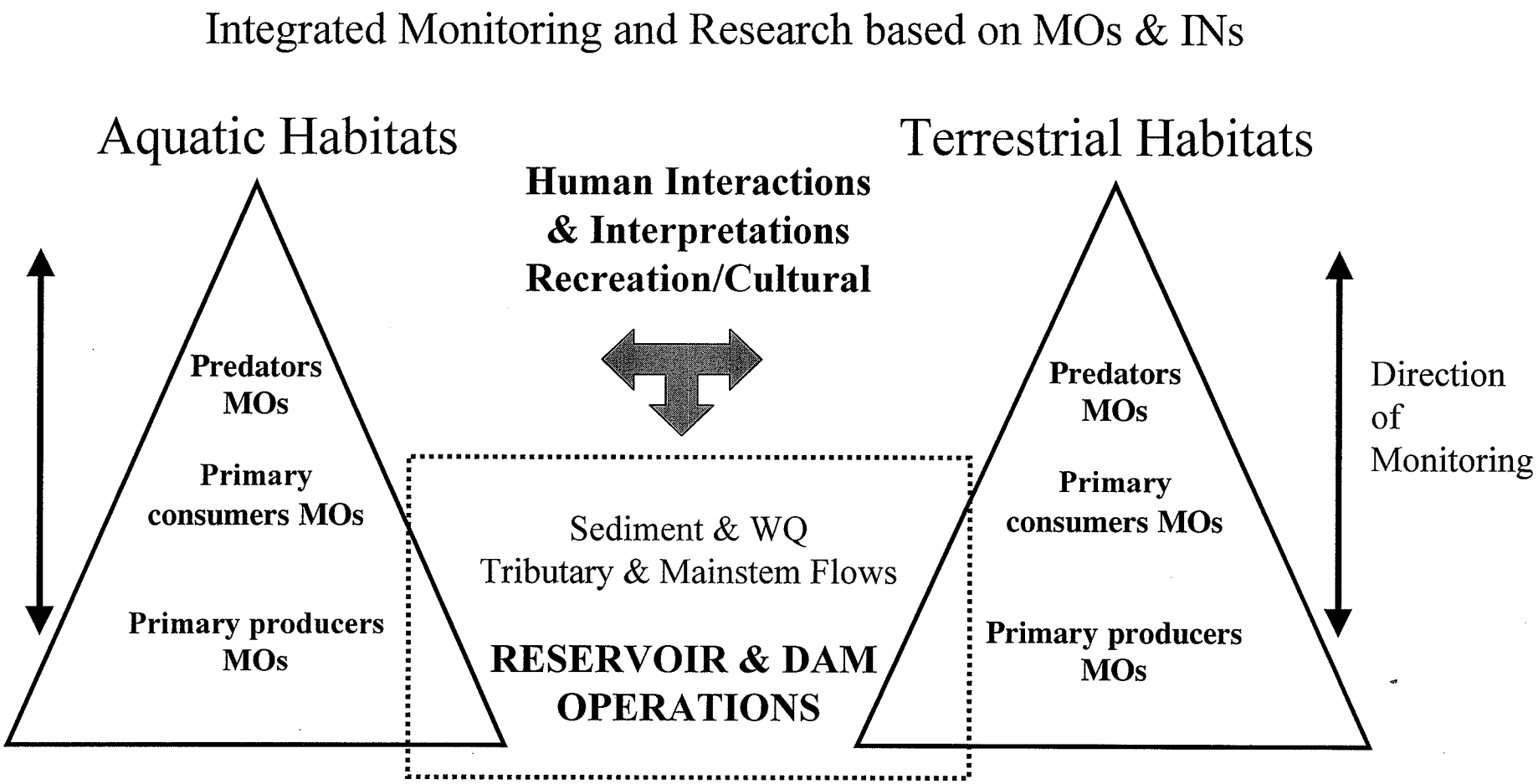

Figure 1.3 Integrated Long-term Monitoring and Research Program

PROTOCOL EVALUATION PROGRAM

The Protocol Evaluation Program (PEP), is described in a prospectus entitled, "Prospectus for Evaluating GCMRC Monitoring Protocols for the Colorado River Ecosystem" (Appendix 3). The information gained through the PEP process is intended to support decisions by the GCMRC Chief and his staff as to the specific monitoring protocols that will be used within the ecosystem. Details on the specific monitoring techniques will be discussed with the TWG and the Science Advisory Board (SAB), and conveyed through RFPs to prospective cooperators that are selected through a competitive process. Although technologies, science and management needs may cause evolution in monitoring protocols and strategies through time, the GCMRC is committed to ensuring that all monitoring data sets are comparable to the greatest extent possible with previously collected information.

The PEP process for evaluating current and new alternative protocols in all program resources area is scheduled for completion by the end of FY 2002. A PEP review workshop on remote-sensing technologies was held in May 1998. PEP review workshops for physical resource monitoring were held in August 1998, and 1999. Reports on the results of those meetings have been submitted to the GCMRC and distributed to the TWG and AMWG. PEP activities in FYs 2000 and 2001 will focus on protocols that support long-term monitoring of biological, cultural and social resources. All PEP workshops and evaluations are conducted in cooperation with external experts identified through a nationwide scoping and competitive selection process, as well as GCMRC science cooperators, contractors, and Technical Work Group members.

CONTINGENCY PLANNING

The TWG and AMWG have adopted hydrologic criteria and resource criteria for triggering managed high flood flows from Glen Canyon Dam (BHBFs). When triggered, these criteria provide little lead time for monitoring and research planning. In addition, hydrologic conditions can lead to unplanned release events which will also require GCMRC to implement monitoring and research activities with little to no lead time. The potential for these events to

occur results in the need for contingency planning. Annually, GCMRC will develop contingency plans for implementation of:

(1) supplemental monitoring before and (or) after unplanned events, as appropriate;

(2) research assessments of "flood flows" (as per the GCDEIS) or other short-duration high flow unplanned events; and

(3) a supplemental monitoring and research program for planned events between January-July of a given year.

Funding to support monitoring and research activities beyond those which constitute annual monitoring activities will be sought from the Bureau of Reclamation and the Western Area Power Administration subject to the recommendation of the AMWG/TWG. An example of an outline for a BHBF contingency plan and the associated budget (developed in FY 1999 but never implemented) can be found in Appendix 4.

SCIENCE SYMPOSIUM

The GCMRC has initiated a program of regular scientific symposia to discuss the current state of the knowledge of scientific regarding the Colorado River ecosystem, as well as to learn about similar research in other systems. The GCMRC convenes a biennial Colorado River ecosystem science symposium, and between these years GCMRC program managers and participating scientists make presentations at the biennial Colorado Plateau symposium hosted by the Colorado Plateau Field Station of the Biological Resources Division of the USGS. GCMRC hosted scientific symposia in 1997 and 1999, and will do so again in FY 2001. Typically, these meetings are held in late Winter to early Spring.

FUTURE CHALLENGES

GCMRC and the adaptive management program, in general, face a number of challenges with respect to designing monitoring and research activities to gather information on specific experimental management actions. These include potentially both the construction and operation

of a temperature control device (TCD) on Glen Canyon Dam and the implementation of seasonally adjusted steady flows (SASF).

With respect to the construction and operation of a TCD, the FY 2001 Work Plan is based on the assumption that the TCD, if built, will not be operational until FY 2002. The TCD workshop held at Saguaro Lake Ranch from November 8-10, 1999, identified a number of issues that need to be addressed in a monitoring and research plan for the TCD as well as for baseline monitoring. Finally, it is based on the assumption that any activities required to supplement the planned monitoring and research activities will be supported out of Reclamation's Section 8 funds. With respect to implementation of SASF, the FY 2001 Work Plan is based on the following assumptions. First, that the actual flows to be implemented under the SASF experiment will result from the plan being drafted for GCMRC by SWCA, Inc. Second, we assume that there are two possible scenarios for implementing SASFs. The first assumes that a decision is made in January 2001, for implementation of SASFs in FY 2001. Under this scenario, GCMRC would write and release RFPs in April 2000 for any additional monitoring and research activities that are required. Again, we would expect to support this additional work with Section 8 funds. The second scenario is based on the assumption that the decision to implement SASFs is not made until January 2001, and any supplemental activities are implemented through GCMRC in-house activities and modifications to existing contracts. Again, we would expect to support this additional work from Section 8 funds. Until the SWCA, Inc., plan has undergone external peer review and is accepted by GCMRC, no planning is being done regarding additional monitoring and research activities that may be needed in support of SASFs.

SCHEDULE AND BUDGET[8]

The Annual Work Plan and budget described in this document were reviewed by the TWG in Fall 1999, and the AMWG recommended at their January 20-21, 2000, meeting that it be approved by the Secretary for implementation. The GCMRC FY 2001 Work Plan will be implemented for approximately $7 million. Of this amount, $6.434 million is provided through the GCDAMP from power revenues, $300,000 is provided from Reclamation through Operation and Maintenance funds, and $310,000 is provided from Reclamation through Section 8 funds. In addition to these monies, the GCDAMP expends an additional $1.416 million in support of the adaptive management process and the Programmatic Agreement. For additional information about AMP activities and budget, and the Programmatic Agreement, please contact Mr. Randall Peterson at the Bureau of Reclamation, Salt Lake City, Utah.

[8] The budget for the FY 2001 Work Plan was recommended to the Secretary for adoption by the AMWG at its July 21-22, 1999 meeting.

CHAPTER 2

SCIENTIFIC ACTIVITIES

This chapter provides descriptions of individual monitoring and research projects to be initiated as part of the GCMRC's FY 2001 integrated science program. These scientific activities are grouped into the following categories: (1) Terrestrial Ecosystem; (2) Aquatic Ecosystem; (3) Integrated Terrestrial and Aquatic Ecosystem; (4) PEP and (5) Remote Sensing. These headings reflect a five-year strategy of protocol evaluation, remote sensing technology development and ongoing program development intended to produce an integrated long-term monitoring and research program. Individual projects and their relationships to current management objectives and information needs (Appendix 2) are summarized in Table 2.1. Each of these projects are classified as: (1) Ongoing – meaning a continuation of efforts supported during FYs 1998-2000 without modification until PEP is completed; (2) Ongoing with Modification – meaning that efforts supported in FYs 1998-2000 will continue, but with some modification in methods or focus based on PEP or other review recommendations or information needs; and 3) New – meaning that the project is a new research effort, or a component of the draft long-term monitoring plan using current or new alternative methods and sampling designs. Because the existing science program is still in a transitional phase and is evolving toward a fully integrated design, some of the FY 2001 science activities will remain "ongoing," or "ongoing with modification," until such time that PEP activities are completed program-wide. In the case that formerly used methods and designs are found to fully meet information needs, scientific standards and cost efficiency, ongoing efforts will be continued as part of long-term monitoring. New projects described under the "integrated terrestrial and aquatic" heading in the text and in Table 2.1, represent initial steps toward implementing the draft long-term monitoring program. For example, in the FY 2001 Work Plan, most of these contain elements formerly described as components of the "Physical Resource" research and monitoring under the GCES and FYs 1997-2000 GCMRC annual plans, but are often complemented by new "alternative" or modified sampling methods and designs that were identified through the PEP-SEDS review process completed in Fall 1999.

Additional information in Table 2.2, supports science-project descriptions by showing how total project costs and staff participation are estimated to be distributed across the GCMRC program. A key element in developing an ecosystem science design for long-term monitoring and research is the team approach to project design and oversight being advance by the GCMRC program staff in the FY 2001 Work Plan. The GCMRC believes that this strategy has a higher likelihood for achieving a science program and data base that has potential for integrated advancement of knowledge than has previously occurred under previous program designs.

Table 2.1. Summary table of FY2001 Project titles and associated Management Objectives and Information Needs.

PROJECT TITLE	MANAGEMENT OBJECTIVE	INFORMATION NEED
TERRESTRIAL ECOSYSTEM ACTIVITIES		
Monitoring avifauna **NEW RFP IN SUMMER 2000**	**TERR MO 11:** Protect, restore, and enhance survival of native and special status species (federal, tribal, and state designations). Ensure that the required habitat for these species is preserved. **AVI MO 13:** Protect, restore, and enhance survival of native and special status avifauna.	TERR IN 11.2 Determine species population characteristics to detect departures from natural range of variation. TERR IN 11.3 Determine changes, declines in special status species and characterize ecosystem changes to benefit species. AVI IN 13.2 Determine impacts of dam operations under approved operating criteria on avifauna food chain associations
Monitoring Kanab ambersnail and habitat at Vaseys Paradise **NEW RFP IN SUMMER 2000 OR MAINTAINED INTERNALLY**	**KAS MO 14:** Sustain populations of Kanab ambersnail wherever they currently exist within the Colorado River ecosystem.	KAS IN 14.1 Determine specific habitat characteristics required by the KAS. (T&C 3--p.41) KAS IN 14.2 Determine special flow impacts on Kanab ambersnail to assure that the level of incidental take is not exceeded. (I. T. - p.40) KAS IN 14.3 Complete a census of the population and characterize the habitat. Once habitat require-ments are determined, other potential habitat sites within the Grand Canyon corridor will be surveyed to determine species presence and

		recovery potential. (Conservation Recommendation 5--p.43) KAS IN 14.4 Survey KAS habitat before and after any flow greater than 25,000 cfs to determine population and its species response to disturbance and ability to recover. (T&C 4, p.42; and RPM) KAS IN 14.5 Determine Kanab Ambersnail life history schedule for populations in the Colorado River ecosystem. (Conservation Recommendation 5)
Ongoing research on terrestrial trophic linkages **ONGOING**	**TERR MO 11:** Protect, restore, and enhance survival of native and special status species (federal, tribal, and state designations). Ensure that the required habitat for these species is preserved **AVI MO 13:** Protect, restore, and enhance survival of native and special status avifauna.	TERR IN 11.1 Define and specify ecology of native faunal components, especially threatened and endangered species; including evolutionary and environmental changes, natural range of variation, linkages, interdependencies, and requirements AVI IN 13.1 Define and evaluate food chain associations, interdependencies, requirements, etc. for native avifauna, including the Peregrine Falcon, Southwestern Willow Flycatcher, and other special status species (e.g., Yellow-billed Cuckoo). AVI IN 13.2 Determine impacts of dam operations under approved operating criteria on avifauna food chain associations.

Evaluation of cultural resource monitoring and mitigation strategies **NEW RFP IN 2000**	**CULT MO 1:** Conserve *in situ* all the downstream cultural resources and take into account Native American cultural resource concerns in the Colorado River ecosystem. **CULT MO 2:** If *in situ* conservation is not possible, design mitigative strategies that integrate the full consideration of the values of all concerned tribes with a scientific approach	CULT IN 1.1 Monitor cultural sites potentially impacted by Glen Canyon Dam operations to determine present condition and rate of change to assess: types of degradation, threats; rates of degradation; define immediacy of threats to resources; protection methodologies; protection, monitoring and research costs. CULT IN 2.1 Characterize through scientific study and data development all assumed historical and current values, including scientific values, of resources to tribal nations and to the general public.
Development of historic contexts to evaluate the significance of cultural resource data **NEW RFP IN 2000**	**CULT MO 4:** Maintain and integrate all appropriate cultural data recovered from monitoring, remedial, and mitigative action and incorporate these data into the evolving research designs and mitigative strategies for understanding the human occupation and use of the Colorado River ecosystem.	CULT IN 4.1 Develop evolving research designs and/or other methods including synthesis of existing available data and GIS for understanding human occupation and use.

AQUATIC ECOSYSTEM ACTIVITIES		
Ongoing monitoring phyto-benthic community and evaluating its quality for utilization **ONGOING WITH REVISIONS NAU (BLINN & SHANNON)**	**AFB MO 1:** Maintain and enhance the aquatic food base in the Colorado River ecosystem to support desired populations of native and non-native fish. At a minimum, maintain continuously inundated areas for *Cladophora* and aquatic invertebrates at or above 5,000 cfs discharge levels from Glen Canyon Dam.	AFB IN 1.1 Determine status and trends in aquatic food base species composition and population structure, density and distribution and the influence of ecologically significant processes. AFB IN 1.2 Determine the effects of past, present, and future dam operations under the approved operations criteria on the aquatic food base species composition, population structure, density, and distribution in the Colorado River ecosystem. AFB IN 1.3 Determine the aquatic food base species composition, population structure, density, and distribution required to maintain desired populations of native and non-native fish in the Colorado River ecosystem. HBC IN 3/4.7 Determine origins of fish food resources, energy pathways, and nutrient sources important to their production, and the effects of Glen Canyon Dam operations on these resources. (RPM 1.C.vi) Evaluate linkages between the aquatic food base and the health and sustainability of HBC populations.

Ongoing monitoring of status and trends of fish community **ONGOING WITH REVISIONS**	**HBC MO 4:** Maintain or enhance levels of recruitment of HBC in the mainstem as indexed by size frequency distributions and presence and strength of year-classes. (Focused at young-of-year and juvenile fish, and should include a fish health assessment.) **FMS MO 8:** Achieve healthy, self-sustaining populations of flannelmouth sucker, bluehead sucker, and speckled dace in the Colorado River ecosystem, with special emphasis on flannelmouth sucker in Glen Canyon based upon the capability of the habitat to support those fishes.	HBC IN 3/4.1 Determine adult HBC populations and evaluate life history schedules, population health, and reproductive success. *(Fall 97 RPM 1)* HBC IN 3/4.2 Determine levels of recruitment of humpback chub in the mainstem and the LCR. FMS IN 8.2 Determine population dynamics, distribution, and other life history traits of native fish species. FMS IN 8.3 Determine historic and current character and structure of native fish populations.
Monitoring the status and trends of the Lees Ferry Trout Fishery **NEW RFP IN SPRING 2000**	**TROUT MO 2:** In the Colorado River downstream of Glen Canyon Dam to the confluence of the Paria river, sufficient ecological conditions (such as habitat, foodbase and temperature) should be maintained, which in conjunction with management by Arizona Game and Fish will produce a healthy self-sustaining population of at least 100,000 Age II+ rainbow trout that achieve 18 inches in length by Age III with a mean annual relative weight (Wr) of at least 0.90.	TROUT IN 2.2 Determine trends in rainbow trout population size, character and structure in Glen Canyon. TROUT IN 2.3 Evaluate harvested and field sampled rainbow trout to determine the contribution of naturally reproduced fish to the population in Glen Canyon.

Integrated Water Quality Monitoring **ONGOING WITH REVISION AND COOPERATION BETWEEN GCMRC AND USGS (WRD AZ DISTRICT)**	**LP WQ MO 1:** Prevent impacts that adversely affect the water quality (physical, chemical, biological) of Lake Powell due to dam operations and ensure that fully informed AMWG decisions are possible both now and in the future.	LP-LIMNO IN 1.1 Determine the effect of current dam operations (under approved operating criteria) on reservoir water quality, including but not limited to the following: (a) Determine near dam hydrogen sulfide levels (and other hazardous chemical constituents) within the hypolimnion occurring under current dam operating criteria. (b) Determine the dynamics of lake stratification and advective flows and their effects on chemical constituents (c) Determine/quantify the dynamics of major cations, anions, and nitrate/phosphate ratios resulting from dam operations (d) Determine the effects of dam operations (under approved operating criteria) on the physical/chemical dynamics of Lake Powell side channels and embayments

	WATER MO 2: (water resources) Maintain water quality at levels appropriate to support physical, biotic, and human resource needs…	LP-BIO IN 1.1 Determine the impacts of dam operations and resulting water quality on primary and secondary productivity of Lake Powell, including: • algae (phytoplankton, periphyton) • Macrophytes • Zooplankton WATER IN 2.1 Monitor water quality, composition, temperature (a more comprehensive list of the INs that are addressed by the IWQP can be seen in Table 1 of the IWQP plan (Vernieu and Hueftle, 1999).
Ongoing research associated with population genetics of HBC in Colorado River ecosystem	**HBC MO 6:** Establish a second spawning aggregation of HBC downstream of Glen Canyon Dam (RPM 4).	HBC IN 6.1 Develop criteria for defining self-sustaining populations of HBC. HBC IN 6.2 Assess feasibility of establishing a second population of HBC downstream of Glen Canyon Dam including other current aggregations.
Native fish/non-native competitive interactions **NEW IN SPRING 2000**	**N/NN FISH MO 10:** Minimize, to the extent possible, competitive and predatory interactions between native and non-native fishes.	N/NN FISH IN 10.1 Define areas and conditions of existing and potential interactions. N/NN FISH IN 10.4 Determine the species composition, relative abundance, and size class structure of non-native fishes in the Colorado River ecosystem and important tributaries.

Section 8 funded research associated with experimental flows which include temperature control device evaluation and assessment. **NEW IN SPRING 2000**	**FMS MO 9:** Attain riverine conditions, including appropriate habitat, that support all life stages of endangered and native fish species. **HBC MO 5:** Remove jeopardy for the HBC in the Colorado River ecosystem *(B.O. 1994)*.	FMS IN 9.2 Quantify to the extent possible the effects of spring high steady flows and summer and fall low steady flows on endangered and native fish (RPM 1.a). FMS IN 9.4 Assess biotic interactions between native and non-native fishes, particularly those that occur in nearshore rearing habitats affected by dam operations (RPM 1.C.iv). HBC IN 5.1 Determine a set of possible temperature changes in the mainstem Colorado River resulting from implementing selective withdrawal (RPM 1.B.i). HBC IN 5.2 Determine the anticipated effects on HBC and other native populations which may result from installing a selective withdrawal structure for thermal modification in the mainstem of the Colorado River downstream of Glen Canyon Dam. Determine the range of temperatures for successful larval fish development and recruitment and the relationship between larval/juvenile growth and temperature (RPM 1.B.ii).

New research associated with water quality in Lake Powell **NEW SPRING 2000 AS RFP(?)**	**LP WQ MO 1:** Prevent impacts that adversely affect the water quality (physical, chemical, biological) of Lake Powell due to dam operations and ensure that fully informed AMWG decisions are possible both now and in the future.	LP LIMNO-IN 1.1(e) Quantify/model the heat budget for Lake Powell to determine near-term and long-term (monthly/weekly and annual summaries respectively) effects of a selective withdrawal system.
INTEGRATED TERRESTRIAL AND AQUATIC ECOSYSTEM ACTIVITIES		
Long-term monitoring of fine-grained sediment storage throughout the main channel **NEW RFP IN SPRING 2000**	**SED MO 1:** (sediment resources) Maintain a long-term balance of river-stored sand to support maintenance flow, BHBF flow and unscheduled flood flows…	SED IN 1.1 Define historical and current levels of river stored sediment. SED IN 1.2 Define minimum levels of river stored sediments necessary to maintain sandbars, backwaters and in-stream sediment deposits. SED IN 1.3 Develop procedures to monitor and predict impacts of alternative operating criteria (flow regimes) on river stored sediment, and impacts in select reaches SED IN 1.4 Measure and model sediment contributions from all contributing sources, including tributary and high terrace sources.

		SED IN 1.5 (sediment) Evaluate the geology/geomorphology within Glen Canyon to: (1) determine historical changes in size and extent of beaches, sandbars and backwaters, (2) quantify sediment (size class and quantity) input from side channels, (3) understand bed morphology dynamics, (4) evaluate high terrace erosion and contribution to river sediment.
	SED MO 2: As a minimum for each reach, maintain the number and average size (area and thickness) of sandbars and backwaters between the stages associated with flows of 8,000 and 45,000 cfs that existed during the 1990/91 research flows.	SED IN 2.4 Evaluation of flow regime (under the approved operating criteria) impacts on terrace and cultural resources SED IN 2.6 Determine implications of dam operating criteria on beach and sandbar and backwater character and structure, including suitability of camping beaches. SED IN 2.7 Quantify the extent and location of existing sandbars, beaches and backwaters along the Colorado River corridor
	SED MO 4: Maintain system dynamics and disturbance by redistributing sand stored in the river channel and eddies to areas inundated by river flows up to 45,000 cfs in as many years as possible when BHBF hydrologic and resource criteria are met.	SED IN 4.1 Define character and structure of all beaches and backwaters in system after 1996 test flows

	REC MO 2: Maintain flows (under approved operating criteria) and sediment processes that create an adequate quantity, distribution and variety of beaches for camping, as long as such flows are consistent with management of natural recreation and cultural resource values (other natural resource values).	REC IN 2.2 Evaluate impacts of operating criteria on establishing and maintaining adequate beaches and distribution of other resources, quality, character and structure. REC IN 2.3 Develop methodology to evaluate distribution, quantity and quality changes in all campable beaches through time
	AFB MO 1: Maintain and enhance the aquatic food base in the Colorado River ecosystem to support desired populations of native and non-native fish. At a minimum, maintain continuously inundated areas for *Cladophora* and aquatic invertebrates at or above 5,000 cfs discharge levels from Glen Canyon Dam.	AFB IN 1.3 Determine the aquatic food base species composition, population structure, density, and distribution required to maintain desired populations of native and non-native fish in the Colorado River ecosystem.
	TROUT MO 2: In the Colorado River downstream of Glen Canyon Dam to the confluence of the Paria river, sufficient ecological conditions (such as habitat, food base and temperature) should be maintained, which in conjunction with management by Arizona Game and Fish will produce a healthy self-sustaining population of at least 100,000 Age II+ rainbow trout that achieve 18 inches in length by Age III with a mean annual relative weight (Wr) of at least 0.90.	TROUT IN 2.4 Determine the availability and quality of spawning substrates in the Glen Canyon reach, necessary to sustain the rainbow trout fishery.

	HBC MO 4: Maintain or enhance levels of recruitment of HBC in the mainstem as indexed by size frequency distributions and presence and strength of year-classes. (Focused at young-of-year and juvenile fish, and should include a fish health assessment.)	HBC IN 3/4.5 Determine the effects of mainstem hydrology on the number of nearshore rearing habitats, environmental conditions in these habitats, and their successful utilization by HBC. (RPM 1.C.iii) HBC IN 3/4.8 Determine effects on physical habitat used by young fishes, food base, and direct effect on larval, juvenile, and adult native and non-native fishes of 1996 BHBF. Develop methods to detect changes in numbers of HBC or their habitat from 1996 BHBF. (1996 BHBF HBC RPM 3)
	CULT MO 1: Conserve *in situ* all the downstream cultural resources and take into account Native American cultural resource concerns in the Colorado River ecosystem.	CULT IN 1.4 Preservation, stabilization and/or documentation of cultural resources as impacted by sediment resources associated with alternative operating criteria CULT IN 1.5 Preservation, stabilization of flood terraces holding cultural resources CULT IN 1.6 Evaluate flood terrace stability necessary to maintain cultural resources and terraces at pre-dam conditions

Long-term Streamflow and fine sediment transport in the main channel Colorado, Paria and Little Colorado Rivers **ONGOING WITH REVISION THROUGH SOLE SOURCE TO USGS (WRD AZ DISTRICT)**	**WATER MO 1:** ...Operate GCD in a manner fully consistent with the ROD and subject to the "Law of the River"... **WATER MO 2**: Maintain water quality at levels appropriate to support physical, biotic, and human resource needs of various ecosystems downstream of Glen Canyon Dam as mandated by the Grand Canyon Protection Act and incorporated into the Record of Decision. **SED MO 1:** Maintain a long-term balance of river-stored sand to support maintenance flow (in years of low reservoir storage), beach/habitat-building flow (in years of high reservoir storage), and unscheduled flood flows. Maintain system dynamics and disturbance by annually (in years which Lake Powell water storage is low) redistributing sand stored in the river channel and eddies to areas inundated by river flows between 20,000 cfs and maximum power plant capacity.	WATER IN 1.1 Annually collect and report GCD flow release information. WATER IN 2.1 Characterize sandbar/backwater baselines and character and structure in 1990/1991 WATER IN 2.2 Working with various resource agencies and specialists, select most appropriate flow levels/regimes under the approved operating criteria to determine baseline for comparisons for all resources. SED IN 1.2 Define minimal levels of river stored sediments necessary to maintain long term sandbar, backwater, instream sediment deposits SED IN 1.3 Develop procedures to monitor and predict impacts of alternative operating criteria (flow regimes) on river stored sediment, and impacts in select reaches SED IN 1.4 Measure and model sediment contributions from all contributing sources, including tributary and high terrace sources

		SED IN 1.5 Evaluate the geology/geomorphology within Glen Canyon to: (1) determine historical changes in size and extent of beaches, sandbars and backwaters, (2) quantify sediment (size class and quantity) input from side channels, (3) understand bed morphology dynamics, (4) evaluate high terrace erosion and contribution to river sediment.
	SED MO 4: Maintain system dynamics and disturbance by redistributing sand stored in the river channel and eddies to areas inundated by river flows up to 45,000 cfs in as many years as possible when BHBF hydrologic and resource criteria are met	SED IN 4.2 Develop methodologies to define future flow regimes under approved operating criteria to maximize benefit to sediment and backwater character and structure SED IN 4.3 Develop an assessment of dam operations under approved operating criteria impacts on range of variation in sediment and other resources within Colorado River ecosystem and the associated processes that created these ranges
	REC MO 4: Maintain flows (under approved operating criteria) and habitat suitable for quality cold water fishery opportunities in Glen Canyon.	REC IN 4.1 Determine flow regimes (under approved operating criteria) necessary to maintain fish populations of 100,000 adult Trout (age class II plus)

Long-term monitoring of coarse-sediment inputs, storage and impacts to physical habitats **NEW RFP IN SPRING 2000**	**REC MO 1:** Provide quality recreation experiences consistent with other resource objectives. **SED MO 1:** Maintain a long-term balance of river-stored sand to support maintenance flow (in years of low reservoir storage), beach/habitat-building flow (in years of high reservoir storage), and unscheduled flood flows. Maintain system dynamics and disturbance by annually (in years which Lake Powell water storage is low) redistributing sand stored in the river channel and eddies to areas inundated by river flows between 20,000 cfs and maximum power plant capacity. **AFB MO 1:** Maintain and enhance the aquatic food base in the Colorado River ecosystem to support desired populations of native and non-native fish. At a minimum, maintain continuously inundated areas for *Cladophora* and aquatic invertebrates at or above 5,000 cfs discharge levels from Glen Canyon Dam. **TROUT MO 2:** In the Colorado River downstream of Glen Canyon Dam to the confluence of the Paria river, sufficient ecological conditions (such as habitat, food base and temperature) should be maintained, which in conjunction with management by Arizona Game and Fish will produce a healthy self-sustaining population of at least 100,000 Age II+ rainbow trout that achieve 18 inches in length by Age III with a mean annual relative weight (Wr) of at least 0.90.	REC IN 1.1 Determine criteria and aspects that are important to or detract from recreational experience. SED IN 1.4 Measure and model sediment contributions from all contributing sources, including tributary and high terrace sources AFB IN 1.3 Determine the aquatic food base species composition, population structure, density, and distribution required to maintain desired populations of native and non-native fish in the Colorado River ecosystem. TROUT IN 2.4 Determine the availability and quality of spawning substrates in the Glen Canyon reach, necessary to sustain the rainbow trout fishery.

	FMS MO 8: Achieve healthy, self-sustaining populations of flannelmouth sucker, bluehead sucker, and speckled dace in the Colorado River ecosystem, with special emphasis on flannelmouth sucker in Glen Canyon based upon the capability of the habitat to support those fishes.	FMS IN 8.4 Determine historic and current ecosystem requirements (habitat, spacing, food source, interdependencies, etc.) of native fish species.
	TERR MO 11: Protect, restore, and enhance survival of native and special status species (federal, tribal, and state designations). Ensure that the required habitat for these species is preserved.	TERR IN 11.4 Identify and characterize riparian wildlife habitat types along the river corridor
	VEG MO 16: Maintain, enhance or restore vegetative communities made up of diverse groups of native riparian and upland species with special emphasis on preservation of unique plant communities and special status species at different stages of succession and at different elevations above the water line.	VEG IN 16.1 Determine distribution and abundance of native and non-native riparian and upland vegetation, including federal-, state- and tribal-listed sensitive species, old high water zone, new high water zone, and nearshore marshes
Modeling reach-averaged sandbar evolution in response to discharge and sediment conditions **NEW RFP FOR SPRING 2000**	**SED MO 1:** Maintain a long-term balance of river-stored sand to support maintenance flow (in years of low reservoir storage), beach/habitat-building flow (in years of high reservoir storage), and unscheduled flood flows. Maintain system dynamics and disturbance by annually (in years which Lake Powell water storage is low) redistributing sand stored in the river channel and eddies to areas inundated by river flows between 20,000 cfs and maximum power plant capacity.	SED IN 1.2 Define minimal levels of river stored sediments necessary to maintain long term sandbar, backwater, instream sediment deposits SED IN 1.3 Develop procedures to monitor and predict impacts of alternative operating criteria (flow regimes) on river stored sediment, and impacts in select reaches

		SED IN 1.5 Evaluate the geology/geomorphology within Glen Canyon to: (1) determine historical changes in size and extent of beaches, sandbars and backwaters, (2) quantify sediment (size class and quantity) input from side channels, (3) understand bed morphology dynamics, (4) evaluate high terrace erosion and contribution to river sediment.
	SED MO 2: As a minimum for each reach, maintain the number and average size (area and thickness) of sandbars and backwaters between the stages associated with flows of 8,000 and 45,000 cfs that existed during the 1990/91 research flows.	SED IN 2.4 Evaluation of flow regime (under the approved operating criteria) impacts on terrace and cultural resources
	SED MO 4: Maintain system dynamics and disturbance by redistributing sand stored in the river channel and eddies to areas inundated by river flows up to 45,000 cfs in as many years as possible when BHBF hydrologic and resource criteria are met.	SED IN 4.2 Develop methodologies to define future flow regimes under approved operating criteria to maximize benefit to sediment and backwater character and structure SED IN 4.3 Develop an assessment of dam operations under approved operating criteria impacts on range of variation in sediment and other resources within Colorado River ecosystem and the associated processes that created these ranges

Development of one-dimensional fine sediment routing model along the main channel **NEW RFP FOR SPRING 2000**	**SED MO 1:** Maintain a long-term balance of river-stored sand to support maintenance flow (in years of low reservoir storage), beach/ habitat-building flow (in years of high reservoir storage), and unscheduled flood flows. Maintain system dynamics and disturbance by annually (in years which Lake Powell water storage is low) redistributing sand stored in the river channel and eddies to areas inundated by river flows between 20,000 cfs and maximum power plant capacity.	SED IN 1.2 Define minimal levels of river stored sediments necessary to maintain long term sandbar, backwater, instream sediment deposits SED IN 1.3 Develop procedures to monitor and predict impacts of alternative operating criteria (flow regimes) on river stored sediment, and impacts in select reaches SED IN 1.5 Evaluate the geology/geomorphology within Glen Canyon to: (1) determine historical changes in size and extent of beaches, sandbars and backwaters, (2) quantify sediment (size class and quantity) input from side channels, (3) understand bed morphology dynamics, (4) evaluate high terrace erosion and contribution to river sediment

Advance conceptual modeling of coarse-grained sediments related to evolving physical habitats and aquatic processes **ONGOING WITH REVISION THROUGH ECOMETRIC RESEARCH (KORMAN, ET. AL.)**	**SED MO 1:** Maintain a long-term balance of river-stored sand to support maintenance flow (in years of low reservoir storage), beach/habitat-building flow (in years of high reservoir storage), and unscheduled flood flows. Maintain system dynamics and disturbance by annually (in years which Lake Powell water storage is low) redistributing sand stored in the river channel and eddies to areas inundated by river flows between 20,000 cfs and maximum power plant capacity. **SED MO 4:** Maintain system dynamics and disturbance by redistributing sand stored in the river channel and eddies to areas inundated by river flows up to 45,000 cfs in as many years as possible when BHBF hydrologic and resource criteria are met. **REC MO 2:** Maintain flows (under approved operating criteria) and sediment processes that create an adequate quantity, distribution and variety of beaches for camping, as long as such flows are consistent with management of natural recreation and cultural resource values (other natural resource values).	SED IN 1.4 Measure and model sediment contributions from all contributing sources, including tributary and high terrace sources. SED IN 1.5 Evaluate the geology/geomorphology within Glen Canyon to: (1) determine historical changes in size and extent of beaches, sandbars and backwaters, (2) quantify sediment (size class and quantity) input from side channels, (3) understand bed morphology dynamics, (4) evaluate high terrace erosion and contribution to river sediment. SED IN 4.3 Develop an assessment of dam operations under approved operating criteria impacts on range of variation in sediment and other resources within Colorado River ecosystem and the associated processes that created these ranges REC IN 2.1 Determine adequate beach quantity, quality, distribution, character and structure for camping throughout system. REC IN 2.2 Evaluate impacts of operating criteria on establishing and maintaining adequate beaches and distribution of other resources, quality, character and structure.

Evaluating ground-based and airborne remote sensing technologies	**GIS MO 1:** Creation of GIS base coverages in support of integrated monitoring efforts.	GIS IN 1.1 Develop a comprehensive GIS base map for topography, geology and soils for the Colorado River ecosystem
IT/GIS development	**GIS MO 1:** Creation of GIS base coverages in support of integrated monitoring efforts	GIS IN 1.1 Develop a comprehensive GIS base map for topography, geology and soils for the Colorado River ecosystem

TERRESTRIAL ECOSYSTEM ACTIVITIES

TITLE: MONITORING AVIFAUNA

General Project Description: Monitoring the influences of Glen Canyon Dam operations on abundance and distribution of avifauna within the Colorado River ecosystem.

Rationale/Problem Statement: Avifauna refers to overwintering waterfowl and summer breeding birds that utilize the Colorado River ecosystem. The resource provides recreational benefits to bird watchers, is of cultural value to tribes, or has intrinsic value determined to be of concern by stakeholders. The abundance and distribution of this resource is influenced by available habitat and interspecific interactions. While habitat structure is addressed in another monitoring program, habitat use by birds is a variable that will be addressed in this monitoring program. The presence and abundance of species can reflect the quality of terrestrial habitats. The relationships between operations from Glen Canyon Dam, habitat quality and their use along the Colorado River ecosystem resources 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 avifauna abundance and distribution and habitat utilization: (1) allows managers to assess the status of terrestrial faunal diversity in association with biological, cultural and recreational resources; (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 higher trophic levels associated with terrestrial habitats.

-Integration: To achieve ecosystem-level scientific understanding of the relationships between resources of the Colorado River and Glen Canyon Dam operations, integration of long-term monitoring between physical, cultural, biological, and recreational resources is required.

The primary goal of this project is to document significant changes in the abundance and distribution of waterfowl, nesting avifuana, raptors, and other culturally important birds within the main channel resulting from interactions of dam operations and changes in available vegetated habitat within the context of the Colorado River's geomorphic framework.

-MO's and IN's to be Addressed: The avifaunal monitoring project provides information needs related to management objectives as shown in Table 2.1.

Project Goals and Objectives: To annually measure, evaluate and report distribution and abundance changes in avifauna. These data will be related to available habitat changes relative to annual operations of Glen Canyon Dam and life history requirement of the species of concern. Specific monitoring objectives of the project include change detection:

- Related to species abundance and distribution for waterfowl, breeding birds, nesting avifuana, raptors, and other culturally important birds.
- Related to diet needs vs. food availability and abundance and distribution.
- Related to encroachment of vegetation to campable area.
- Related to advancement of exotic plant species that diminish habitat quality.

Expected Products: Annual delivery of data on changes in species abundance and distribution that result from interactions between available habitat and dam operations. Report delivery about the status of species abundance, distribution and compositional change. Data delivery and exchange for integration with campsite monitoring regarding expansion of useable avifaunal habitat and reduced campable beach habitat.

Recommended Approach/Methods: Avifaunal monitoring data will be collected using primarily field-based survey measurements that are augmented by vegetation monitoring data at prescribed long-term monitoring sites along the main channel. Data regarding annual changes in species abundance and distribution will be collected at designated monitoring sites and may include pre-dam river terraces where appropriate. Data collection efforts may be coordinated

with commercial river trip participation either with river guides or passengers, dependent on protocol review. Available habitat associated with vegetation change and campsite areas will be extracted from campsite monitoring data. Structural and compositional habitat data collected will be scheduled to coincide with nesting avifaunal monitoring (April, May). Under contingency plans, additional measurements of vegetated habitat will occur in the event of large-scale flow experiments (e.g., BHBF and SASF).

Schedule: This long-term monitoring will be initiated in FY 2001 and continued annually through at least FY 2005 through contract and (or) cooperative agreements.

Cost Range: $90,000 per annum (external contract or agreement awarded through competitive RFP).

GCMRC Involvement:

Personnel –Ralston (5%), Lambert (5%).

Technical Support Services – Contract management and oversight with highest levels of participation involving oversight and coordination in data sharing and delivery to contractor.

Logistics – Three to four, 10-15 day river trips. Trips coinciding with waterfowl or breeding bird monitoring. (~$36,000-48,000).

TITLE: **MONITORING TERRESTRIAL HABITAT AND EVALUATING ITS QUALITY FOR UTILIZATION**

General Project Description: Influences of Glen Canyon Dam operations on terrestrial habitat associated with avifauna, recreation, and ethnobotanical resources within the Colorado River ecosystem.

Rationale/Problem Statement: Terrestrial habitat refers to the vegetation that is utilized by animals and humans. The resource is utilized for shelter/nesting or feeding in the case of birds or other animals, and represents a traditional cultural resource to Native American stakeholders. Habitats traits such as composition and density are influenced by substrate and by subsequent water availability. The occupation and use or quality of these habitats by all organisms is dependent on their quality or availability. The relationships between operations from Glen Canyon Dam, natural fine-sediment inputs (substrate), vegetated habitats and their use along the Colorado River ecosystem resources 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 terrestrial habitats and evaluating their quality for utilization: (1) allows managers to assess the status of terrestrial habitats where vegetation and associated fauna, recreation and cultural resources are of management concern; (2) provides data that allows identification and interpretation of linkages between physical and vegetative variables and other terrestrial-based Colorado River ecosystem resources; (3) provides data on the effect of periodic management of sediment through high flows under the Record of Decision on terrestrial habitats and related resources.

-Integration: To achieve ecosystem-level scientific understanding of the relationships between resources of the Colorado River and Glen Canyon Dam operations, integration of long-term monitoring between physical, cultural, biological, and recreational resources is required. In this case, terrestrial habitats support vegetation and associated fauna that constitute important traditional and ethnobotanical resources to Native American stakeholders. The primary goal is to document significant changes in the composition, structure and volume/density of vegetation within the main channel resulting from interactions of dam operations and changes in sediment supply (substrate) within the context of the Colorado River's geomorphic framework.

-MO's and IN's to be Addressed: The terrestrial habitat monitoring and evaluation project provides information needs related to management objectives as shown in Table 2.1.

Project Goals and Objectives: To annually measure, evaluate and report structural and compositional changes in terrestrial vegetation zones that supports avifaunal and traditional cultural resources. These vegetation data will be related to changes in cultural, recreational and biological resources relative to annual operations of Glen Canyon Dam and fine-sediment monitoring data, downstream of the dam. Specific monitoring objectives of the project include change detection:

- Related to species abundance of utilized cultural resources.
- Related to composition and structure of vegetation associated with nesting birds.
- Related to encroachment of vegetation to campable area.
- Related to advancement of exotic plant species that diminish habitat quality.
- Related to fine grain sediment deposition and erosion.

Expected Products: Annual delivery of data on changes in species abundance of plants with cultural importance that result from interactions between sediment supply and dam operations. Annual preliminary report(s) on vegetation structure and compositional changes and data delivery and exchange for integration with avifaunal and campsite monitoring.

Recommended Approach/Methods: Terrestrial habitat data will be measured using a combination of remote and field-based survey measurements that characterize changes in vegetated habitat at prescribed long-term monitoring sites along the main channel. Annual changes in species abundance will be measured at designated monitoring sites and may include pre-dam river terraces where appropriate. Vegetation change data associated with campsite areas will be extracted from campsite monitoring data. Structural and compositional data collected will be scheduled to coincide with nesting avifaunal monitoring (April, May). Project specifics and methodologies will be developed with Native American participants. Under contingency plans, additional measurements of vegetated habitat will occur in the event of large-scale flow experiments (e.g., BHBF and SASF).

Schedule: This long-term monitoring will be initiated in FY 2001 and continued annually through at least FY 2005 through contract and (or) cooperative agreements.

Cost Range: $90,000 per annum (external contract or agreement awarded through competitive RFP)

GCMRC Involvement:

Personnel –Ralston (10%), Lambert (10%), and Melis (2%).

Technical Support Services – Team contract management and oversight with highest levels of participation by Ralston and Lambert involving oversight for spatial QA/QC or role in collection of field data for delivery to contractor.

Logistics – At least one 10-15 day river trip. Trips or data collection needs to be coordinated with breeding bird avifaunal monitoring and ethnobotanical resource and campsite monitoring trips. (~$12,000-18,000).

TITLE: MONITORING KANAB AMBERSNAIL AND HABITAT AT VASEYS PARADISE

General Project Description: Influences of Glen Canyon Dam operations on abundance and distribution of Kanab ambersnail at Vaseys Paradise within the Colorado River ecosystem.

Rationale/Problem Statement: Kanab ambersnail is a federally-listed endangered species occurring in one location in Grand Canyon: Vaseys 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. Monitoring of this habitat is more detailed than previously described habitat monitoring. While yearly compositional change is involved in the previous monitoring, seasonal habitat change and snail

densities in useable habitat is also documented for KAS habitat. The relationships between operations from Glen Canyon Dam, habitat quality and its use by Kanab ambersnail at Vaseys 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.

-Integration: To achieve ecosystem-level scientific understanding of the relationships between resources of the Colorado River and Glen Canyon Dam operations, integration of long-term monitoring between physical, cultural, biological, and recreational resources is required. Vaseys Paradise is a site that has is a unique physical feature that has biological, cultural and recreational value. In addition, the location is a sensitive cultural resource to Native American stakeholders. The primary goal for this monitoring project is to document significant changes in snail densities and size classes and available habitat at Vaseys Paradise resulting from interactions of dam operations and these variables.

-MO's and IN's to be Addressed: The Kanab ambersnail monitoring project provides information needs related to management objectives as shown in Table 2.1.

Project Goals and Objectives: To annually and seasonally measure, evaluate and report on the habitat quality, distribution, density and size class changes in Kanab ambersnail. These data will be related to available habitat changes relative to annual operations of Glen Canyon Dam and life history requirement of the species of concern. Specific monitoring objectives of the project include change detection:

- Related to species abundance and distribution for Kanab ambersnail.

- Related to densities and size class distribution to available habitat.

Expected Products: Annual delivery of data on changes in species abundance and distribution that result from interactions between available habitat and dam operations. Report delivery about the status of species abundance, distribution and compositional changes associated with habitat.

Recommended Approach/Methods: Kanab ambersnail monitoring data will be collected using primarily field-based survey methods for snail densities and available habitat, but the use of remote survey methods may be investigated and eventually deployed to quantify habitat change. Data regarding annual changes in species abundance and distribution will be collected and may include pre-dam river vegetated habitat. Project consultation will be conducted with Native American stakeholders. Under contingency plans, additional measurements of habitat will occur in the event of large-scale flow experiments (e.g., BHBF and SASF).

Schedule: This long-term monitoring will be initiated in FY 2001 and continued annually through at least FY 2005 through contract and (or) cooperative agreements.

Cost Range: $10,000 to 20,000 per annum (external contract or agreement awarded through competitive RFP).

GCMRC Involvement:

Personnel –Ralston (10%), Lambert (3%), Gonzales (5%), and Kohl (20%)

Technical Support Services – Team contract management and oversight with highest levels of participation by Ralston and Gonzales involving oversight and QA/QC of land survey data and map generation and delivery to contractor.

Logistics – two-to-four 10-15 day river trips. Trips coinciding with downstream augmented population surveys. (~$36,000-48,000).

TITLE: ONGOING RESEARCH ON TERRESTRIAL TROPHIC LINKAGES

General Project Description: Monitoring the influences of Glen Canyon Dam operations on the terrestrial insect/host community downstream in the Colorado River ecosystem.

Rationale/Problem Statement: Insect/host community refers to the guild of insects that colonize the terrestrial vegetation along the river corridor. These groups of insects and the plants they depend on for their life cycles are a food source for riparian breeding birds found in Grand Canyon. The types and densities of insects influence the amount and kinds of bird that the river corridor can sustain. Measuring insect abundance and diversity can also be an indicator of a system's health. The germination, establishment and persistence of host plants like mesquite and tamarisk are affected by operations of Glen Canyon Dam. The relationships between operations from Glen Canyon Dam and host/insects connected to breeding bird requirements may be a useful measure for monitoring avifaunal resources, 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 the host/insect relationships: (1) allows managers to assess the effects of reservoir management on downstream vegetated habitat quality; (2) provides data that allows identification and interpretation of linkages between physical, and biotic variables; (3) provides data on the effect of periodic management of sediment through high flows under the Record of Decision on food resources for consumers (birds).

-Integration: To achieve ecosystem-level scientific understanding of the relationships between resources of the Colorado River and Glen Canyon Dam operations, integration of long-term monitoring between physical, cultural, biological, and recreational resources is required. The primary goal of this project is to determine relationships between bird nesting and foraging needs.

-MO's and IN's to be Addressed: The plant/insect research project provides

information needs related to management objectives as shown in Table 2.1.

Project Goals and Objectives: To measure, evaluate and report patterns associated with plant/insect and bird foraging. These data will be related to changes relative to annual operations of Glen Canyon Dam and vegetation and bird monitoring.

Expected Products: Delivery of report and data on the relationship between breeding bird nesting and foraging behavior.

Recommended Approach/Methods: This will be the second of two years of study and the approach and methods will follow those outlined in the funded proposal. Field work will coincide with riparian breeding bird occupation in the river corridor.

Schedule: This project will be completed in FY2001 with reports delivered by Dec 2001.

Cost Range: $30,000

GCMRC Involvement:

Personnel – Ralston (5%).

Technical Support Services – Contract oversight.

Logistics – A least two downstream trips (~$16,000).

TITLE: **EVALUATION OF CULTURAL RESOURCE MONITORING AND MITIGATION STRATEGIES**

General Project Description: Evaluate the effectiveness of cultural resource monitoring and mitigation strategies at selected locations along the Colorado River corridor using remotely sensed technologies.

Rationale/Problem Statement: Relationships between Glen Canyon Dam operations and downstream physical, biological, and socio-cultural resources are of primary management concern. Monitoring data on cultural resources and linkages with other resources and processes offer insight on the effectiveness of the current experimental flow treatment (Secretary's 1996 Record of Decision) relative to management objectives.

The evaluation of the utility of monitoring and mitigation strategies of cultural resources provides data: (1) to managers who need to assess the status of the preservation of cultural resources, including biological and physical traditional resources that are of management concern; (2) on the effects of controlled floods believed to preserve and sustain cultural resources through the deposition of fine sediment along channel margins; (3) that allow identification and interpretation of linkages between dam operations and changes in socio-cultural, physical, and biological ecosystem resources. The use of remote sensing technologies can provide resource assessment methods that are cost effective, less intrusive than traditional field methods, and may provide expanded spatial coverage than can be gathered by field-based efforts. These areas of information support science-based evaluations of large-scale flow experiments (e.g., the Secretary's actions), and associated decision responses required for adaptive management to succeed.

-Integration: Cultural resource locations along the main channel include physical and biological, and recreational ecosystem resources. Information effectiveness of monitoring and mitigation strategies to preserve cultural resources must be measured in ways that can be related to dam operations.

-MO's and IN's to be Addressed: This project provides data related to management objectives and information needs as indicated in Table 2.1. The investigations provide information on effectiveness of the monitoring and mitigation techniques used to preserve cultural resources and the processes that may affect the effectiveness of these strategies.

Project Goals and Objectives: The *primary goal* is to evaluate the effectiveness of monitoring

and mitigation strategies for cultural resources, including traditional resources within the physical and biological resources, using appropriate remote sensing technologies.

Secondary goals relate to the identification of the factors that may influence the effectiveness of monitoring and mitigation strategies at cultural resource locations. These data provide information needed to interpret changes in cultural resources relative to annual operations of Glen Canyon Dam. Specific objectives of the project include:

- Using existing and ongoing studies, identify geomorphic and other processes that operate in specific resource locations to promote or hamper resource preservation.
- Monitor these processes using remote sensing technologies.
- As appropriate, evaluate PEP recommendations using remotely sensed data.

Expected Products: A project report with associated data bases providing: (1) an evaluation of the effectiveness of the existing monitoring and mitigation efforts for cultural resources at project locations and; (2) information on the processes affecting cultural resources.

Recommended Approach/Methods: Selected resource locations will be targeted for evaluation. Locations will include sites where monitoring and mitigation activities have occurred or where resources appear to be at high risk. Examples of evaluated strategies include onsite monitoring and mapping and construction of check dams within arroyos and gullies. Project data will be coordinated with existing NPS data. These locations will be assessed using remote sensing technologies such as photogrammetric applications to aerial photography and other technologies currently being evaluated through the GCMRC remote sensing initiative. Geomorphic processes that may affect the utility of treatment efforts will be identified, quantified, and documented at selected cultural resource locations that exemplify settings dominated by particular geomorphic processes. These investigations will be used to refine, clarify, and field test the predictive model generated by current studies that are evaluating the hypothesis that dam operations, through lowered mainstem base levels, foster erosion in river-

marginal deposits containing cultural materials. Remote sensing will help to identify areas where erosion is increasing to prioritize sites for mitigation. Remotely sensed data may also be used to evaluate the PEP recommendations for collecting monitoring data for cultural resources.

Schedule: This project will be initiated in FY 2001 through a competitive call for proposals and review/selection process. Products related to this project will be subject to peer review to evaluate the overall success of the project with a focus on the integration between the biological, physical and information technology resources.

Cost Range: Estimated at $ 65,000

GCMRC Involvement:

Personnel – Lambert (15%), Melis (2%), Ralston (2%), Gonzales/Kohl (10%), and Mietz (5%)

Technical Support Services – Survey and GIS support.

Logistics – At minimum, two 14-18 day river trips for data collection and ground truthing. Multiple upstream river trips from Lee Ferry for the same purpose. Cost estimate at $40,000.

TITLE: DEVELOPMENT OF HISTORIC CONTEXTS TO EVALUATE THE SIGNIFICANCE OF CULTURAL RESOURCE DATA

General Project Description: Development of historic contexts to evaluate and interpret the significance of identified cultural resources within the Colorado River corridor.

Rationale/Problem Statement: Relationships between Glen Canyon Dam operations and downstream physical, biological, and socio-cultural resources are of primary management concern. The evaluation of cultural resource data and the linkages with other resources offers

important information on the impacts and the effectiveness of the current experimental flow treatment (Secretary's 1996 Record of Decision) relative to management objectives.

The development of historic contexts provides a basis for evaluating cultural resources. This evaluation assists in the prioritization of resources for treatment and mitigation efforts. Historic contexts constitute themes with various elements such as architecture, technology, for specific spatial and temporal parameters. Certain resource types may be represented within the context and examples of these resources types can be compared and evaluated. When resources are evaluated they can be prioritized for treatment and monitoring. The development of historic contexts can provide data on the significance of resources. These data: (1) assist managers in evaluating and prioritizing resources for preservation efforts; (2) provide managers with information concerning resource significance relative to impacts related to dam operations and the effects of controlled floods believed to preserve and sustain cultural resources; (3) incorporate tribal perspectives in historic context development to formulate a comprehensive view of the resource context; and (4) include physical, biological and recreation resource components. This information is important for science-based evaluations of large-scale flow experiments (e.g., the Secretary's actions), and associated decision responses required for adaptive management to succeed.

-Integration: Cultural resource locations along the main channel include physical and biological, and recreational ecosystem resources. Information on the contexts and significance of these resources affect the preservation of cultural resources and are related to dam operations.

-MO's and IN's to be Addressed: This project shall provide data related to management objectives and information needs as indicated in Table 2.1. The development of historic contexts can provide information that is important to the preservation of cultural resources.

Project Goals and Objectives: The *primary goal* is to develop historic contexts that assist in the interpretation of the past human occupation and activities within the Colorado River corridor. *Secondary goals* relate to the evaluation of the significance and prioritization of

preservation efforts for cultural resources. These data provide important information for the potential impacts of the operations of Glen Canyon Dam on downstream cultural resources. Specific objectives of the project include:

- Develop historic contexts for the cultural resources within the Colorado River corridor to understand the past human occupation of the area.
- Utilizing these data in consultation with PA participants, evaluate and prioritize cultural resources for appropriate treatment measures.
- Project data will assist in implementing the Historic Preservation Plan (HPP) that is being developed as a stipulation within Reclamation's Programmatic Agreement (PA) Program.

Expected Products: A project report with associated data bases providing: (1) information on the historic contexts; (2) evaluation of cultural resources relative to the developed contexts.

Recommended Approach/Methods: Historic contexts will be developed for the river corridor with specific contextual elements identified. Possible examples of contexts include: (1) agriculture; (2) historic mining; (3) puebloan architecture; and (4) development of recreational river activities. Using existing information, contextual elements will be defined that provide associated property, or resource, types. A selected sample of cultural resources will be evaluated based on the guidance provided within the context. Resources will be prioritized based on these evaluations. Project information will be provided to the PA Program for assistance in the implementation of the HPP.

Schedule: This project will be initiated in FY 2001 through a competitive call for proposals and review/selection process. Products related to this project will be subject to peer review to evaluate the overall success of the project with a focus on the integration between the biological, physical and information technology resources.

Cost Range: Estimated at $25,000.

GCMRC Involvement:

-Personnel – Lambert (15%) , Melis (2%), Ralston (2%)

-Technical Support Services – None identified at this time.

-Logistics – One 14-18 day river trip for resource assessment. Cost estimated at $26,000.

AQUATIC ECOSYSTEM ACTIVITIES

TITLE: ONGOING MONITORING PHYTO-BENTHIC COMMUNITY AND EVALUATING ITS QUALITY FOR UTILIZATION

General Project Description: Monitoring the influences of Glen Canyon Dam operations on the phyto-benthic community associated with Colorado River ecosystem.

Rationale/Problem Statement: Phyto-benthic community refers to the aquatic vegetation and invertebrates that are utilized by consumers such as fish, birds and humans. The constituents either form habitat that is utilized by invertebrates and vertebrates, or provide a source of food to consumers. Its condition is the basis for the status of higher level species such as trout and waterfowl. Community traits such as composition and density are influenced by substrate, water quality and water availability. The occupation and use of these habitats or resources by all organisms is dependent on their quality, distribution and availability. The relationships between operations from Glen Canyon Dam, natural fine and course-sediment inputs that form substrate for aquatic habitats and their colonization and use along the Colorado River ecosystem resources 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 phyto-benthic communities and evaluating their quality for utilization: (1) allows managers to assess the status of this community throughout the Colorado River ecosystem; (2) provides data that allows identification and interpretation of linkages between physical and biotic variables; (3) provides data on the effect of periodic management of sediment through high flows under the Record of Decision on the phyto-benthic community and higher trophic levels.

-Integration: To achieve ecosystem-level scientific understanding of the relationships between resources of the Colorado River and Glen Canyon Dam operations, integration of long-term monitoring between physical, cultural, biological, and recreational resources is required. The primary goal is to document significant changes in the composition, structure and volume/density of the phyto-benthic community within the main channel resulting from interactions of dam operations, changes in sediment supply (substrate) within the context of the Colorado River's geomorphic framework.

-MO's and IN's to be Addressed: The phyto-bentho monitoring and evaluation project provides information needs related to management objectives as shown in Table 2.1.

Project Goals and Objectives: To annually measure, evaluate and report compositional and volume/density changes in the phyto-benthic community that supports the aquatic resources including native and sport fish, avifauna and cultural and recreational interests. These phyto-benthic data will be related to changes relative to annual operations of Glen Canyon Dam and coarse and fine-sediment monitoring data, downstream of the dam. Specific monitoring objectives of the project include change detection:

- Related to sediment inputs and available habitat vs. habitat colonized and utilized by the phyto-benthic community.
- Related to composition and structure of aquatic plant community to benthic colonizers.
- Related to water quality associated with reservoir and dam operations.
- Using stable isotope analysis, determine primary constituents of the foodbase for fish community.

Expected Products: Annual delivery of data on changes in species abundance of aquatic plants and invertebrates that are important to the structure of the aquatic community that result from interactions between sediment supply and dam operations. Annual preliminary report(s) on community structure and compositional changes and data delivery and exchange for integration with avifaunal and coarse and fine sediment and water quality monitoring.

Recommended Approach/Methods: Phyto-benthic data will be measured using a combination of remote and field-based survey measurements that characterize changes in available river channel habitat and the communities composition and structure at prescribed long-term monitoring sites along the main channel. Annual changes in species abundance or density will be measured at designated monitoring sites. Structural and compositional data collected will be scheduled to coincide with important seasonal changes or projected changes in operations. Under contingency plans, additional measurements of the phyto-benthic community will occur in the event of large-scale flow experiments (e.g., BHBF and SASF).

Schedule: While long-term monitoring will not become officially instituted until FY2002, the current phyto-benthic monitoring contains elements that are similar to projected long-term monitoring goals. Integration of current and future monitoring techniques will be initiated in FY 2002 and continued annually through at least FY 2005 through contract and (or) cooperative agreements determined through competitive RFP.

Cost Range: $230,000 per annum (continuing agreement awarded through competitive RFP to Northern Arizona University).

GCMRC Involvement:

Personnel –Ralston (5%), Yard (5%), and Melis (2%).

Technical Support Services – Team contract management and oversight with highest

levels of participation by Ralston and Lambert involving oversight for spatial QA/QC or role in collection of field data for delivery to contractor.

Logistics – At least one 10-15 day river trip. Trips or data collection needs to be coordinated with seasonal changes in productivity and dam operations.

TITLE: ONGOING MONITORING OF THE STATUS AND TRENDS OF DOWNSTREAM FISH COMMUNITY

General Project Description: Monitoring the influences of Glen Canyon Dam operations on the fish community in the Colorado River ecosystem.

Rationale/Problem Statement: The downstream fish community is the assemblage of native and non-native fish that occur in the Colorado River ecosystem. This assemblage is exclusive of the trout fishery that is managed in Glen Canyon. The constituents include four native fish and introduced competitors/predators like brown trout, carp, and striped bass. The status and trends of the fishery is linked to the phyto-benthic community and to operations of Glen Canyon Dam. Community traits such spawning and recruitment are influenced by the quality of substrate, water, and food. Competitive interactions between fish species also account for species abundance. The relationships between operations from Glen Canyon Dam, natural fine and coarse-sediment inputs that form substrate for aquatic habitats and their colonization and use by fish along the Colorado River ecosystem resources 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 the fish community: (1) allows managers to assess the status of this community throughout the Colorado River ecosystem; (2) provides data that allows identification and interpretation of linkages between physical and biotic variables; (3) provides data on the effect of periodic management of sediment through high flows under the Record of

Decision on the fish community and the resources it depends on including the phyto-benthic community.

-Integration: To achieve ecosystem-level scientific understanding of the relationships between resources of the Colorado River and Glen Canyon Dam operations, integration of long-term monitoring between physical, cultural, biological, and recreational resources is required. The primary goal is to document significant changes in the abundance and distribution of the fish community within the main channel resulting from interactions of dam operations, changes in sediment supply (substrate), and the phyto-benthic community within the Colorado River ecosystem.

-MO's and IN's to be Addressed: The fish community monitoring and evaluation project provides information needs related to management objectives as shown in Table 2.1.

Project Goals and Objectives: To annually measure, evaluate and report abundance and distribution in the fish community. These data will be related to changes relative to annual operations of Glen Canyon Dam, sediment inputs (coarse and fine) monitoring data, and phyto-benthic monitoring data downstream of the dam. Specific monitoring objectives of the project include change detection:

- In community structure related to sediment inputs and available habitat for spawning, recruitment and foraging.
- Related to distribution and relative abundance of native fish relative to non-native competitors.
- Related to water quality associated with reservoir and dam operations that affect spawning and recruitment.

Expected Products: Annual delivery of data on changes in species abundance, distribution and age structure of sampled fish community. Annual preliminary report(s) on community structure and compositional changes and data delivery and exchange for integration with phyto-benthic community monitoring and coarse and fine sediment and water quality monitoring.

Recommended Approach/Methods: Fish community data will be measured using a primarily field-based survey measurements that characterize changes in the fish community at prescribed long-term monitoring sites along the main channel and its tributaries. Annual changes in species abundance and distribution will be measured at designated monitoring sites. Community change data associated with food or habitat resources will be extracted from phyto-benthic and sediment monitoring data. Field data associated with the fish community will be scheduled to coincide with important life history stages (e.g., spawning/overwinter survival, fall recruitment). Under contingency plans, additional measurements of the fish community will occur in the event of large-scale flow experiments (e.g., BHBF and SASF).

Schedule: While long-term monitoring will not become officially instituted until FY2002, the current fish community monitoring contains elements that are similar to projected long-term monitoring goals. Integration of current and future monitoring techniques will be initiated in FY 2002 and continued annually through at least FY 2005 through contract and (or) cooperative agreements.

Cost Range: $300,000 to 500,000 per annum (external contract or agreement awarded through competitive RFP)

GCMRC Involvement:

Personnel –Ralston (5%), Yard (5%), and Melis (2%).

Technical Support Services – Team contract management and oversight with highest levels of participation by Ralston and Yard involving oversight for data quality or role in collection of field data for delivery to contractor.

Logistics – At least two 15-day river trips, with supplemental trips to tributaries. (~$90,000-120,000).

TITLE: MONITORING OF THE STATUS AND TRENDS OF THE LEES FERRY TROUT FISHERY

General Project Description: Monitoring the influences of Glen Canyon Dam operations on the Lees Ferry trout fishery in the Colorado River ecosystem.

Rationale/Problem Statement: The Lees Ferry trout fishery refers to the rainbow trout that exist in Glen Canyon, are managed by Arizona Game and Fish Department and represent an important recreational and economic resource to the tailwaters portion of the Colorado River ecosystem. This assemblage includes flannelmouth suckers and competitors such as carp and catfish. The status and trends of the fishery is linked to the phyto-benthic community and to operations of Glen Canyon Dam. Community traits such as spawning and recruitment are influenced by the quality of substrate, water, and food. Competitive interactions between trout and other fish species and among trout also account for population status. The relationships between operations from Glen Canyon Dam, natural fine and coarse-sediment inputs that form substrate for aquatic habitats and their colonization and use by trout in the Glen Canyon portion of the Colorado River ecosystem resources 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 the rainbow trout population: (1) allows managers to assess the status of this population in Glen Canyon; (2) provides data that allows identification and interpretation of linkages between physical and biotic variables; (3) provides data on the effect of periodic management of sediment through high flows under the Record of Decision on the trout population in Glen Canyon and the resources it depends on including the phyto-benthic community.

-Integration: To achieve ecosystem-level scientific understanding of the relationships between resources of the Colorado River and Glen Canyon Dam operations, integration of long-

term monitoring between physical, cultural, biological, and recreational resources is required. The primary goal is to document significant changes in the abundance, age structure and condition of the trout population in Glen Canyon resulting from interactions of dam operations, changes in sediment supply (substrate), and the phyto-benthic community within the Colorado River ecosystem.

-MO's and IN's to be Addressed: The trout population monitoring and evaluation project provides information needs related to management objectives as shown in Table 2.1.

Project Goals and Objectives: To annually measure, evaluate and report abundance, age structure and condition of the rainbow trout population in Glen Canyon. These data will be related to changes relative to annual operations of Glen Canyon Dam, sediment inputs (coarse and fine) monitoring data, and phyto-benthic monitoring data downstream of the dam. Specific monitoring objectives of the project include change detection:

- In community structure related to sediment inputs and available habitat for spawning, recruitment and foraging.
- Related to condition factor of trout population.
- Related to water quality associated with reservoir and dam operations (e.g., nutrients, temperature) that affect spawning and recruitment.

Expected Products: Annual delivery of data on changes in species abundance, age structure and condition of sampled trout population. Annual preliminary report(s) on community structure and compositional changes and data delivery and exchange for integration with phyto-benthic community monitoring and coarse and fine sediment and water quality monitoring.

Recommended Approach/Methods: The trout population data will be collected using a primarily field-based survey measurements that characterize changes in the fish population at prescribed long-term monitoring sites within Glen Canyon. Annual changes in trout size class distribution, recruitment and condition will be measured at designated monitoring sites.

Populations change data associated with food or habitat resources will be extracted from phyto-benthic and sediment monitoring data. Field data associated with the trout population will be scheduled to coincide with important life history stages (e.g., winter spawning, summer recruitment). Under contingency plans, additional measurements of the trout population will occur in the event of large-scale flow experiments (e.g., BHBF and SASF).

Schedule: Long-term monitoring will be initiated in FY 2001 and continued annually through at least FY 2005 through contract and (or) cooperative agreements.

Cost Range: $130,000 per annum (external contract or agreement awarded through competitive RFP).

GCMRC Involvement:

Personnel –Ralston (5%), Yard (5%), and Melis (2%).

Technical Support Services – Team contract management and oversight with highest levels of participation by Ralston and Yard involving oversight for data quality or role in collection of field data for delivery to contractor.

Logistics –Two-to-three 3-day trips in Glen Canyon reach. (~$10,000).

TITLE: INTEGRATED WATER QUALITY MONITORING

General Project Description: Monitoring the influences of Glen Canyon Dam operations on the water quality in Lake Powell and downstream in the Colorado River ecosystem.

Rationale/Problem Statement: Water quality refers to the physical, chemical and biological characteristics of water. The components effect higher level community quality and interactions and represent a cornerstone resource upon which all other aquatic and terrestrial resources depend. The water quality parameters are linked to upper basin inflows, reservoir dynamics, and

operations of Glen Canyon Dam, and downstream tributary inputs. The relationship between operations of Glen Canyon Dam and water quality variables affecting downstream resources is 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 the water quality parameters: (1) allows managers to assess the effects of dam operations on downstream water quality; (2) provides data that allows identification and interpretation of linkages between physical, chemical and biotic variables; (3) provides data on the effect of periodic management of sediment through high flows under the Record of Decision on the water quality in the reservoir (forebay) and downstream water quality.

-Integration: To achieve ecosystem-level scientific understanding of the relationships between resources of the Colorado River and Glen Canyon Dam operations, integration of long-term monitoring between physical, cultural, biological, and recreational resources is required. The primary goal of this project is to document significant changes in the physical, chemical and biological constituents associated with water quality that can be linked to other Colorado River ecosystem resources.

-MO's and IN's to be Addressed: The water quality monitoring project provides information needs related to management objectives as shown in Table 2.1 and in greater detail in the Integrated Water Quality Plan (Vernieu and Hueftle, 1999).

Project Goals and Objectives: The goals are to provide further understanding of linkages between dam operations, water quality, and the aquatic ecosystem of the Colorado River. Understanding is achieved by the following objectives measure, evaluate and report patterns of change in water quality parameters in the reservoir, tailwaters and downstream, and to describe changes that differ from expected or historic values associated with the reservoir and downstream water quality. Information associated with water quality will be shared with other monitoring projects like the phyto-benthic and fish community monitoring projects. Specific monitoring objectives of the project include change detection:

- Related to detectable levels of chemical constituents (organic, inorganic) that affect biological processes and associated recreational and cultural resources.
- Related to mainstem temperature that affect biological and subsequently recreational and cultural resources.
- Related to phytoplankton community that affect downstream aquatic resources and related terrestrial resources.

Expected Products: Annual delivery of data on associated with biological, chemical and physical constituents of water quality. Annual preliminary report(s) on status and changes in these parameters and the effects of reservoir operations and dam operations on reservoir water quality/dynamics and concomitant downstream effects. Timely data delivery and exchange for integration with phyto-benthic community monitoring and fish community monitoring and parties associated with upper basin water quality (Lake Powell cooperators group).

Recommended Approach/Methods: The data for the water quality monitoring project will be collected using both field and remotely-based survey methods (dataloggers) that characterize changes in water quality at prescribed long-term monitoring sites in the reservoir and along the Colorado River mainstem and its tributaries (see Vernieu and Hueftle, 1999). Field data associated with water quality will be scheduled to coincide with important seasonal changes associated with reservoir dynamics and that coincide with changes in dam operations. Under contingency plans, additional measurements of the water quality parameters will occur in the event of large-scale flow experiments (e.g., BHBF and SASF, temperature modification).

Schedule: While long-term monitoring will not become officially instituted until FY2002, the current monitoring contains elements that are likely to continue into GCMRC's long-term monitoring program for water quality. Integration of current and future monitoring techniques will be initiated in FY 2002 and continued annually through at least FY 2005 through contract

and (or) cooperative agreements, or completed using GCMRC's personnel.

Cost Range: $175,000-$474,000 (internal or external contract or agreement awarded through competitive RFP). Estimated cost included budget supported by the Bureau of Reclamation from O&M funds.

GCMRC Involvement:

Personnel –Hueftle (75%), Vernieu (80%), and Ralston (2%).

Technical Support Services – Team contract management and oversight with equal levels of participation involving oversight for data quality, delivery or role in collection of field data for delivery to contractor.

Logistics –Quarterly and monthly reservoir trips and downstream trips for the purposes of downloading data loggers (~$28,000).

TITLE: ONGOING RESEARCH ASSOCIATED WITH POPULATION GENETICS OF HUMPBACK CHUB IN COLORADO RIVER ECOSYSTEM

General Project Description: Patterns of genetic diversity within and between Humpback chub aggregations.

Rationale/Problem Statement: Humpback chub is a federally-listed endangered fish species that occurs in Grand Canyon. Plans are either in place or are being developed to address elements of the Biological Opinion. The status of this species and other native fish species is a management concern. These plans center on providing mainstem habitat that permits spawning and recruitment. Determining the relationship of chub aggregates found in the mainstem and in the Little Colorado River will help in the evaluation and success of these management strategies.

Determining the genetic diversity of humpback chub aggregates: (1) allows managers to

predict the effects of managed flows or selective withdrawal on recruitment by this species; (2) provides data that allows fish and wildlife personnel to recommend alternative management strategies or actions that will assist the species.

-Integration: To achieve ecosystem-level scientific understanding of the relationships between resources of the Colorado River and Glen Canyon Dam operations, integration of long-term monitoring, research and management is required. The primary goal of this project is to document the genetic diversity that exists among humpback chub aggregates that provides managers information regarding the origin of humpback chub in the mainstem and its tributaries.

-MO's and IN's to be Addressed: The humpback chub genetics project provides information needs related to management objectives as shown in Table 2.1.

Project Goals and Objectives: Understanding the inter-population relationships are integral to management actions associated with endangered fish. To collect sufficient samples to quantify genetic variation that exists within and between humpback chub aggregates found in the Colorado River ecosystem and provide information on the relationship of mainstem aggregates to those fish found in the Little Colorado River. Information about these relationships will be used to determine the best methods available to assist the species towards recovery.

Expected Products: Delivery of a preliminary and final report on the genetic diversity of humpback chub aggregates in the Colorado River ecosystem. Delivery will be provided in a format and manner that are useful to managers involved with experimental flows research or hatchery programs.

Recommended Approach/Methods: The project will use molecular techniques that sufficiently quantify inter- and intra-populational diversity. Sufficient sample size will also be determined and obtained in order to address the goals of this project. Under contingency plans, no additional measurements will occur.

Schedule: This will be the second of a two year funded project through contract and (or) cooperative agreements.

Cost Range: $50,000 (external contract or agreement awarded through competitive RFP).

GCMRC Involvement:

Personnel – Ralston (5%), and Yard (5%).

Technical Support Services – Team contract management and oversight with equal levels of participation involving oversight for data quality, delivery or role in collection of field data for delivery to contractor.

Logistics – One or two downstream trips to collect tissue samples, coordinated with fish community monitoring. (~$2000. Principal costs covered under fish community monitoring.)

TITLE: NEW RESEARCH ASSOCIATED INTERACTIONS BETWEEN NATIVE AND NON-NATIVE FISH SPECIES

General Project Description: Identification of variables that affect predation rates on native fish by non-natives.

Rationale/Problem Statement: Non-native fish (brown trout, rainbow trout and catfish to name a few), are predators on native fish, and they exist in great enough numbers in the mainstem to pose a problem to native fish recruitment. Several proposed management strategies to increase native fish recruitment (temperature control device, experimental flows for fish) may also benefit non-native fish recruitment and increase predation pressure on native fish. The habitats that young fish are found in is well documented. However, how the predation rates change on young fish as these variables change is not well known. Determining predation rates associated with variables like turbidity, temperature and velocities will help identify mainstem habitats or

conditions that merit monitoring and possibly mitigation during flows designed to help native fish species recruitment.

Collecting and analyzing data about fish species predation rates: (1) allows managers to assess the effects of dam operations aimed at supporting native fish on young fish and predators; (2) provides data that allows identification of potential threats to a resource that can be monitored, and mitigated for, during a proposed action.

-Integration: To achieve ecosystem-level scientific understanding of the relationships between resources of the Colorado River and Glen Canyon Dam operations, integration of long-term monitoring between physical, cultural, biological, and recreational resources is required. The primary goal of this project is to determine relationships between habitat and fish interactions in the mainstem.

-MO's and IN's to be Addressed: The fish interactions project provides information needs related to management objectives as shown in Table 2.1.

Project Goals and Objectives: To measure, evaluate and report patterns associated with predation rates on native fish and changing habitat variables. Identify variables that have the greatest effect on predation. These data will be related to changes relative to annual operations of Glen Canyon Dam and native fish recruitment.

Expected Products: Delivery of report and data that identifies key habitat variables that affect predation on young native fish. Delivery of data and report on predation rates as variables change.

Recommended Approach/Methods: Utilize available published life history information on predators and prey to determine time when feeding and movement is greatest. Utilize laboratory setting to determine effects of habitat variables (temperature, turbidity, structure) on rates of predation on larvae and juvenile native fish. Use laboratory information and test identified variables in the field for predictability.

Schedule: This project will be funded for two years.

Cost Range: $30,000-90,000/year—dependent on available funds from monitoring projects that come in under estimated costs.

GCMRC Involvement:

Personnel – Ralston (5%), and Yard (5%).

Technical Support Services – Contract oversight, data collection.

Logistics – None for first year, or will be coordinated with ongoing fish monitoring.

TITLE: NEW RESEARCH ASSOCIATED WITH EXPERIMENTAL FLOWS FOR FISH AND TEMPERATURE CONTROL DEVICE

General Project Description: Titles associated with this effort will be identified following the TCD science plan workshop held November 8-10, 1999. Preliminary projects include: (1) Determining/modeling the heat budget for Lake Powell using CE Qualw3 for different lake levels and operating scenarios; (2) Determine the effects of temperature and photo period on initiating spawning condition in Humpback chub; (3) Determine the effects of temperature changes on young fish—what is the threshold level of temperature at which young-of-year fish (20-40 mm) are negatively affected—laboratory setting; (4) Determine the effect of warmer water on whirling disease/parasite infestation; (5) Determine the effect of warming on colonization by diatoms and productivity of gammarus.

Rationale/Problem Statement: Mainstem temperature is considered a limiting factor to recruitment by native fish in the mainstem. Operational and physical mechanisms are available to promote warming the mainstem (temperature control device, steady flows). Warming the river will have an effect on the native fish and other biotic resources, including the food base.

Prior to operations of a temperature control device, some experiments can be done to help narrow the focus of operations and determine the possible consequences of operations.

Collecting and analyzing data about fish life history needs or food base shifts: (1) allows managers to assess the effects of dam operations on fish and related resources; (2) provides data that allows identification of potential threats to a resource that can be monitored, and mitigated for, during a proposed action.

-Integration: To achieve ecosystem-level scientific understanding of the relationships between resources of the Colorado River and Glen Canyon Dam operations, integration of long-term monitoring between physical, cultural, biological, and recreational resources is required. The primary goal of these projects are to determine relationships between habitat trophic level interactions (foodbase, parasites, fish) in the mainstem.

-MO's and IN's to be Addressed: The trophic level interactions project provides information needs related to management objectives as shown in Table 2.1.

Project Goals and Objectives: To measure, evaluate and report patterns associated with temperature changes in the mainstem. Identify variables that have the greatest effect on food quality, spawning, recruitment and disease. These data will be related to changes relative to annual operations of Glen Canyon Dam and native fish recruitment.

Expected Products: Delivery of report and data that identifies key variables that affect resources associated with temperature changes, prior to operations.

Recommended Approach/Methods: Primarily use laboratory-based experiments in such a manner that the results can be used in the field to verify hypotheses.

Schedule: These projects will be funded for up to two years.

Cost Range: $30,000-90,000/project/year

GCMRC Involvement:

Personnel – Ralston (5%), Yard (10%), Hueftle (5%), and Vernieu (10%).

Technical Support Services –Team contract management and oversight with equal levels of participation involving oversight for data quality, delivery or role in collection of field data for delivery to contractor.

Logistics – Unknown at this time.

TITLE: NEW RESEARCH ASSOCIATED WITH WATER QUALITY IN LAKE POWELL

General Project Description: Effect of ambient conditions (wind speeds), solar radiation on reservoir warming to levels projected to be affected by selective withdrawal.

Rationale/Problem Statement: Mainstem temperature is considered a limiting factor to recruitment by native fish in the mainstem. Operational and physical mechanisms are available to promote warming the mainstem (temperature control device, steady flows). Warming the river will have an effect on the native fish and other biotic resources, including the food base. Prior to operations of a temperature control device, some experiments can be done to help narrow the focus of operations and determine the possible consequences of operations.

The feasibility of changing water temperature at a given point in Grand Canyon through the use of a TCD is dependent on availability, quantity, and rate of regeneration of warm water in Lake Powell, depth of withdrawal from the reservoir, time of withdrawal, and warming patterns dependent on discharge level and geomorphic reach. The Bureau of Reclamation is evaluating feasibility of a TCD from an engineering standpoint. Included in this evaluation should be the collection of data that evaluated the physical feasibility of a TCD. Current models for Lake Powell's heat budget use available environmental data, but these data are not directly associated with Lake Powell. Increased predictive ability of the selective withdrawal on Lake Powell heat budget would benefit from direct environmental measures.

Collecting and analyzing data about environmental factors affecting Lake Powell temperatures: (1) allows managers to assess the effects of dam operations on epilimnion water quality dynamics associated with the selective withdrawal structure; (2) provides data that allows identification of potential threats to a resource that can be monitored, and mitigated for, during a proposed action.

-Integration: To achieve ecosystem-level scientific understanding of the relationships between resources of the Colorado River and Glen Canyon Dam operations, integration of long-term monitoring between physical, cultural, biological, and recreational resources is required. The primary goal of this project is to determine relationships between environmental variables on temperature in the upper levels of Lake Powell.

-MO's and IN's to be Addressed: The project provides information needs related to management objectives as shown in Table 2.1.

Project Goals and Objectives: To measure, evaluate and report patterns associated with environmental factors and temperature changes in Lake Powell. Identify variables that have the greatest effect on temperature change. These data will be related to proposed changes to annual operations of Glen Canyon Dam and native fish recruitment.

Expected Products: Delivery of report and data that identifies key variables that affect resources associated with temperature changes, prior to operations.

Recommended Approach/Methods: Primarily field collected data. Use of data loggers or other continuous data collection methods that record solar radiation, wind speeds in Lake Powell that can be used in model calibration for Lake Powell heat budget.

Schedule: These projects will be funded for up to two years.

Cost Range: $50,000/year

GCMRC Involvement:

Personnel – Hueftle (15%).

Technical Support Services –Contract management and oversight with participation involving oversight for data quality, delivery or role in collection of field data.

Logistics – Unknown at this time, but costs will be in addition to current IWQP logistics and will involve trips in addition to current IWQP proposed trips.

INTEGRATED TERRESTRIAL AND AQUATIC ECOSYSTEM ACTIVITIES

TITLE: LONG-TERM MONITORING OF FINE-GRAINED SEDIMENT STORAGE THROUGHOUT THE MAIN CHANNEL

General Project Description: Fine-grained deposits (sand and finer) of the main channel constitute a major storage component of the Colorado River ecosystem's sediment budget. Glen Canyon Dam operations influence fine deposits in ways that affect aquatic and terrestrial habitats over both short and long periods. The emphasis of this long-term sediment monitoring project shall be to document system-wide changes in fine-grained deposits relative to dam operations and natural inputs, with emphasis on key storage settings within critical reaches.

Rationale/Problem Statement: Relationships between Glen Canyon Dam operations, fine-sediments input from gaged and ungaged tributaries below the dam, and interrelated downstream biological, socio-cultural resources are of primary management concern. Monitoring data on fine-grained deposits, linkages with physical habitats and relationships to non-physical resources and processes offer insight on the effectiveness of the current experimental flow treatment (Secretary's 1996 Record of Decision) relative to management objectives.

Annual monitoring of fine-grained sediment storage provides data: (1) to managers who

need to assess the status of near-shore aquatic and terrestrial habitats where vegetation and associated fauna, socio-cultural resources are of management concern; (2) on the availability of fine-grained sediment that can be periodically manipulated through controlled floods to preserve and sustain downstream resources dependent on fine sediment; (3) that allow identification and interpretation of linkages between dam operations and changes in physical habitats and related ecosystem resources. All three areas of information support science-based evaluations of large-scale flow experiments (e.g., the Secretary's actions), and associated decision responses required for adaptive management to succeed.

-Integration: Fine-sediment deposits along the main channel form many physical habitats for both terrestrial and aquatic organisms of the ecosystem; including ethno-botanical resources. They are also comprise sources and sinks for nutrients, recreational campsites and settings for in-situ preservation of cultural resources. Information on the distribution and characteristics of these deposits must be measured in ways that can be related to dam operations. Further, the measurements must be made over spatial and temporal scales that allow fine-sediment related resources to be linked to changing conditions of the sediment budget.

-MO's and IN's to be Addressed: This integrated long-term monitoring project shall provide data related to management objectives and information needs as indicated in Table 2.1. Annual surveys of channel-stored fine deposits shall provide information on the condition of both terrestrial and aquatic sand bar morphologies and grain-size characteristics, including return-current channels (backwaters) and riparian plant substrates. In addition, fine-grained terraces that are relicts of the pre-dam system shall be remotely monitored to detect lateral erosion, and any trends will be evaluated relative to historical changes in terraces determined through current synthesis research. A system-wide subset of terrestrial sand bars will also be evaluated for recreational camping suitability at elevations above the 25,000 cfs stage.

Project Goals and Objectives: The *primary goal* is to annually measure, report and evaluate system-wide relative changes in the morphology, volume and grain-size characteristics of fine-sediment deposits in aquatic and terrestrial settings of the main channel. These monitoring data

will mostly be comprised of field measurements made using standard hydrographic and surveying methods within designated monitoring reaches. Of particular concern are deposits within the first 240 miles downstream of the dam related to near-shore, terrestrial habitats, and recreational campsites, and areas where cultural resources occur. Habitats influenced by dam operations and fine-sediment storage include: aquatic near-shore habitats important to fish (backwaters and sandy shorelines that support vegetation), channel environments where benthic organisms occur and are affected by fine-sediment flux (cobble bars, debris fans and talus shorelines), terrestrial habitats that support riparian vegetation and associated fauna, terrestrial substrates used by recreational backcountry visitors, and terrestrial substrates that support and preserve cultural resources (frequently inundated sand bars and up to the tops of pre-dam river terraces).

Secondary goals shall be to relate changes in fine-sediment storage to dam operations, and to the distribution and condition of physical habitats of the aquatic and terrestrial ecosystem related to biological and socio-cultural resources of concern. These physical resource data provide information needed to interpret changes in cultural, recreational and biological resources relative to annual operations of Glen Canyon Dam. Specific monitoring objectives of the project include change detection data:

- For pre-dam river terraces needed to determine the ongoing stability or erosion of these relict fine-sediment deposits of the pre-dam river associated cultural resources.
- For near-shore aquatic and terrestrial substrates and associated fauna related to biological and cultural resources.
- On grain-size (relative texture) and abundance (relative volume) of fine-sediments available for use in restoring and preserving sediment-dependent resources through periodic flow manipulation.
- Availability and quality of recreational campsites in critical reaches and system-wide.
- On the system-wide, channel-bed distribution of fine- versus coarse-sediment substrates.

Expected Products: Annual data on main channel topographic and grain-size changes of fine-sediment deposits that result from interactions between sediment supply and dam operations. Also required, shall be a system-wide, GIS-based map of the main channel documenting the distribution of channel-bed substrates, with specific emphasis on fine- versus coarse-sediment and bedrock. Annual interpretive reports based on change-detection data for fine-sediment deposits documenting relationships between the above physical data sets and related Colorado River ecosystem attributes. Emphasis shall be on relationships between fine-sediment distribution and near-shore aquatic and terrestrial habitats where vegetation and associated fauna, recreation and cultural resources are of management and scientific concern.

Recommended Approach/Methods: Fine-grained sediment storage data will be measured throughout monitoring reaches upstream of Phantom Ranch annually using a combination of remote and ground-based topographic survey and sedimentology measurements that characterize changes in grain-size, morphology and storage volume changes in fine-sediment deposits at prescribed long-term monitoring sites. Existing monitoring reaches below Phantom Ranch will be surveyed on a biennial schedule, with the exception of special reaches where relations between physical habitat and endangered native fishes are of interest (second population of Humpback chub), or in years when changes in fine-grained sediment storage are influenced by flood flows.

Campsite areas will be included within monitoring reaches as a subset of deposits monitored, and may include a sub-sample of as many as fifty campsites, located within reaches designated as "critical." Campsite assessments shall be conducted annually within critical reaches using existing survey methods to document campable areas at elevations above 25,000 cfs. Campsites outside of critical reaches will be monitored on a biennial schedule. These data shall be related to stages up to at least 45,000 cfs, and possibly higher.

Side-scan sonar surveys shall be conducted on a system-wide basis in February or March to map the distribution of fine versus coarse sediment and bedrock channel-bed substrates. Substrate data shall be processed in a timely manner that allows wide use of these data by other

cooperating scientists during the monitoring period and immediately following the end of the funding cycle.

Under contingency plans, additional measurements of fine-sediment storage, channel-bed substrates and grain-size characteristics shall be conducted using additional fiscal resources in the event of large-scale flow experiments (e.g., BHBF and SASF).

Schedule: This long-term monitoring program will be initiated in FY 2001 through a competitive call for proposals and review/selection process, and will be continued annually through at least FY 2005 through an annually renewed contract(s) and (or) cooperative agreement(s). Status of the monitoring program methods, temporal and spatial scale shall be evaluated through a PEP-SEDS approach during years 4-5; with special focus on the level of integration with biological resource management and information needs.

Cost Range: Estimated at $320,000 annually.

GCMRC Involvement:

Personnel – Melis (10%), Ralston (2%), Lambert (2%), and Gonzales (15%).

Technical Support Services – (1) Team contract management and oversight with highest levels of participation by Melis and Lambert; (2) oversight by survey staff to ensure that terrestrial and bathymetric field surveys meet GCMRC standards and are tied to the established survey control network; (3) scientific collaboration by Melis with project team.

Logistics – One 16-day motor trip, and one 16-day rowing trip ($62,000).

TITLE: **LONG-TERM MONITORING OF STREAMFLOW AND FINE-SEDIMENT TRANSPORT IN THE MAIN CHANNEL COLORADO, PARIA AND LITTLE COLORADO RIVERS**

General Project Description: This is the core of the long-term monitoring effort for sediment and streamflow resources. The project is intended to document: (1) discharges from Glen Canyon Dam at the existing Glen Canyon streamgage; (2) streamflows and fine-sediment inputs entering the Colorado River ecosystem from the Paria and Little Colorado Rivers at existing streamgages; (3) combined streamflows and fine-sediment transport along the main channel at the existing streamgages at Lees Ferry, upstream of the confluence with the Little Colorado River, Grand Canyon, and Diamond Creek (river miles -14, 0, 61, 87, and 225, respectively); (4) evaluate model-derived estimates of fine-sediment inputs from the Paria and Little Colorado Rivers with sediment-transport field measurements; (5) monitor model-reach characteristics before and after major tributary floods and evaluate channel changes with respect to model variables and modeling assumptions associated with those variables; (6) "event" monitoring of streamflow floods that occur in significant ungaged drainage areas in Glen and Marble Canyons to verify existing estimates for discharge and sediment inputs from ungaged tributaries; (7) quality of water data from the above sites that contribute to water quality information needs, as well as development of a system-wide nutrient budget.

Rationale/Problem Statement: Glen Canyon Dam operations prescribed by the Secretary's Record of Decision and their relationship with downstream resources of management concern are the primary focus of the ongoing adaptive management program. It is therefore necessary that discharges from the dam be measured and reported, as well as additional streamflows and fine-sediment inputs that result downstream from gaged and ungaged tributaries.

Inflows from the Paria and Little Colorado Rivers are a major source of both inorganic and organic fine-sediments that support physical and biological habitats of the ecosystem. Therefore, field measurements of these inputs are required for tracking the system-wide fine-

sediment and nutrient budgets. In addition, measuring export of fine-sediment out of the ecosystem is another vital component of the system-wide sediment and nutrient budgets related to estimating the residence time for inputs. Residence time and fate of nutrients and fine inorganic sediments is related to dam operations, and influences the stability and characteristics of physical habitats, as well as biological processes.

Monitoring streamflow and fine-grained sediment transport: (1) allows managers to track the status of fine-sediment flux into and out of the ecosystem on a seasonal to annual basis; (2) provides data that allow development of a 1-dimensional model for routing fine sediment through the main channel related to tributary sediment inputs "events" that can dramatically influence Colorado River ecosystem resources in both aquatic and terrestrial habitats; (3) provides data that supports interpretation of other monitoring data on the availability and grain-size of fine-grained sediment stored within geomorphic environments of the main channel.

-**Integration:** Streamflow is the fundamental parameter linking dam operations with changing conditions of downstream resources. Streamflow plays an integral part in driving sediment transport, and thus in relating dam operations to changes in downstream resources that are linked to the sediment budget. Streamflow also links with nutrient flux between Lake Powell, the Paria and Little Colorado River and hundreds of ungaged tributaries downstream from the dam that input both organic and inorganic constituents. Data on streamflow, sediment transport and quality of water need to be documented consistently throughout the ecosystem so that trends in non-physical resources downstream of the dam can be linked back to dam operations, or to non-dam related factors.

-MO's and IN's to be Addressed: This integrated physical resource monitoring project provides information needs related to management objectives as described in Table 2.1. Management objectives and information needs associated with long-term monitoring of dam operations, fine-grained sediment flux and streamflow throughout the main channel shall be obtained through this project under an interagency agreement with the U.S. Geological Survey. Additionally, key water quality parameters related to main channel, and gaged tributaries shall be obtained through the existing USGS stream gage network in support of biological management

objectives and information needs.

Project Goals and Objectives: The major emphasis of this project will be to document the flux of streamflow and fine-grained sediments system-wide through an existing network of USGS operated streamgages and numerical models developed for the gaged tributaries.

The *primary goal* is to document the flux of fine inorganic sediment into and out of the main channel of the ecosystem and relate this flux to data on system-wide storage of fine-sediment in the main channel. *Secondary goals* include improved understanding of streamflow and sediment-transport processes in gaged tributaries and along the main channel; continued data collection that supports flow and sediment model development and verification; and a consistent process for segregating sediment samples into their respective organic and inorganic components to support development of a nutrient budget—with an emphasis on organic Carbon. Both inorganic and organic components of the fine-sediment budget are known to influence organisms of the food base, as well as physical habitats of the aquatic and terrestrial ecosystem, such as aquatic near-shore habitats important to fish, terrestrial habitats that support riparian vegetation and associated fauna, terrestrial substrates used by recreational backcountry visitors, and terrestrial substrates that support and preserve cultural resources.

These physical resource data shall be related to changes in cultural, recreational and biological resources relative to annual operations of Glen Canyon Dam and fine-sediment inputs downstream of the dam. Specific monitoring objectives of the project:

- Measurement of unit-value discharge and fine-sediment transport along the main channel Colorado River between Glen Canyon Dam and river mile 225.
- Measurement of unit-value discharge and fine-sediment transport of the Paria and Little Colorado Rivers.
- Characterize grain-size of channel-bed and transported fine sediments where discharge measurements are made, as well as at key intermediate locations.
- Monitor channel attributes of the Paria and Little Colorado Rivers within modeling reaches and compare these data with assumptions associated with flow and sediment

input model performance estimated for these tributaries.

- Evaluate and report on annual flux of fine sediment with respect to data for similar periods on status of channel-storage component of system-wide fine-sediment budget.

Expected Products: Annual data reports on main channel and gaged tributary streamflows and sediment transport that reflect tributary inputs and interactions between those inputs and dam operations. These measurements will reflect two key elements of the fine-sediment and Carbon budgets–inputs, and export from the Colorado River ecosystem (as determined at the Diamond Creek, Grand Canyon and gage immediately upstream of the Little Colorado River confluence). Annual data and interpretive report(s) on streamflow and sediment transport relationships between tributary inputs and the main channel of management and scientific concern. Of particular concern will be reports and presentations to the GCMRC and SAB assessing the performance of geomorphically based flow and sediment models for the Paria and Little Colorado Rivers.

Streamflow will be measured and reported in 15-minute unit values, and posted along with daily mean values on the USGS web site. Suspended-sediment and bed-sediment, and water quality samples will be collected and analyzed throughout the monitoring period on a daily to weekly basis and reported annually through the USGS web site. Monitoring of tributary model reaches shall be conducted periodically as needed relative to flows that have potential for changing channel characteristics related to model parameters and assumptions.

Recommended Approach/Methods: Ongoing measurement of streamflow, water quality, suspended-sediment concentration and grain-size, and bed-sediment grain-size characteristics at five main channel locations downstream of Glen Canyon Dam, and on established gages located on the Paria and Little Colorado Rivers. These measurements will be made using standard protocols established and maintained by USGS at similar monitoring sites nationwide. Analyses of sediment and water samples will be conducted by USGS personnel using standard methods at the Coastal and Marine Geology Sediment Laboratory located at Menlo Park, California, office

of the USGS, and other national laboratories as needed for nutrient budget purposes.

Motorized trips will be conducted to maintain five existing main channel streamgage sites, and to deploy intensive sediment sampling teams at above sites on a seasonal basis. Under contingency plans, additional measurements of streamflow, suspended and bed sediment concentration and grain-size characteristics will occur in the event of large-scale flow experiments (e.g., BHBF and SASF).

Schedule: This long-term monitoring project will be initiated in FY 2001 and will be continued annually through at least FY 2005. The annual work plan for this project will be drafted by GCMRC program managers to reflect the information needs of the adaptive management program. This work plan will be the basis for an ongoing interagency agreement with the Arizona District of the U.S. Geological Survey-Water Resources Division. During FYs 2004 through 2005, this core long-term monitoring program will be evaluated through the PEP-SEDS external review process to ensure efficiency and effective integration are being achieved.

Cost Range: Estimated at $470,000 annually.

GCMRC Involvement:

-Personnel – Melis (10%), Ralston (2%), Lambert (2%), and Gonzales (5%).

-Technical Support Services – (1) Team contract management and oversight with highest levels of participation by Melis and Ralston; (2) scientific collaboration by Melis and Ralston with project team.

-Logistics – Six 8-day motor trips to service streamgages; and one 14-day motor trip for intensive monitoring of sediment transport during input season of July through October ($50,000).

TITLE: LONG-TERM MONITORING OF COARSE-GRAINED SEDIMENT INPUTS, STORAGE AND IMPACTS TO PHYSICAL HABITATS

General Project Title: Monitoring Glen Canyon Dam operations and their interactions with coarse-grained sediment deposits that structure the geomorphic framework of the Colorado River ecosystem. Specifically, interactions between coarse-sediment deposits introduced to the main channel by tributary debris flows and Glen Canyon Dam operations, relative to system-wide distributions of aquatic and terrestrial habitats. This sediment monitoring activity consists mainly of change detection with respect to coarse-sediment inputs and channel features that support physical habitats, such as debris fans, cobble bars, and channel-bed topography and distribution of channel-bed coarse-sediment substrates.

Rationale/Problem Statement: Coarse-grained sediment deposits (composed of particles larger than sand-sized) are influenced by dam operations, and are also linked to biological, physical and recreational resources. Specifically, coarse-sediment deposits containing boulders form debris-fans that are stable features of the main channel. Debris fans impinge on the flow of the channel at hundreds of locations, and thus control streamflow and fine-sediment deposition throughout the ecosystem. Dam operations influence continued inputs of coarse-grained sediment from tributaries in unique ways that modify upper pool and downstream eddy environments where fine sediments are stored.

With respect to biological resources, coarse sediments form the substrates needed by benthic organisms associated with the food base, as well as spawning habitats for fish. Coarse-sediment deposits contribute to the formation and maintenance of hundreds of rapids that attract whitewater recreation enthusiasts; supporting a tourism industry that contributes substantially to the regional economy. Recent research has also documented that recreational camping areas are periodically degraded through erosion and (or) burial when tributary debris flows deposit coarse sediments along the main channel of the ecosystem (Melis et al., 1994). Results from the 1996 Beach/Habitat-Building Test, indicate that dam operations can be used to manage new coarse-

sediment deposits through river reworking during controlled floods (Webb et al., 1999).

Monitoring tributary debris-flow impacts and resulting coarse-sediment deposits, with respect to operations of Glen Canyon Dam, provides data on: (1) changing physical-habitat conditions related to coarse sediment that influence biological resources (such as the food base and spawning habitats for fish) and are of interest to scientists conducting related monitoring projects; (2) changing navigational conditions of whitewater rapids; (3) degradation of camping areas owing to erosion and (or) burial by coarse debris; () system-wide influences of flow regulation on the geomorphology of the main channel with respect to potential distribution and storage of fine sediment deposits.

-Integration: Coarse sediments of the main channel provide both substrates and a geomorphic framework that makes the Colorado River in Grand Canyon unique. Coarse lag deposits of the channel such as cobble bars and debris fans are physical habitats that support the benthic organisms of the food base, and support spawning and rearing habitats. Consistent measurements of changes in coarse-grain sediment storage are essential to linking dam operations to food base trends and patterns of fish behavior related to physical habitat use.

-MO's and IN's to be Addressed: This integrated long-term monitoring project provides data related to management objectives and information needs as described in Table 2.1. Information shall be provided on changes in the navigational characteristics of rapids, degradation of terrestrial sand bars, enhancement of sand-storage potential within upper pools and recirculating zones (eddies), distribution of cobble bars, and other aspects of physical habitat characteristics related to channel geomorphology.

Project Goals and Objectives: The *primary goal* is to annually document and evaluate coarse-sediment inputs from tributary debris flows and floods. *Secondary goals* include evaluating annual coarse-sediment inputs to: local and system-wide changes in aquatic and terrestrial physical habitats, storage settings for fine-sediment deposits, impacts to campsites caused by debris-flow deposits, changes to navigational characteristics of rapids, etc. Specific monitoring objectives of the project include change detection:

- Distribution and abundance of coarse substrates associated with biological habitats.
- Quality of recreational campsites and navigational conditions in rapids.
- For conditions and potential for fine-sediment storage in pools and rapids.

Expected Products: Annual data on coarse-sediment inputs to main channel that result from tributary events, and interactions between coarse-sediment storage and dam operations. Annual interpretive report(s) on ecological linkages between the above data sets and related Colorado River ecosystem resources, including changing conditions of biological habitats, recreational resources and main-channel fine-sediment storage.

Recommended Approach/Methods: A combination of remotely and field-based survey measurements documenting annual impacts from tributary debris flows and floods on the texture and topography of debris fans of the main channel, substrates of the terrestrial and aquatic habitats, and characteristics of rapids and campsites. These data shall be used in combination with annual channel-substrate mapping data collected as part of the long-term monitoring of fine-sediment storage to assess the magnitude of pre- versus post-tributary event impacts.

Schedule: Initiated in FY 2001 and continued annually through at least FY 2005 through contract(s) and (or) cooperative agreement(s).

Cost Range: Estimated at $75,000 annually.

GCMRC Involvement:

Personnel – Melis (10%), Ralston (2%), Lambert (2%) and Gonzales (5%).

Technical Support Services – (1) Team contract management and coordination by Melis, Ralston and Lambert, (2) scientific collaboration by Melis with project team.

Logistics – One 16-day motor trip ($18,000), likely to be conducted in the winter season. Level of annual monitoring activity will depend on the magnitude of annual tributary

debris-flow and flood activity, and whether or not flood flows occur during the annual funding cycle.

Note - Flood flows in excess of 45,000 cfs shall be of special interest to this monitoring program since none have occurred since the time that the ROD has been in effect.

TITLE: MODELING REACH-AVERAGED SAND BAR EVOLUTION IN RESPONSE TO A RANGE OF DISCHARGE AND SEDIMENT CONDITIONS ALONG THE MAIN CHANNEL

General Project Description: Development of a sediment-transport model capable of predicting 3-dimensional sand bar evolution under a range of dam operations and sediment supply conditions in selected geomorphic reaches of the main channel. The model development shall be conducted in a way that results in predictions of reach-averaged sand bar responses within geomorphic reaches identified by GCMRC and Ecometric Research, Inc., in advance of the project (FY 2000 activity). The model will also be able to simulate changing bar conditions at specific sites of concern, provided that high-resolution channel geometry is available for the reach or site of interest.

Rationale/Problem Statement: One useful method that has been used to screen options for managing fine-grained sediment deposits along the main channel has been development of a conceptual model that includes flow routing and sedimentation sub-routines. Unfortunately, the existing model lacks the capability to predict sand bar deposition and erosion locally at sites where 3-D bar morphology and process-rate information is needed (fate of backwater habitats, for example). By selecting representative sub-reaches in which process-based sediment-transport and streamflow modeling can be developed, estimates of sand bar responses can be predicted in ways that allow for 3-D bar morphologies to be better anticipated under changing flow and sediment supply conditions.

Predicting sand bar size and morphology is critical for anticipating how sand bars

supporting physical habitats will respond over short and long periods to a range of sediment supply conditions and experimental dam operations, such as the current treatment. This modeling capability also allows for large-scale flow experiments, especially those intended for sand bar restoration, to be evaluated in advance of conducting field tests. Screening of large-scale experiments through preliminary modeling is one way to assess and minimize risks associated with alternative flood-flows, such as BHBFs of variable duration and floods in excess of 45,000 cfs under varied sediment supply conditions. In addition, sand bar simulations allow managers and scientists opportunities to better design flood experiments related to key hypotheses that need to be addressed, such as short and longer-term impacts to the system's fine-sediment budget, distribution and characteristics of camping beaches, abundance and availability of backwater habitats, and potential for fine-sediment deposition along river terraces containing cultural resources.

-Integration: Sand bar distribution, size and morphology are related to habitat types thought to be important to biological organisms of the ecosystem, such as early life stages of the Humpback chub. Dam operations affect not only the fine-sediment budget of the system, but also the individual characteristics of sand bars that support habitat types, such as backwaters. In addition, sand bar characteristics also affect recreational campsites and settings where cultural resources are preserved. As a result, being able to predict how the range of dam operations and sediment conditions relate to sand bar abundance and morphologies can help promote integrated understanding of how physical and non-physical resources are related to dam releases.

-MO's and IN's to be Addressed: This integrated physical resource research project shall provide information needs related to predicting influences of dam operations on fine sediment and related resources as described in Table 2.1. This research project shall provide: (1) greater understanding of flow and depositional processes related to sand bar evolution; (2) predictive insight into the fate of individual sand bar types and site-specific morphologies under a range of hypothetical conditions; and (3) sand-storage exchange data between eddies and the main channel within key reaches where 1-dimensional fine-sediment export predictions are needed.

Project Goals and Objectives: The *primary goal* is to advance the understanding of sediment and flow processes along the main channel, while developing reach-averaged estimates of sand bar deposition and erosion under varied sediment supply conditions and dam operations up to 100,000 cfs. These estimates shall be based on selected portions of individual geomorphic reaches defined on the basis of average channel attributes and (or) proximity to points of major sediment inputs.

Secondary goals are: to produce data on estimated exchanges of fine-sediment transfer between eddies and the main channel for use in development of a 1-dimensional sand-transport model for routing fine sediment inputs through the main channel to Upper Lake Mead; to evaluate evolution of specific sand bar types related to backwaters and other physical habitats; to better estimate sand bar building flows related to distribution of camping areas, and to assess sand-bar deposition and erosion potential along pre-dam terraces where arroyo development threatens in-situ preservation of cultural resources. Because all flood flows must be routed through the relatively sediment-depleted Glen Canyon reach, it is crucial to conduct simulations to determine whether such flows are likely to erode pre-dam river terraces.

Expected Products: Numerical model code and documentation on model development and use within study reaches of the main channel. Model output data on flow and sediment-transport simulations for a range of conditions as specified by the GCMRC. Interpretive report(s) on model theory and assumptions related to sediment storage changes along geomorphic reaches related to dam operations and fine-sediment flux.

Recommended Approach/Methods: Limited development and verification of similar modeling capability has been previously undertaken by the U.S. Geological Survey, for the reach between river mile 61 and 72 below Glen Canyon Dam. Results of these activities indicate good correspondence with documented floods in 1993 and 1996 that have resulted in bar building in this reach. Methods similar to these are currently being used in the same reach to support

information needs related to the cultural resources program. It is assumed that such methods will likely be successful when applied to other geomorphic reaches throughout the ecosystem.

Schedule: This research will be initiated in FY 2001 and will likely continue through at least FY 2003. Progress in modeling will be partially dependent on the GCMRC's ability to provide 3-D geometry data for selected reaches of the main channel. Funding will be awarded on the basis of peer-evaluation of proposals solicited by a request for proposals in Spring 2000. Emphasis for model development will focus on critical upstream reaches first where physical habitats are of most interest, where sediment supplies are most limited, and where impacts of dam operations are most exaggerated.

Cost Range: $100,000 annually (not including GCMRC costs to map reaches of the main channel).

GCMRC Involvement:

-Personnel – Melis (5%), Lambert (2%), Ralston (2%), and Gonzales (20%).

-Technical Support Services – (1) Team contract management and oversight, as well as collaboration in selection of geomorphic reaches (Melis and Korman) to be modeled (FY 2000 activity); (2) Melis will define the range of dam operations and sediment conditions under which model results are developed, relative to the scope and need of the adaptive management program; (3) the GCMRC survey department shall provide main-channel geometry data (boundary conditions) upon which flow and sediment-transport modeling will be based.

-Logistics – One 16-day motor trip per year, in addition to motorized hydrographic trips conducted by GCMRC to map channel topography within modeling reaches ($18,000).

TITLE: DEVELOPMENT OF A ONE-DIMENSIONAL FINE SEDIMENT-ROUTING MODEL ALONG THE MAIN CHANNEL

General Project Description: A research program to develop an efficient numerical method for evaluating the influence of dam operations on tributary sediment inputs (sand and silt/clay) and the related fine-sediment budget. A numerical method of routing fine-sediment through the ecosystem is needed to track the fate of channel-stored sediment over short periods following tributary floods from the Paria and Little Colorado Rivers. This capability is also needed to make advance estimates of fine-sediment export from the ecosystem that result from planned or unplanned flood flows, as well as to simulate impacts of alternative dam operations. Because the grain-size distribution of channel-stored fine sediments directly impacts transport rates, this model will focus on tracking sediment loads in 1-dimension (tied to existing flow-routing model) for several size classes of sand, as well as silt and clay.

Rationale/Problem Statement: At present, the instability of bed-storage grain-size distributions and related sediment-transport rating curves for measurement sites on the main channel (Lees Ferry, above confluence with Little Colorado River, Grand Canyon, and above Diamond Creek) make it impossible to estimate changes in the ecosystem's fine-sediment budget over time frames of interest to managers (hours to seasons). To document changes in the storage of fine sediment in critical reaches, the current approach is to make relatively intensive field measurements for suspended-sediment transport. Such measurements are difficult to obtain for extended periods, costly to analyze, and are often associated with errors large enough that long-term sediment budgeting has little meaning. Development of a fine-sediment routing model that can track the fate of tributary inputs over hours to weeks can provide rapid evaluation of short-term changes in the system-wide flux of fine sediment needed to evaluate the influence of dam operations.

-**Integration:** The ability to accurately estimate the export of fine sediment from the ecosystem following tributary floods is vital for predicting the potential for restoration of sediment-dependent resources through controlled floods. A major premise of the management

program is that downstream resources may be preserved and sustained when a positive fine-sediment budget is maintained–one where sand supplies are available for manipulation through controlled floods. Sediment routing models allow for evaluations on how effective current dam operations are at maintaining a positive supply of stored fines in the main channel. This information is another source of information that can be used to relate non-physical resources back to dam operations.

-MO's and IN's to be Addressed: This sediment-transport research project provides information needs related to predictions about how dam operations influence fine sediment and related resources, as described in Table 2.1. Successful development of this model and predictive capability has the potential for allowing managers to more quickly assess the system-wide influences of dam operations on fine-sediment inputs from gaged tributaries, while reducing the need for intensive field measurements and delays caused by laboratory analyses of sediment-transport samples.

Project Goals and Objectives: The *primary goal* is to obtain a 1-dimensional sediment routing model that links streamflow to suspended transport of fine sediment between, at a minimum, Glen Canyon Dam and the Grand Canyon streamgage near Phantom Ranch. *Secondary goals* include improved understanding of relationships between suspended-sediment transport and grain-size evolution of fines stored on the channel bed; improved ability to track fine-sediment budget within critical reaches for periods of weeks to months following gaged tributary floods; improved estimates of the residence time for storage of fine inputs in main channel eddies and pools relative to ROD dam operations.

Expected Products: Numerical model code and documentation on 1-D routing model development and use within the main channel below Glen Canyon Dam. Model output data on flow and sediment-transport simulations. Interpretive report(s) on model theory, linkages with results of 3-D eddy and sand bar simulations, and descriptions of the key model assumptions related to numerical estimation of fine-sediment flux along critical reaches related to dam

operations and gaged tributary fine-sediment flux.

Recommended Approach/Methods: Conceptually, this sediment routing model shall combine the existing streamflow routing model (USGS) with results from 3-D sand bar evolution simulations, as well as existing reach-averaged channel geometry data, sediment-transport theory, and ongoing sediment-transport and streamflow monitoring data collected as part of core long-term monitoring of streamflow and sediment. Input data for model simulations will include unit-value discharge data from Glen Canyon Dam and associated downstream gage network site, fine-sediment input data from the Paria and Little Colorado Rivers (existing flow-based sediment models), and estimated antecedent conditions of grain size for main channel bed storage.

The model's initial development will be followed by an intensive verification period in which streamflow, suspended-sediment concentration and grain size, and bed grain-size distribution data (above the confluence of the Little Colorado River and Grand Canyon gages) will be compared with model simulation outputs. The length of this required verification period will be dependent on the desired range of dam operations for which the model is intended to be used, and level of tributary flood activity that occurs following model development.

Schedule: This research will be initiated in FY 2001 and will likely continue as a research effort through at FY 2003. The post-development verification may last an additional period of several years, but will be supported through collection of ongoing streamflow and sediment-transport data at main channel gage sites. Funding will be awarded on the basis of peer-evaluation of proposals solicited by a request for proposals in Spring 2000. Emphasis for development of sediment routing prediction will be on critical upstream reaches where fine-sediments and related physical habitats are of most interest; Glen Canyon Dam to river mile 87 (Grand Canyon gage). Ultimately, the point at which sediment export is simulated may extend down to Diamond Creek. This project shall be highly supported by the long-term monitoring program for streamflow and sediment transport (USGS, Arizona District). Eventually, the successful development of this sediment routing model may reduce the need for intensive suspended-sediment sampling of the

mainstem that is currently required to track the fine-sediment flux following large floods on the Paria and Little Colorado Rivers.

Cost Range: Estimated at $100,000 annually.

GCMRC Involvement:

-Personnel – Melis (5%).

-Technical Support Services – (1) Contract management, oversight and coordination with main channel streamflow and sediment-transport monitoring program (USGS); (2) collaboration between Melis and project team members in developing routing model and user interface for scientists and managers.

-Logistics – One 16-day trip per year to collect additional field measurements related to evolution of main channel bed storage and grain-size distributions ($18,000).

TITLE: **ADVANCED CONCEPTUAL MODELING OF COARSE-GRAINED SEDIMENT INPUTS RELATED TO EVOLVING PHYSICAL HABITATS AND AQUATIC PROCESSES**

General Project Description: Development of advanced simulations to predict long-term impacts of river regulation and inputs of coarse-grained sediments from ungaged tributaries at hundreds of sites along the main channel.

Rationale/Problem Statement: Since closure of Glen Canyon Dam in 1963, local geomorphic changes have continued to occur at sites along the main channel owing to coarse-grained sediment inputs that result from debris flows in ungaged tributaries. Because of the reduced flood frequency imposed by the dam, the natural level of reworking of coarse sediments in the main channel is drastically reduced compared with pre-dam annual floods (Melis, 1997). However, the 1996 controlled flood experiment was shown to be an effective means of partially

reworking rapids and debris fans aggraded by recent debris flows (Webb et al., 1999). Inputs of coarse sediments to the system-wide sediment budget of the ecosystem have been shown to have implications for enhanced storage of fine sediment in upper pools and eddies, as well as for increasing navigational hazards in rapids.

In addition, coarse-grained deposits generally bury or degrade sand bars used by recreational camping, while at the same time adding to coarse substrates on which the food base relies (benthic organisms). Simulation of long-term trends in physical habitats related to coarse sediments and ongoing inputs shall provide information on how biological and socio-cultural resources are likely to respond to increased storage of coarse sediments along the main channel under regulated flows. Information on the potential degree to which deposits, such as cobble bars, rapids and debris fans, can be reworked by controlled floods to mitigate impacts of coarse inputs that may not be desired. Long-term trends that might be countered by dam operations include periodic reworking of aggraded rapids that become impassable owing to debris flows, or flood-induced restoration of camping sand bars following burial by debris flows.

-Integration: As physical habitats of the main channel evolve in response to regulation and continued inputs of coarse sediments, resources are likely to follow in ways that may or may not be fully anticipated. As a result, it is vital to further develop abilities to simulate how long-term trends in the coarse-sediment budget might influence the food base, campsite availability, spawning habitats for fish, or fine-sediment storage along the main channel. Advanced development of geomorphic and biological sub-models of the conceptual ecosystem model shall provide opportunities for scientists from varied disciplines to test hypotheses about how the geomorphic framework of the Colorado River will evolve under regulated flows, and more importantly, how such changes will influence the biological processes of the main channel.

-MO's and IN's to be Addressed: This integrated physical resource monitoring project provides information needs related to management objective as described in Table 2.1. Information on the estimated trends related to changing navigational conditions of rapids system-wide is an obvious initial area where information will be gained. Additionally, information about how physical habitats and camping areas will be changed under future conditions shall also

provide greater understanding about how dam operations will influence downstream resources in the long term.

Project Goals and Objectives: The *primary goal* is to develop a geomorphic sub-model of the main channel that simulates long-term trends in local and reach-averaged changes in fine-sediment storage settings, physical habitats such as cobble bars and debris fans that support the food base, and degradation of recreational camping areas that result from continued inputs of coarse-grained sediments (debris flows). *Secondary goals* are to improve current understanding of how coarse-grained sediment inputs and dam operations relate to the ongoing channel framework evolution that results from regulation, and to promote further understanding of how the fine and coarse sediment budgets of the Colorado River are linked to the bottom-up structure and function of the ecosystem.

Expected Products: Advanced physical and biological sub-models that further advance the conceptual model's ability to simulate long-term physical changes in the geomorphic framework of the Colorado River ecosystem. The advanced biological sub-model shall link the projected geomorphic changes to biological processes of the river. The advanced geomorphic sub-model shall link the projected physical changes to potential for fine-sediment storage and camping area navigational conditions of rapids that evolve through time.

Recommended Approach/Methods: The basis for development of these additional sub-models will be integration of all existing physical data sets for the Colorado River ecosystem, estimates for long-term inputs of fine and coarse-grained sediments from gaged and ungaged tributaries, statistically derived probabilities for tributary debris flows for all ungaged tributaries, and associated resource area data sets. Development of the advanced sub-models will be facilitated through a workshop approach, similar to that used to initially develop the Colorado River ecosystem conceptual model.

Schedule: This research will be initiated in FY 2001 and will likely continue through FY 2002. This project will be accomplished through a continuation of the Ecometric Research, Inc., agreement, and in collaboration with GCMRC staff and cooperating scientists. Emphasis will be on critical upstream reaches first where physical habitats and the food base are of most interest with respect to native endangered fishes. Integration with other physical and biology monitoring programs shall be required to simulate future impacts of coarse inputs on recreational camping areas and food base.

Cost Range: Estimated at $75,000 annually.

GCMRC Involvement:

-Personnel – Melis (15%), Ralston (5%), Lambert (5%).

-Technical Support Services – (1) Contract management and oversight; (2) scientific collaboration by Melis, Ralston and Lambert with Ecometric Research, Inc., and cooperators in development of advanced geomorphic framework sub-model.

-Logistics – None anticipated.

PROTOCOL EVALUATION PROGRAM ACTIVITIES

Biological Resources and IWQP PEP

The GCMRC biological resources program will conduct protocol evaluation activities in FY 2001 as a means of evaluating and developing the detailed protocols which will comprise the GCMRC long-term monitoring program. This will be done through the use of visiting committees of scientists with relevant expertise in the field of study (Fig 2.1).

The strategy will be to identify a lead reviewer with relevant expertise in the field of study and work with that reviewer to identify additional reviewers. These reviewers will be provided with the past two to three years of reports from a given project as well as the currently

funded proposal to review. They will be invited to meet with the current PI(s) for a series of project briefings immediately before a scheduled river trip. Time permitting, they will accompany the PI(s) on a river trip to evaluate their field methodology and gain familiarity with the ecosystem. The reviewers will be required to provide a rigorous review of the protocols currently in use and recommendations for changes in protocols, as appropriate. This information would be used to modify, as appropriate, the FY 2002 monitoring program.

While terrestrial and the Lees Ferry trout monitoring programs will undergo protocol review in FY2000, water quality, and fish and phyto-benthic communities will undergo a protocol review in FY2001. In order to have these completed in a time frame that allows integration with long-term monitoring RFP's these review panels will take place in October 2000. Because these three elements are tightly linked, it is proposed that the panel will be cross-disciplinary. If funds permit, both the fish and phyto-benthic community monitoring may be completed prior to FY2001 (May/June 2000). In an effort to put long-term monitoring in place by FY2002 for all resources, the first year of monitoring for any biological resources may include testing and evaluating protocols. The timeframe currently set for long-term monitoring precludes testing of new protocols prior to releasing of RFPs for long-term monitoring.

Socio-Cultural Resources PEP

Protocol assessments conducted by a Protocol Evaluation Panel (PEP) are being initiated in FY 2000 for the cultural resource component of the Socio-cultural Program. The PEP will combine assessments of GCMRC's and Reclamation's Programmatic Agreement (PA) activities to provide a comprehensive evaluation of cultural resource activities along the Colorado River Corridor. The PEP will assess the GCMRC activities relative to the Management Objectives and Information Needs of the AMP. PA activities will be assessed relative to the stipulations of that program to meet legal compliance by Reclamation. Finally, the PEP will evaluate the coordination between the program. The PEP will provide a report with recommendations and suggestions to the participants. In FY 2001, follow-up PEP activities are anticipated. These may include implementation and review of PEP

recommendations as well as additional assessments. Recommendations derived from the PEP will be incorporated into long-term monitoring that is anticipated to begin in FY 2001/2002.

The recreational resource component of the program is scheduled in FY 2000. It is anticipated that the recreational fishing PEP will be combined with the trout studies PEP scheduled by the biological resources program in FY 2000. The FY 2001 monies will be used for implementation and review of PEP recommendations (Fig 2.1).

REMOTE SENSING ACTIVITIES

TITLE: EVALUATING GROUND-BASED AND AIRBORNE REMOTE SENSING TECHNOLOGIES

Rationale/Problem Statement: The GCMRC has historically used conventional aerial photography/photogrammetry and color video for data collection in the Colorado River ecosystem. In March 1997, GCMRC proposed lowering flows from Glen Canyon Dam to 5,000 cubic feet per second (cfs) in support of Labor Day aerial photography. Members of the Technical Work Group (TWG) opposed this proposal. Their main concern was that lowering flows in "high-water" years could have a negative effect on the very resource GCMRC was trying to monitor (i.e., the monitoring protocol represented a treatment potentially more harmful to downstream resources than current dam operations). In response to the discussion around lower flows for conducting aerial photography, the suggestion emerged from the TWG that GCMRC investigate the potential of expanded use of remote-sensing technologies for data collection. To facilitate this process, GCMRC convened a PEP of remote sensing experts in May, 1998. Methodologies and protocols used in current GCMRC research projects were presented to the panel. The panel subsequently made recommendations of potential new technologies that might better meet GCMRC monitoring and research needs.

-Integration: The evaluation of remote sensing technologies is intended to address monitoring and research needs of the biological, cultural, and physical resource programs at the

GCMRC. If successful, remotely-sensed data sets could be utilized for multiple monitoring and research projects and provide spatial integration of multiple resource parameters.

-MOs and INs to be Addressed: Remote sensing technologies will be evaluated for all MOs and INs relating to resource projects currently underway or planned within the next five years for which a remote sensing solution might exist. MOs and INs specifically addressed by the remote sensing evaluation will be identified utilizing the process described below under Recommended Approach/Methods.

Project Goals and Objectives: GCMRC proposed the evaluation of ground-based and airborne remote sensing technologies with the goal of finding technologies and protocols that would result in a long-term monitoring program that is:

- Cost-effective (reduced costs over conventional approaches)
- Less intrusive (the monitoring doesn't have a greater effect on the system than normal dam operations)
- Expanded spatial coverage (has the ability to capture denser spatial data than can be gathered by field-based efforts)

Expected Products: A report recommending remote sensing technologies that address specific monitoring and research needs that meet the above described Project Goals and Objectives.

Recommended Approach/Methods: Ground-based and Airborne Remote Sensing Technologies will be identified, tested, and evaluated using the following steps:

1. Identify the GCMRC science program information needs that could be obtained through the use of ground-based and/or airborne remote sensing technologies.
2. Determine what technologies exist or are being developed that could collect the data required in support of GCMRC science program information needs.
3. Convene a PEP to recommend potential ground-based and airborne remote monitoring technologies.
4. Evaluate through literature reviews and expert opinion ground-based and airborne remote

monitoring technologies based on science information needs and sensor specifications and capabilities.

5. Prioritize promising technologies based on this evaluation into ones which deserve further evaluation and possible field testing.
6. Conduct pilot field tests of selected technologies and evaluate the results of those field tests.
7. Recommend to the GCMRC Chief which, if any, of the ground-based and airborne remote sensing technologies should be utilized in the Grand Canyon.
8. Develop the needed protocols and implement a ground-based and airborne remote sensing program, as appropriate.

Schedule: The remote sensing initiative begins in FY 2000 and continues for three years through FY 2002. A report summarizing the evaluation is scheduled for 2003.

Cost Range: Approximately $400,000 per year for a total cost of $1,200,000.

GCMRC Involvement

Personnel – Project Coordinator, GCMRC Program managers, Survey and GIS technical support staff

Technical Support Services – Survey and GIS support

Logistics – Two downstream river trips for data collection and ground truthing. Multiple upstream river trips in the Lees Ferry reach for the same.

Summary Budget for Scientific Activities

Table 2.2. Summary table of projected FY2001 budget for projects and by GCMRC program allocations. *

TERRESTRIAL ECOSYSTEM ACTIVITIES										
Project Title	Physical	Biological	Cultural	GIS Support	Survey Support	Remote Sensing	Database Mgmt	Estimated Logistics	GCMRC Personnel (Salary & Overhead)	Total
Monitoring Avifauna **NEW RFP IN SUMMER 2000**	---	90,000	---	---	---	---	---	32,000	Ralston .05 - 3,900	$ 125,900
Monitoring terrestrial habitat and evaluating its quality for utilization **NEW RFP IN SUMMER 2000**	---	90,000	75,000	---	---	---	---	10,000	Ralston .10 - 7,800 Lambert .10 - 10,200 Melis .02 - 1,800 (Total - 19,800)	$ 194,800

Project Title	Physical	Biological	Cultural	GIS Support	Survey Support	Remote Sensing	Database Mgmt	Estimated Logistics	GCMRC Personnel (Salary & Overhead)	Total
Monitoring Kanab ambersnails and habitat at Vaseys Paradise **NEW RFP IN SUMMER 2000 OR MAINTAINED INTERNALLY**	---	10,000	---	---	6,000	---	---	30,000	Ralston .10 - 7,800 Kohl .20 - 10,100 Gonzales .05 - 4,200 (Total - 22,100)	$ 68,100
Ongoing trophic interactions research **ONGOING**	---	30,000	---	---	---	---	---	20,000	Ralston .05 - 3,900	$ 53,900
Evaluation of Cultural Resource Monitoring and Mitigation Strategies **NEW RFP IN 2000**	---	---	65,000	---	---	---	---	40,000	Lambert .15 - 15,300 Melis .02 - 1,800 Ralston .02 - 1,600 Kohl .10 - 5,000 Mietz .05 - 3,200 (Total - 26,900)	$ 131,900

Project Title	Physical	Biological	Cultural	GIS Support	Survey Support	Remote Sensing	Database Mgmt	Estimated Logistics	GCMRC Personnel (Salary & Overhead)	Total
Development of historic contexts to evaluate the significance of cultural resource data **NEW RFP IN 2000**	---	---	25,000	---	---	---	---	26,000	Lambert .15 - 15,300 Melis .02 - 1,800 Ralston .02 - 1,600 (Total - 18,700)	$ 69,700
AQUATIC ECOSYSTEM ACTIVITIES										
Ongoing monitoring phyto-benthic community and evaluating its quality for utilization **ONGOING WITH REVISIONS NAU (BLINN & SHANNON)**	---	230,000	---	---	---	---	---	10,000	Ralston .05 - 3,900 Yard .05 - 3,600 Melis .02 - 1,800 (Total - 9,300)	$249,300

Project Title	Physical	Biological	Cultural	GIS Support	Survey Support	Remote Sensing	Database Mgmt	Estimated Logistics	GCMRC Personnel (Salary & Overhead)	Total
Ongoing monitoring of status and trends of fish community **ONGOING WITH REVISIONS**	---	460,000	---	---	---	---	---	90,000	Ralston .05 - 3,900 Yard .10 - 7,200 Melis .02 - 1,800 (Total - 12,900)	$562,900
Monitoring the status and trends of the Lees Ferry Trout Fishery **NEW RFP IN SPRING 2000**	---	120,000	---	---	---	---	---	10,000	Ralston .05 – 3,900 Yard .05 – 3,600 Melis .02 – 1,600 (Total – 9,300)	$129,300

Project Title	Physical	Biological	Cultural	GIS Support	Survey Support	Remote Sensing	Database Mgmt	Estimated Logistics	GCMRC Personnel (Salary & Overhead)	Total
Integrated Water Quality Monitoring - Lake Powell **ONGOING WITH REVISION AND COOPERATION BETWEEN GCMRC AND USGS (WRD AZ DISTRICT)**	---	95,000[9]	---	---	---	---	---	20,000[2]	Hueftle .70 - 54,000 Vernieu .70 - 54,000 Ralston .02 - 1,600 Env. Studies Asst. .70 – 25,000 (Total - 134,600)	$249,600

9 O&M funds are used to support these IWQP activities in Lake Powell. Includes costs for sample processing, travel, and data analysis and report preparation
2 O&M Funds are used to support these IWQP activities in Lake Powell

Project Title	Physical	Biological	Cultural	GIS Support	Survey Support	Remote Sensing	Database Mgmt	Estimated Logistics	GCMRC Personnel (Salary & Overhead)	Total
IWQP – Tailwater **ONGOING WITH REVISION AND COOPERATION BETWEEN GCMRC AND USGS (WRD AZ DISTRICT)**		10,000[3]						8,000[4]	Vernieu- .10- 7,700 OT-Personnel –10,000	35,700
Ongoing research associated with population genetics of HBC in Colorado River ecosystem	---	50,000	---	---	---	---	---	2,000	Ralston .05 - 3,900 Yard .05 - 3,600 (Total - 7,500)	$57,500

3 AMP funds are used to support these IWQP activities in the tailwaters of Glen Canyon Dam. Included costs for sample processing, travel, in depth analysis and report preparation

4 AMP funds are used to support these IWQP activities in the tailwaters of Glen Canyon Dam.

Project Title	Physical	Biological	Cultural	GIS Support	Survey Support	Remote Sensing	Database Mgmt	Estimated Logistics	GCMRC Personnel (Salary & Overhead)	Total
Native fish/non-native competitive interactions **NEW IN SPRING 2000**	---	90,000	---	---	---	---	---	None	Ralston .05 - 3,900 Yard .10 - 7,200 (Total - 11,100)	TBD 11,100

Project Title	Physical	Biological	Cultural	GIS Support	Survey Support	Remote Sensing	Database Mgmt	Estimated Logistics	GCMRC Personnel	Total
(Section 8 funded) New research associated with experimental flows which include temperature control device evaluation and assessment. **NEW IN SPRING 2000**	---	310,000	TBD	---	---	---	---	TBD	Ralston .05 - 3,900 Yard .10 - 7,100 Hueftle .05 - 3,700 Vernieu .10 - 9,100 (Total - 23,800)	$ 333,800

Project Title	Physical	Biological	Cultural	GIS Support	Survey Support	Remote Sensing	Database Mgmt	Estimated Logistics	GCMRC Personnel	Total
New research associated with water quality in Lake Powell	---	30,000[6]	---	---	---	---	---	Logistics costs are included in the research costs	Hueftle .10 - 7,7 00 Env. Studies Asst. .30-10,000	$47,700
Downstream **NEW IN SPRING 2000 AS RFP (?)**		20,000[7] (Total 50,000)							Hueftle .05 – 3,300 Other personnel – 10,000	33,300

6 The funds to support this research activity will come from O&M funds for activities in Lake Powell. In FY2001, these funds may be used to support the PEP.
7 The funds to support this research activity will come from AMP funds for activities in the mainstem. In FY2001, these funds may be used to support the PEP.

INTEGRATED TERRESTRIAL AND AQUATIC ECOSYSTEM ACTIVITIES										
Project Title	Physical	Biological	Cultural	GIS Support	Survey Support	Remote Sensing	Database Mgmt	Estimated Logistics	GCMRC Personnel (Salary & Overhead)	Total
Long-term monitoring of fine-grained sediment storage throughout the main channel **NEW RFP IN SPRING 2000**	225,000	30,000	85,000	---	19,000	32,000	---	60,000	Melis .10 - 9,200 Ralston .02 - 1,600 Lambert .02 - 2,000 Gonzales .15 - 12,700 (Total - 25,500)	$ 458,500

Project Title	Physical	Biological	Cultural	GIS Support	Survey Support	Remote Sensing	Database Mgmt	Estimated Logistics	GCMRC Personnel	Total
Long-term Streamflow and fine sediment transport in the main channel Colorado, Paria and Little Colorado Rivers **ONGOING WITH REVISION THROUGH SOLE SOURCE TO USGS (WRD AZ DISTRICT)**	400,000	70,000[5]	---	---	---	---	---	50,000	Melis .10 - 9,200 Ralston .02 - 1,600 Lambert .02 - 2,000 Gonzales .05 - 4,200 (Total – 17,000)	$527,000

5 These funds are provided from the IWQP – AMP budget to support water quality work in the mainstem through a contract that was competitively awarded in FY 1998 tp the USGS.

Project Title	Physical	Biological	Cultural	GIS Support	Survey Support	Remote Sensing	Database Mgmt	Estimated Logistics	GCMRC Personnel	Total
Long-term monitoring of coarse-sediment inputs, storage and impacts to physical habitats **NEW RFP IN SPRING 2000**	75,000	---	---	---	5,000	8,000	---	18,000	Melis .10 - 9,200 Ralston .02 - 1,600 Lambert .02 - 2,000 Gonzales .05 - 4,200 (Total - 17,000)	$ 123,000
Modeling reach-averaged sandbar evolution in response to discharge and sediment conditions **NEW RFP IN SPRING 2000**	75,000	---	25,000	---	10,000	16,000	---	18,000	Melis .05 - 4,600 Ralston .02 - 1,600 Lambert .02 - 2,000 Gonzales .20 - 16,800 (Total - 25,000)	$169,000

Project Title	Physical	Biological	Cultural	GIS Support	Survey Support	Remote Sensing	Database Mgmt	Estimated Logistics	GCMRC Personnel (Salary & Overhead)	Total
Development of one-dimensional fine sediment routing model along the main channel **NEW RFP IN SPRING 2000**	100,000	---	---	---	---	---	---	18,000	Melis .05 - 4,600	$ 122,600

Project Title	Physical	Biological	Cultural	GIS Support	Survey Support	Remote Sensing	Database Mgmt	Estimated Logistics	GCMRC Personnel	Total
Advance conceptual modeling of coarse-grained sediments related to evolving physical habitats and aquatic processes **ONGOING WITH REVISION THROUGH ECOMETRIC RESEARCH (KORMAN ETAL.)**	75,000	---	---	---	---	---	---	---	Melis .15 - 13,900 Ralston .05 - 3,900 Lambert .05 - 5,100 (Total - 22,900)	$ 97,900

PEP ACTIVITIES										
Project Title	Physical	Biological	Cultural	GIS Support	Survey Support	Remote Sensing	Database Mgmt	Estimated Logistics	GCMRC Personnel (Salary & Overhead)	Total
IWQP PEP	---	30,000[8]	---	---	---	---	---	TBD	Hueftle .10 7,700 Vernieu .10 7,700 Ralston .02 1,600/17,00	$ 47,000[8]
Project Title	Physical	Biological	Cultural	GIS Support	Survey Support	Remote Sensing	Database Mgmt	Estimated Logistics	GCMRC Personnel	Total
Aquatic Foodbase PEP	---	40,000	---	---	---	---	---	TBD	Ralston .02 1,600 Yard .05 3,600 (Total – 5,200)	$ 45,200
Native Fish PEP	---	30,000[9]	---	---	---	---	---	TBD	Ralston .02 1,600 Yard .10 7,200 (Total – 8,800)	$ 38,800
Evaluate Cultural Resources PEP	---	---	55,000	---	---	---	---	20,000	Lambert .10 10,200 Kohl .05 2,500 Mietz .05 3,200 (Total - 16,900)	$ 91,900

8 O&M and/or AMP funds will be used to support this activity, as appropriate.
9 Funds to support the native fish PEP may be supplemented from the 460,000 proposed for monitoring of status and trends of native fish, as needed.

ITP ACTIVITIES										
Project Title	Physical	Biological	Cultural	GIS Support	Survey Support	Remote Sensing	Database Mgmt	Estimated Logistics	GCMRC Personnel (Salary & Overhead)	Total
Evaluating ground-based and airborne remote sensing technologies	---	---	---	---	5,000	400,000	---	TBD	Gonzales .10 - 8,400 Mietz .10 - 6,400 Liszewski .10 - 10,500 (Total - 25,300)	430,300
IT/GIS development	---	---	---	20,000	---	---	---	---	Mietz .50 – 33,200	53,200
PUBLIC OUTREACH ACTIVITIES										
Public Outreach Activities[10]	---	---	35,000	---	---	---	---	15,000	Lambert .10- 10,200	$ 60,200

10 These activities are not included in Chapter 2 but are described as a cultural resource project in Chapter 3 (see Public Outreach, page 113) and contribute to the total expenditures for the Cultural Resources program.

TOTALS										
Project Title	Physical	Biological	Cultural	GIS Support	Survey Support	Remote Sensing	Database Mgmt	Estimated Logistics	GCMRC Personnel (Salary & Overhead)	Total
AMP FUNDS	950,000	1,280,000[11]	365,000	---	---	---	---	475,000	---	$4,089,900
OTHER FUNDS	---	610,000	---	---	---	---	---	----	---	$ 610,000
TOTAL PROGRAM FUNDS	950,000	1,890,000	365,000	---	---	---	---	475,000	---	$4,699,900

11 Sec. 8 and O&M funds are not included in this total. In addition, funds used to support the IWQP PEP are not included in this total since they will come from proposed research and or monitoring activities, as appropriate.

Table 2.3. Budget breakdown for funds supporting IWQP for FY2001

Program Elements	Source of Funds O&M	AMP	Total
1. Personnel[1]			
-- Limnologist	$54,000	$23,000	$77,000[2]
-- Aquatic Biologist	$54,000	$23,000	$77,000
-- Environmental Studies Asst	$25,000	$10,000	$35,000
-- Other	$22,000	$10,000	$32,000
Sub-total	$155,000	$66,000	$221,000
2. Sample Processing[3]	$ 85,000	$ 7,000	$ 92,000
3. Downstream Water Quality (USGS)[4]	$ - 0 -	$ 70,000	$ 70,000
4. Research	$ 30,000	$ 20,000	$ 50,000
5. Logistics[5]	$ 20,000	$ 8,000	$ 28,000
6. Travel	$ 8,000	$ 2,000	$ 10,000
7. Data Analysis & Report Preparation[6]	$ 2,000	$ 1,000	$ 3,000
TOTAL	**$300,000**	**$174,000**	**$474,000**

1 These costs cover personnel for Lake Powell data collection, data analysis, and reporting, as well as tailwater and downstream activities, including thermal monitoring. Also included are trips required to maintain the sensors that are in the field.
2 Includes base salary, benefits, and leave assessment.
3 Sample analysis is contracted out through a competitive process to a qualified water quality lab.
4 USGS currently has a contract, obtained through the competitive RFP process to collect water quality data at gages in the Grand Canyon.
5 Includes boat operating and O&M expenses, foodpacks, equipment maintenance and reagents.
6 This covers the cost of additional sample analysis that may be required, and the cost of report preparation, including color copies, as well as the cost of preparing slides and posters for scientific and public meetings.

CHAPTER 3

MANAGEMENT AND BUDGET

UNSOLICITED PROPOSALS

General Proposals:

The GCMRC proposes to set aside some funds in support of unsolicited proposals. This will allow for flexibility in the program and help ensure that GCMRC can address critical issues in a timely fashion. It will also provide GCMRC the ability to fund a truly outstanding proposal that addresses a key concern which may be overlooked in the research planning process. All unsolicited proposals will be discussed with the TWG and will undergo independent, external peer review prior to funding.

Tribal Proposals:

The GCMRC encourages Tribal groups to submit proposals for projects that address resource issues related to Management Objectives and Information Needs. Because these groups define their resource issues from tribal perspectives and formulate their work proposals, the GCMRC considers these submittals as unsolicited proposals. These proposals are reviewed by internal and external peer reviewers to evaluate the proposed project methodologies relative to the project objectives. Unsolicited proposals may be submitted to the GCMRC at any time. Examples of current tribal proposals include an ethnobotanical monitoring project by the Hopi Tribe and a public outreach project conducted by the Southern Paiute Consortium to disseminate their ethnobotanical information.

IN-HOUSE RESEARCH

The GCMRC supports in-house research by GCMRC Program Mangers and scientific staff. In-house research is supported as a means of ensuring that GCMRC program managers and scientific staff remain subject area experts in their respective fields through the conduct of their own research on the Colorado River ecosystem. This also ensures that they are able to provide the highest quality of technical assistance in the form of expert analysis, opinion, and

advice to the Chief, TWG and the AMWG as requested. In-house research may be in the form of original research or synthesis. In all cases, GCMRC in-house research proposals undergo the same independent external review as all GCMRC proposals.

AMWG & TWG SUPPORT

In addition, GCMRC plans to create a pool of money which can be used by GCMRC staff in support of requests for analysis that arise from the TWG during the course of the year. Such funds may be used to gather data, conduct analyses, support the convening of a group of scientists to provide an analysis of a given issue (i.e., the annual BHBF resources evaluation) or to obtain expertise not contained within the GCMRC staff or contractors. Such funds may be carried over from one year to the next, depending upon need and availability.

TECHNICAL SUPPORT SERVICES: INFORMATION TECHNOLOGY PROGRAM

Introduction

The GCMRC Information Technology Program facilitates the adaptive management process of the Colorado River ecosystem by: (1) organizing, archiving, and delivering scientific data and other information to stakeholders, scientists, and the public, (2) providing technology based solutions to data collection, manipulation, and analysis, and (3) providing support in areas of computers, surveying, GIS, and remote sensing.

The GCMRC has extensive historical data and information collected over many years relating to the condition of resources in the Colorado River ecosystem. This information represents an extremely valuable asset to researchers, managers, and interested stakeholders, but has yet to be developed into an ecologically integrated information system. Its potential for problem solving, improving management guidelines, modeling relationships, or increasing understanding of the various resources and systems under study underlies the GCMRC program of information management including data collection, analysis, and dissemination.

The goal of the Information Technology Program (ITP) is to "satisfy the information needs of stakeholders, scientists, and the public relative to the Colorado River ecosystem" in terms of content and delivery. Key to achieving this goal is the development and maintenance of

three core information technologies with the express purpose of organizing, archiving, and disseminating information: (1) a data base management system (DBMS) for tabular information and other electronic non-spatial information, (2) a geographic information system (GIS) for electronic spatial information, and (3) a library for hardcopy information. Content of these systems will consist of all information gathered as the result of GCMRC investigations, both past and present, and additional information relating to the Colorado River ecosystem. In addition, the ITP also provides:

- Survey support and training for GCMRC staff and investigators
- GIS analysis support and training for GCMRC staff, AMWG, and TWG
- Computer support and training to GCMRC staff
- World Wide Web publishing environment
- Remotely sensed data collection and development of technology solutions

These ancillary services augment the core information infrastructures by providing the support, training, and development necessary to provide a comprehensive ITP. These information systems and services facilitate the monitoring and research programs at the GCMRC and provide a convenient interface for information dissemination to the AMWG and TWG (Figure 3.1).

Data Base Management System

The data base management system is an information management function of the GCMRC ITP. The DBMS supports GCMRC scientists and investigators, AMWG and TWG members, and public interest in the Colorado River ecosystem by providing an infrastructure for organizing, archiving, and disseminating tabular information about the ecosystem. GCMRC is currently in the formative stages of data base development. It is anticipated that data base structure will be designed and programmed in FY2000. Development activities will continue into FY2001 focusing on:

1. Populating the GCMRC Oracle database
2. Developing user interfaces
3. Developing WWW interfaces
4. Documenting administrative procedures of the data base

In addition to a full time Oracle data base administrator, an Oracle data base development consultant will be retained through FY2001 to aid in populating the data base and developing interfaces and documentation. It is anticipated that the first development cycle of the data base will be largely complete at the close of 2001 and that the Oracle consultant will no longer be needed except for periodic updating and tuning perhaps in five year cycles.

Geographic Information System

The geographic information system performs both an information management and a data analysis functions within the GCMRC ITP. The GIS supports GCMRC scientists and investigators, AMWG and TWG members, and public interests in the Colorado River ecosystem by providing an infrastructure for organizing, archiving, and disseminating spatial information about the ecosystem. In addition, the GIS function provides map making and spatial analysis capabilities in areas of biological, cultural, and physical program areas such as native fish habitat and population occurrences, change detection of main channel elements, and identification of areas of cultural concern. The GIS also provides an efficient mechanism to query and extract tabular data from the DBMS for reporting and analysis. Current emphasis of the GIS for FY2000 is to organize and catalog existing GCMRC GIS holdings inherited from GCMRC's predecessor, the GCES program. GIS also provides support to the GCMRC remote sensing initiative. FY2001 activities will focus on:

1. Servicing GIS map, data, and analysis requests
2. Developing an Internet map server to aid in the dissemination of spatial data through web based mapping software
3. Consulting on remote sensing initiative

The GCMRC GIS is staffed with one full time GIS Coordinator and one part time student.

Library

The library is an information management function of the GCMRC ITP. The Library supports GCMRC scientists and investigators, AMWG and TWG members, and public interest in the Colorado River ecosystem by providing an infrastructure for organizing, archiving, and disseminating hard copy information such as reports, maps, aerial photography, slides, and videos. As with the DBMS and GIS, current activities are largely to organize and catalog existing materials inherited from GCMRC's predecessor, the Glen Canyon Environmental Studies program. FY2001 activities will focus on:

1. Service library requests
2. Continue to catalog library contents
3. Continue to make materials available on-line

It is anticipated that the library will be staffed by a full time Librarian/Review Coordinator. As the job title implies, the Librarian/Review Coordinator position will be divided between library duties and review coordinator duties.

Surveying

Surveying is a service function of the GCMRC ITP. GCMRC provides surveying services to staff and investigators that require spatial information for there research projects. This service facilitates research in the Colorado River ecosystem by providing coordination of all survey activities within the ecosystem, providing control and base maps for georeferencing remote data collection, and providing terrestrial and bathymetric base maps for sediment and flow modeling. In addition to providing surveying services, current activities include organizing and cataloging the inventory of survey data largely assembled by GCMRC's predecessor, the GCES program. Survey activities for FY2001 will focus on:

1. Servicing requests for surveying and survey data
2. Continued development of a high precision control network from GCD to Phantom Ranch
3. Continued development of terrestrial and hydrographic base maps of the Colorado River ecosystem
4. Continued organization of legacy survey data

It is anticipated that the survey department will be staffed by one full-time Survey Coordinator, one full time Survey Technician, and one part-time Student in FY2001.

Systems Administration

Systems administration is a service function of the GCMRC ITP. Systems administration provides the GCMRC infrastructure and support for office computing, networking, automation systems, and World Wide Web publishing. Current activities are largely focused on the design, implementation, documentation, and troubleshooting of the computer and networking environment. FY2001 activities will largely be a continuation of these activities with emphasis on:

1. Administration of the computer and networking environment
2. Developing an integrated WWW publishing environment
3. Enhancing office automation capabilities

It is anticipated that GCMRC systems administration will be staffed with one full time Systems Administrator and one part time student in FY 2001.

Remotely Sensed Data Collection

Remotely sensed data collection is a service function of the GCMRC ITP. This service facilitates monitoring and research in the Colorado River ecosystem by providing quality remotely sensed data sets, such as aerial photography, to multiple researchers. This results in high quality and consistent data sets and eliminates duplicate data collection by the multiple researchers who use them. The collection of remotely sensed data sets could increase as a result of the remote sensing initiative.

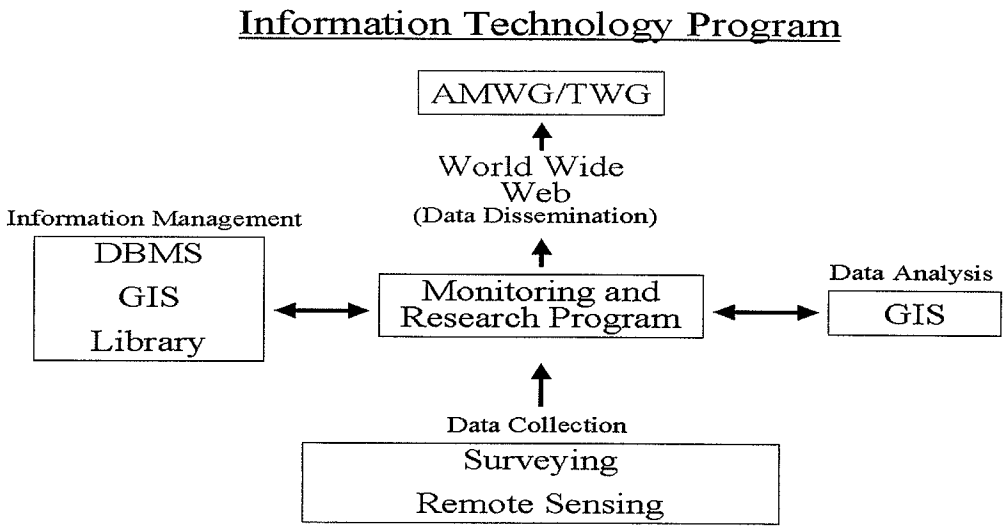

Figure 3.1. – Schematic illustrating the relationship of various Information Technology Program functions to the GCMRC monitoring and research program and the AMWG and TWG.

LOGISTICS PROGRAM

GCMRC monitoring and research programs are conducted by contracted Principal Investigators (PIs) whose work is administered by Program Managers in physical, biological and social-cultural resource programs. GCMRC staff also initiate some of their own in-house scientific activities which require logistical support, including the Integrated Water Quality Program. The GCMRC also supports Reclamation's logistics needs for five stakeholder Native Tribes, as specified under the Programmatic Agreement, and endangered species activities, as appropriate. In addition, GCMRC provides logistics support for any contingency plans or experimental floods.

To meet these responsibilities, the GCMRC supports approximately 50 downriver trips annually on the Colorado River through Grand Canyon. These trips range from four to thirty-two people in size, seven to twenty days in length, and are comprised of a variety of combinations of oar and motor-powered boats. Trip planning begins in the fall, when a draft schedule of trips for the next fiscal year is generated by the PIs, GCMRC Logistics

Coordinator and GCMRC Program Managers. Launch and take-out dates, boats to be used, trip rosters and itineraries are firmed up as soon thereafter as possible, and *must* be finalized 60 days prior to launch date and submitted to the Logistics Coordinator in order to meet the 45 day deadline for submitting launch permit application packets for each trip to the GCNP/NPS.

The GCMRC uses a "partially in-house" method of supporting trips in which government-owned boats and river logistical equipment are used in conjunction with four contracted vendors who supply Boat Operators, food packs, river put-in and take-out transportation and equipment rentals when needs exceed GCMRC inventory. Taken together, competitive bids from multiple subcontractors and better oversight over trip particulars that most influence cost (number of boats and Boat Operators, foodpacks, shuttle services) give the GCMRC much more control over trip costs.

In addition, the GCMRC in-house Logistics Coordinator and Program Managers are more able than subcontracted vendors to accommodate scientists who may be leaders in their field, but new to the Colorado River Ecosystem. More effective communication with PIs, and greater sensitivity to and awareness of the challenges they face in implementing their studies, enable the GCMRC to offer more tailored (and therefore more cost-effective) logistical support than any subcontracted vendor. Retaining more control over the process of supporting trips also facilitates better compliance with NPS regulations, and enables the GCMRC to match PIs with the best Boat Operators for their particular study.

A full-time Logistics Coordinator and Warehouse Manager are necessary under this approach. The partially in-house approach has proven to be most cost-effective because rental of frequently used river equipment is minimized, while Boat Operators, drivers, and the capital-intensive, high maintenance vehicles used for put-ins and take-outs can be retained as needed through subcontractors.

Arrangements for operations services (Logistical and Technical Boat Operators) and support services (food packs, put-in/take-out transportation, equipment rentals) are made two to four weeks prior to launch date. Operations services are obtained through one of two contracted vendors, while support services are obtained through one of three contracted

vendors. In certain cases, when the necessary expertise is available "in house," some operational and support services may be supplied by either GCMRC and/or the PI without the use of contracted vendors.

The GCMRC logistics budget for FY 2001 is $650,000. Approximately 50 trips will be supported by GCMRC in FY 2001. Capital investment for replacement of worn out equipment, compliance with NPS wilderness regulations and/or expansion of GCMRC logistical capabilities is needed in order to continue running safe and cost-effective trips.

INDEPENDENT REVIEW PANELS

Peer Review

All of GCMRC's scientific activities undergo an independent, external peer-review. This is true for all proposals, whether unsolicited, submitted in response to an RFP, or an in-house proposal. Similarly all draft reports received by GCMRC undergo independent, external peer-review. The peer-review protocols developed by GCMRC meet or exceed the standards articulated by the Secretary of the Interior for Department of the Interior agencies.

Peer-review for proposals received by GCMRC in response to an RFP is conducted through a panel process, while peer-review for unsolicited and in-house proposals, as well as project reports is conducted thorough the mail. In all cases, the peer-reviewers are offered anonymity and the individual and panel reviews, where applicable, are provided to the PIs along with comments from GCMRC.

The GCMRC review process is handled by a report review coordinator to ensure that the peer-review process is conducted one-step removed from the GCMRC program managers to guard against any conflicts of interest, real or perceived. Strict conflict-of-interest guidelines are adhered to. GCMRC annually recruits new individuals to join the ranks of its peer-reviewers and maintains a data base of almost 500 potential reviewers, organized by areas of expertise. GCMRC peer-reviewers come from academia, Federal and State government, non-governmental organizations, and the private sectors. Reviewers are selected on the basis of their record of scientific accomplishment.

Science Advisory Board

The GCMRC established a Science Advisory Board (SAB) in FY 2000 as one of its independent review panels. The SAB is an advisory and not a decision-making body. It is an interdisciplinary board, composed of scientists who are qualified, based on their record of publication in the peer-reviewed literature, or other demonstrable scientific achievements. Members have expertise in the following areas:

1. Adaptive management
2. Anthropology
3. Archaeology
4. Fisheries biology
5. Ecosystem/Riparian ecology
6. Economics
7. Geomorphology
8. GIS
9. Hydrology
10. Limnology

The SAB together and individually will be expected in FY 2001, among other things, to review and comment to the AMWG and GCMRC on: (1) GCMRC's annual work plan and budget proposal, (2) GCMRC's long-term monitoring and research plan, (3) the results of GCMRC's completed monitoring and research activities, (4) the results of any synthesis and assessment activities initiated by the GCMRC, and (5) any other activities (i.e., program specific scientific advice) it is asked to address by the GCMRC Chief or the AMWG.

PUBLIC OUTREACH

In response to the urging of the Deputy Secretary of the Interior and in conjunction with an ad hoc group of the AMWG, GCMRC is developing public outreach activities. These will range from material for articles to video tapes describing the adaptive management program and associated scientific activities, to providing GCMRC staff to speak at different meetings. The range of activities is currently under discussion with the ad hoc group. Some modification to the

FY 2001 Work Plan may have to be made, once the ad hoc group completes its task.

To complement GCMRC's overall public outreach efforts, an outreach project is proposed that links the IT Program and Socio-cultural Program with the dissemination of cultural resource data. Included within this project are funds to continue the Data Protocol Working Group that is preparing guidelines for the AMP to appropriately disseminate sensitive cultural and biological information in a report to the AMWG; hold training workshops for using the conceptual model ; employ student interns from stakeholder groups for resource projects; and to sponsor tribally hosted lectures and talks to present cultural information. Funds to implement this project are currently budgeted within the Socio-cultural Resources Program and total $35,000.

ADMINISTRATION & PERSONNEL

The GCMRC organizational structure has been developed in response to GCMRC's mission and roles and responsibilities within the AMP, as well as in response to the comments of the National Research Council (NRC 1999), to ensure successful implementation of the FY 2001 Work Plan. The GCMRC will be administered by a Chief and four program managers (physical, biological, socio-cultural, and information technologies) to oversee the individual resource areas and an extensive program of data analysis and management, GIS technology and information transfer, surveying and evaluation of remote sensing technologies. Together with the Chief, they will focus on program integration and evaluation of Colorado River ecosystem resource interactions in response to dam operations. One of these program managers will also serve as a deputy to the Chief and as Acting Chief in the Chief's absence.

In addition to their program management responsibilities, the program managers are also expected to remain subject area experts in their respective fields through the conduct of their own research on the Colorado River ecosystem. It is important that GCMRC program managers and scientific staff maintain this expertise so they can provide high quality technical assistance in the form of expert analysis, opinion, and advice to the Chief, TWG and the AMWG as requested. This will include but is not limited to the annual State of the Canyon Resources Report, evaluation of the BHBF resource criteria, preparing draft biological assessments and other such

synthesis and activities which may be requested. The Socio-cultural Program Manager will also function as the Native American coordinator mentioned in the EIS. The program managers will supervise additional technical and support staff.

The GCMRC will continue to conduct all logistics for its programs internally in FY 2001, with direct coordination with appropriate NPS offices. This approach has proven its cost-effectiveness. In addition to cost savings, by running the logistics program in-house, GCMRC is able to ensure compliance with all NPS directives, consolidate and coordinate river trips, and create a level playing field so all researchers have an equal chance at competing for proposals and successfully implementing their projects. All river trip logistics and permitting, air photography, rescue, etc., is overseen by the logistics coordinator in cooperation with the NPS. GCMRC expects to initiate between 50 and 60 river trips in FY 2001. Running this many river trips requires a full-time logistics coordinator and a full-time warehouse technician.

All completed proposals, Principal Investigator reports, GCMRC reports, cooperative programs, etc. are subject to independent peer review according to GCMRC's peer-review protocols. Monitoring and research proposals are subjected to independent external peer- review and awards are made competitively based on these reviews. All research proposed by GCMRC program managers and scientists also undergoes an independent external review. Similarly, all PI reports and GCMRC reports are subject to independent external review. Managing GCMRC's peer-review process requires 3 to 6 person months and is the responsibility of the Librarian / Review Coordinator. The Review Coordinator reports directly to the Chief and serves to see that the peer-reviews are overseen by someone one-step removed from the program activities to ensure the objectivity of the review, as specified in the DOI peer-review guidelines.

A Cultural Resources Task Group operates to facilitate the incorporation of cultural concerns within all GCMRC program areas to assist the GCMRC in the development of a more integrated program that incorporates Native American perspectives. The Task Group consists of the GCMRC Socio-cultural Resources Program Manager, Reclamation's Regional Archaeologist, NPS managers, and Western Area Power Administration's Archaeologist, and Tribal representatives.

A Biological Opinion Task Group operates to ensure appropriate coordination between

GCMRC and the monitoring and research needs of the Bureau and USFWS under various biological opinions. The Task Group consists of the GCMRC Biological Resources Program Manager and appropriate representatives of Reclamation, FWS, AGFD and other AMWG members. All proposed activities are reviewed by the TWG.

The Information Technologies program has personnel with specific responsibility for its Systems Administration, Data Base Management, GIS, Remote Sensing, and surveying activities. These personnel assure critical timely support to managers and other stakeholders in their interactions with the GCMRC, especially in their requests for information. For example, the surveying department is staffed by two full-time surveyors and a staff assistant who provide GCMRC and PIs with high quality, cost-effective, and timely support of their program and activities in the areas of terrestrial and bathymetric surveying, as well as remote sensing. Having in-house capability ensures familiarity with the challenges of surveying in the canyon and promotes reproducible, quality data critical to sound monitoring and research programs.

As called for in the GCDEIS, independent review panels are utilized to evaluate GCMRC's Annual Plan, review proposals submitted to GCMRC for potential funding, review reports resulting from GCMRC sponsored activities, and provide advice to GCMRC and the AMWG. With respect to the SAB, GCMRC will designate a staff person to serve as the Executive Director who can provide leadership to the SAB and serve as the liaison officer to the AMWG and the GCMRC. It is anticipated that the role of Executive Director will require one to three person-months annually.

Program Schedule

The tentative schedule for implementation of the FY 2001 Monitoring and Research Plan (annual plan) is as follows:

January 20-21, 2000	AMWG review of FY 2001 Annual Plan and recommendations for implementation
March 2000	Review of FY 1999 program accomplishments
April 2000	First Progress Report due on FY 2000 program activities
April 2000	Release of RFPs
July 2000	Second Progress Report due on FY 2000 program activities

July 2000	Receipt of Proposals for FY 2001 program
August 2000	Panel Review of FY 2001 Proposals
September 2000	Notification of Intent to Award FY 2001 Contracts
September 2000	Draft Final Reports due on FY 2000 program activities
Sept./Oct. 2000	Award FY 2001 Contracts
October 2000	Develop Logistics Plan for FY 2001 program
October 2000	Draft FY 2002 Annual Plan and FY 2000 "State of the Colorado River Ecosystem Resources" report for review by TWG/AMWG
December 2000	Final "State of the Colorado River Ecosystem Resources" report to AMWG.
December 2000	Final Reports on FY 2000 programs with all contract deliverables
January 2001	AMWG review of FY 2002 Annual Plan and recommendations for implementation

Adaptive Management Program Budget

The FY 2001 budget for the Glen Canyon Dam Adaptive Management Program is $7,850,000. Of this total, $1,416,000 is programmed for the management and administration of the AMP and the PA, with the remaining $6,434,000 programmed for GCMRC and its implementation of the FY 2001 Annual Plan. In addition, $300,000 is programmed for the IWQP from Reclamation operation and maintenance funds and $310,000 is programmed for activities related to the Temperature Control Device from Reclamation Section 8 funds.

Following are the proposed budget allocations for the GCMRC FY 2001 Work Plan:

GCMRC Program and Operating Costs

AMP Funding

A. Bureau Support Services 125,000
B. Operations, Personnel, Contract Services 1,969,000
C. Physical Resources Science 950,000
D. Biological Resources Science 1,290,000
E. Socio-cultural Resources Science
   i. Science Activities 275,000

ii. PEP 55,000

iii. Public Outreach 35,000

F. Information Technologies Program 320,000

G. Remote Monitoring Technology 400,000

H. Independent Review Panels 175,000

I. Unsolicited Proposals.....120,000

J. AMWG/TWG Requests.....60,000

K. In-House Research 20,000

I. Logistics.....650,000

TOTAL 6,434,000

Other Funding Sources

O&M -- Integrated water quality program (IWQP).....300,000

Sec. 8 -- TCD Related Activities 310,000

References Cited

Gorman O.T., R.G. Bramblett 1998. Monitoring and studies of native fishes of the Colorado River ecosystem in Grand Canyon, Arizona. US Fish and Wildlife Service submitted to Grand Canyon Monitoring and Research Center, Flagstaff, AZ

Kearsley, L. H. 1994. Effects of Glen Canyon Dam on Colorado River sand deposits used as campsites in Grand Canyon National Park, USA. Regulated Rivers: Research and Management, v9, 137-149.

Kearsley, L. H., Quartaroli, R. D. and Kearsley, M. J. C. 1999. Changes in the number and size of campsites as determined by inventory and measurement in The Controlled Flood in Grand Canyon. Geophysical Monograph 110, American Geophysical Union.

Kearsley, L. H. 1994. Effects of Glen Canyon Dam on Colorado River sand deposits used as campsites in Grand Canyon National Park, USA. Regulated Rivers: Research and Management, v9, 137-149.

Kearsley, L. H., 1995. Monitoring the effects of interim flows on campsite size along the Colorado River in Grand Canyon National Park (final report). Grand Canyon National Park Division of Resource Management, National Park Service. In cooperation with USDOI Bureau of Reclamation, Glen Canyon Environmental Studies, Cooperative Agreement CA8022-8-0002.

Kearsley, L. H., Quartaroli, R. D. and Kearsley, M. J. C. 1999. Changes in the number and size of campsites as determined by inventory and measurement in The Controlled Flood in Grand Canyon. Geophysical Monograph 110, American Geophysical Union.

Leap, L. M., J. L. Kunde, D. C. Hubbard, C. E. Downum, N. B. Andrews, J. R. Balsom and A. Miller. 1999. Grand Canyon monitoring project 1992-1999: Synthesis and annual report, FY1999. River Corridor Monitoring Project No. 66, Grand Canyon National Park and Northern Arizona University. Cooperative Agreement No. CA 8210-97-002.

Leap, L. M., J. L. Kunde, D. C. Hubbard, C. E. Downum, N. B. Andrews, J. R. Balsom and A. Miller. 1999. Grand Canyon monitoring project 1992-1999: Synthesis and annual report, FY1999. River Corridor Monitoring Project No. 66, Grand Canyon National Park and Northern Arizona University. Cooperative Agreement No. CA 8210-97-002.

Melis, T.S., 1997, Geomorphology of debris flows and alluvial fans in Grand Canyon National Park and their influence on the Colorado River below Glen Canyon Dam, Arizona: Ph.D. dissertation, 490 p. University of Arizona, Tucson.

Melis, T.S., Webb, R.H., Griffiths, P.G., and Wise, T.W., 1995, Magnitude and frequency data for historic debris flows in Grand Canyon National Park and vicinity, Arizona: U.S. Geological Survey Water Resources Investigation Report 94-4214, 285 p.

Meretsky, V.J. and D. L. Wegner. 1998. Annual report on monitoring of Kanab ambersnail at Vaseys Paradise. SWCA, Environmental Consultants, Inc., submitted to Grand Canyon Monitoring and Research Center, Flagstaff, AZ.

Webb, R.H., Melis, T.S., Griffiths, P.G., and Elliott, J.G., 1999, Reworking of aggraded debris fans: *in* R.H. Webb, J.C. Schmidt, G.R. Marzolf, and R.A. Valdez (editors): The Controlled Flood in Grand Canyon, p. 37-52, American Geophysical Union Monograph 110, Washington.

APPENDIX 1

GRAND CANYON MONITORING AND RESEARCH CENTER (GCMRC)

MISSION

To provide credible, objective scientific information to the Adaptive Management Program on the effects of operating Glen Canyon Dam on the downstream resources of the Colorado River ecosystem, utilizing an ecosystem science approach.

ROLES AND RESPONSIBILITIES OF GCMRC

1. Advocate quality, objective science and the use of that science in the adaptive management decision process.
2. Provide scientific information for all resources of concern identified in the "Operation of Glen Canyon Dam Final Environmental Impact Statement."
3. Support the Secretary's designee and the Adaptive Management Work Group in a technical advisory role.
4. Develop research designs and proposals for implementing, by GCMRC and/or its contractors, monitoring and research activities in support of information needs identified by the Adaptive Management Work Group.
5. Coordinate review of the monitoring and research program with independent review panel(s).
6. Coordinate, prepare, and distribute technical reports and documentation for review and as final products.
7. Prepare and forward technical management recommendations and annual reports, as specified in Section 1804 of the Grand Canyon Protection Act to the Technical Work Group.
8. Manage all data collected as part of the Adaptive Management Program. Serve as a repository (source of information) for others (stakeholders, students, public, etc.) in various formats (paper, electronic, etc.) about the effects of operating Glen Canyon Dam on the downstream resources of the Colorado River ecosystem and the Adaptive Management Program.
9. Administer research proposals through a competitive contract process, as appropriate.
10. Manage GCMRC finances and personnel efficiently and effectively.

July 1999

APPENDIX 2

MANAGEMENT OBJECTIVES AND INFORMATION NEEDS

A. Introduction

Management objectives and information needs help to define measurable standards of desired conditions which will serve as targets expected to be achieved by the participants in the AMP. The objectives and information needs also drive the strategic planning process and they provide the basis for the formulation of the long-term monitoring research program described elsewhere in this plan.

Historical Development Of The Management Objectives And Information Needs

Using the nine resource areas in the EIS, the Upper Colorado Regional Office of the Bureau of Reclamation worked with a subgroup of the Transition Work Group to develop management objectives intended to guide the development of GCMRC monitoring and research activities. This group was disbanded with the completion of their assignment and release of their July, 1996 recommendations.

Many stakeholders that participated in the Transition Work Group now serve in the AMWG and the TWG, providing continuity for the AMP. Also in 1996, under the guidance of GCMRC, several workshops were held with scientists who had conducted research under the auspices of GCES to define information needs associated with the various management objectives.

In July 1997, AMWG requested that the TWG proceed with the evaluation and revision of Management Objectives and the prioritization of Information Needs. The revision represents a concerted effort by the stakeholders to identify objectives as desired resource conditions sought by various stakeholders, and describe information needs in a way that clarifies the required data for assisting stakeholders in determining the condition of these resources, and how conditions are affected by management actions.

Revision Process and Prioritization Planning

Starting in January 1998, an ad hoc group from the TWG met to address the Management Objectives and Information Needs. Meetings were held to discuss general procedures for the revision process and the objectives and information needs by resource area. The purpose of the meetings was to review and revise management objectives and information needs, to establish relative priorities by study type, resource class, and research/monitoring question. The group was also tasked with reporting to the TWG during the process and to present recommendations on the revised information to the AMWG for adoption. The details of the prioritization process and the revised management objectives and prioritized information needs which provide the direction for strategic planning can be found in section B of this Appendix.

The prioritized information needs will permit the GCMRC to stage the various information needs currently specified by stakeholders over years FY2000 to 2004. High priority information needs will be initiated in years FY2000 and FY2001 whereas other monitoring and research needs may be delayed for initiation until FY2002 or beyond. As a result of developing this strategic plan, it has become clear that not all of the information needs currently proposed by stakeholders can be addressed in the next 5 years. Because the information needs are so extensive, and because many relate to annual or intermittent monitoring requirements, it is anticipated that about one-third to one-half of the information needs specified will actually be completed in the 5-year planning period and much monitoring is expected to continue into an extended 10-year program.

B. Summary

Table 2.4 Summary of MOs & INs. (See June 10, 1998, Management Objectives and Information Needs document for more detail.)

Resource Category	Short Name	Mgt Obj	Info Need	O	X	Mon or Res
Ecosystem assessment	Conceptual model	MO 1:	IN 1.1	7	14	R
Aquatic foodbase	Aquatic foodbase - monitor	MO 1:	IN 1.1	10	9	M
Aquatic foodbase	Aquatic foodbase - dam FX	MO 1:	IN 1.2	10	9	R
Aquatic foodbase	Aquatic foodbase for fish	MO 1:	IN 1.3	10	10	R
Trout	Trout population dynamics	MO 2:	IN 2.1	8	9	R
Trout	Trout population trends	MO 2:	IN 2.2	5	5	M
Trout	Trout condition #1	MO 2:	IN 2.3	2	1	M
Trout	Trout spawning habitat availability	MO 2:	IN 2.4	4	4	R
Trout	Trout condition #2	MO 2:	IN 2.5	4	0	M&R
Trout	Trout maintenance RX#1	MO 2:	IN 2.6	4	3	R
Trout	Trout/foodbase trophic dynamics	MO 2:	IN 2.7	3	4	R
Native Fish	HBC population dynamics	MO 3/4:	IN 3/4.1	10	10	M&R
Native Fish	HBC recruitment	MO 3/4:	IN 3/4.2	11	8	M&R
Native Fish	HBC winter survival	MO 3/4:	IN 3/4.3	10	8	R
Native Fish	HBC intrxn with NN fish	MO 3/4:	IN 3/4.4	2	0	R&M
Native Fish	HBC habitat availability	MO 3/4:	IN 3/4.5	10	6	R
Native Fish	HBC protocol and recreation FX	MO 3/4:	IN 3/4.6	2	1	Protocol R
Native Fish	HBC trophic dynamics	MO 3/4:	IN 3/4.7	7	6	R
Native Fish	HBC YOY habitat and NNS interxs	MO 3/4:	IN 3/4.8	7	6	R
Native Fish	HBC population loss to flows	MO 3/4:	IN 3/4.9	6	5	R
Native Fish	HBC good year strategy	MO 3/4:	IN 3/4.10	4	2	Admin.
Native Fish	HBC downstream transport	MO 3/4:	IN 3/4.11	6	3	R
Native Fish	HBC flow-related take	MO 3/4:	IN 3/4.12	9	8	R
Native Fish	HBC flow criteria to limit take	MO 3/4:	IN 3/4.13	8	7	Admin.
Native Fish	Threatened fish - RPM test flows	MO 3/4:	IN 3/4.14	5	4	R
Native Fish	Native fish – mainstream thermal	MO 5:	IN 5.1	6	2	R
Native Fish	Native fish – thermal mod FX#1	MO 5:	IN 5.2	10	10	R
Native Fish	Native fish – thermal mod FX#2	MO 5:	IN 5.3	14	14	R
Native Fish	Thermal mod impacts on LP fish	MO 5:	IN 5.4	7	2	R

Native Fish	NN fish control -- temperature and	MO 5:	IN 5.5	9	9	R
Native Fish	HBC population mgt. criteria	MO 6:	IN 6.1	9	8	R
Native Fish	HBC 2nd pop. Feasibility study	MO 6:	IN 6.2	9	7	R
Native Fish	RBS 2nd pop. Feasibility study	MO 7:	IN 7.1	7	5	R
Native Fish	Native fish pop. Status	MO 8:	IN 8.1	9	8	M
Native Fish	Native fish pop. Dynamics#1	MO 8:	IN 8.2	7	4	M
Native Fish	Native fish historic pop. dynamics #1	MO 8:	IN 8.3	3	1	M&R
Native Fish	Native fish historic pop. dynamics#2	MO 8:	IN 8.4	5	2	M&R
Native Fish	Native fish flow regime FX	MO 8:	IN 8.5	7	4	R
Native Fish	Native fish maintenance criteria	MO 8:	IN 8.6	7	4	R
Native Fish	Native fish experimental flows design	MO 9:	IN 9.1	3	2	R
Native Fish	Native fish experimental flows design	MO 9:	IN 9.2	5	1	R
Native Fish	Native fish trib flows and recruitment	MO 9:	IN 9.3	7	3	M&R
Native Fish	Native - NN fish nearshore intrxns	MO 9:	IN 9.4	6	1	R
Native Fish	Native/NN fish intrxns #1	MO 10:	IN 10.1	6	5	R
Native Fish	Native/NN fish intrxns #2	MO 10:	IN 10.2	4	3	R
Native Fish	Native/NN fish mitigation intrxns	MO 10:	IN 10.3	3	3	R
Native Fish	NN fish distrib. And natural history	MO 10:	IN 10.4	5	2	M
Native Fish	Native/NN fish intrxns #3	MO 10:	IN 10.5	6	2	R
Native Fish	Native and NN fish autecology	MO 10:	IN 10.6	6	2	M&R
Riparian	Autecology of riparian species	MO 11:	IN 11.1	9	9	M&R
Riparian	Riparian population variability	MO 11:	IN 11.2	4	6	M&R
Riparian	Riparian SOC population changes	MO 11:	IN 11.3	2	4	M&R
Riparian	Riparian species habitat distribution	MO 11:	IN 11.4	5	7	M&R
Riparian	Riparian habitat map	MO 11:	IN 11.5	5	4	R
Riparian	Monitor leopard frogs	MO 11:	IN 11.6	6	8	R
Riparian	Feasibility of 2nd leopard frog	MO 11:	IN 11.7	1	1	Admin.
Riparian	Evaluate amphibian sensitivity	MO 11:	IN 11.8	2	3	R
Riparian	Riparian spp – dam FX on	MO 12:	IN 12.1	6	8	R
Riparian	Riparian spp – ranges	MO 12:	IN 12.2	1	1	R
Riparian	Riparian spp – age classes	MO 12:	IN 12.3	0	0	R
Riparian	Riparian spp – dam FX on	MO 12:	IN 12.4	2	2	R
Riparian	Riparian spp – general dam FX	MO 12:	IN 12.5	1	1	R&M
Riparian	Riparian food webs: SOC	MO 13:	IN 13.1	7	7	R&M
Riparian	Riparian food webs: birds	MO 13:	IN 13.2	6	8	R
Riparian	Pefa - aerie distribution	MO 13:	IN 13.3	1	1	R&M
Riparian	Pefa - population dynamics	MO 13:	IN 13.4	2	2	R
Riparian	Bald eagle - dam FX	MO 13:	IN 13.5	3	3	R&M
Riparian	KAS - habitat RX #1	MO 14:	IN 14.1	9	8	M
Riparian	KAS - special flow impacts	MO 14:	IN 14.2	7	7	R&M
Riparian	KAS - habitat RX #2	MO 14:	IN 14.3	8	8	R&M
Riparian	KAS - monitor exceptional flow	MO 14:	IN 14.4	7	7	M
Riparian	KAS - life history schedule	MO 14:	IN 14.5	7	7	R&M
Riparian	KAS - monitor #1	MO 14:	IN 14.6	11	10	R&M
Riparian	KAS - monitor #2	MO 14:	IN 14.7	5	6	M
Riparian	KAS - genetic relationships	MO 15:	IN 15.1	7	5	R
Riparian	KAS - habitat propagation	MO 15:	IN 15.2	6	4	R
Riparian	Riparian veg – distribution: all #1	MO 16:	IN 16.1	5	6	M

Riparian	Riparian veg – distribution: OHW	MO 16:	IN 16.2	4	5	R&M
Riparian	Riparian veg – maintain and restore	MO 16:	IN 16.3	0	0	M
Riparian	Riparian veg – dam FX	MO 16:	IN 16.4	4	4	R&M
Riparian	Riparian veg - life histories	MO 16:	IN 16.5	2	2	R
Riparian	Riparian veg – NNS and dam FX	MO 16:	IN 16.6	4	5	R&M
Cultural	Cultural sites – monitor	MO 1:	IN 1.1	12	13	M
Cultural	Cultural sites – risk assessment	MO 1:	IN 1.2	6	4	R
Cultural	Cultural sites – info needs	MO 1:	IN 1.3	7	7	Admin.
Cultural	Cultural sites – monitor risk	MO 1:	IN 1.4	6	5	R&M
Cultural	Cultural sites – preserve terraces #1	MO 1:	IN 1.5	5	2	M
Cultural	Cultural sites – preserve terraces #2	MO 1:	IN 1.6	6	2	R&M
Cultural	Cultural sites & recreation FX	MO 1:	IN 1.7	1	0	R
Cultural	Cultural sites – mitigation strategies	MO 2:	IN 2.1	9	9	Admin.
Cultural	Cultural sites – data recovery	MO 2:	IN 2.2	5	2	Admin.
Cultural	Cultural sites – characterize dam FX	MO 3:	IN 3.1	9	6	R
Cultural	Cultural site data management	MO 4:	IN 4.1	7	5	Admin.
Socioeconomic	Socioeconomics - monitor hydropower	MO 1:	IN 1.1			M
Socioeconomic	Socioeconomics - costs of ROD	MO 1:	IN 1.2			M
Socioeconomic	Socioeconomics - research costs	MO 1:	IN 1.3			M
Socioeconomic	Socioeconomics - integrated systems	MO 1:	IN 1.4			Admin.
Water	Flow - monitor releases	MO 1:	IN 1.1			M
Water	Flow - monitor WQ and dam FX on	MO 2:	IN 2.1	9	9	M
Water	Flow - thermal modification	MO 2:	IN 2.2	6	6	R&M
Sediment	Sediment – historic distribution & flow	MO 1:	IN 1.1	5	7	R&M
Sediment	Sediment – minimum storage for	MO 1:	IN 1.2	9	11	R
Sediment	Sediment – monitor flow FX by reach	MO 1:	IN 1.3	7	10	R
Sediment	Sediment - monitor inputs: all	MO 1:	IN 1.4	8	10	R&M
Sediment	Sediment – GCNRA bar distribution,	MO 1:	IN 1.5	5	6	R&M
Sediment	Sediment - bar & backwater	MO 2:	IN 2.1	1	1	M
Sediment	Sediment – establish baselines	MO 2:	IN 2.2	3	2	Admin.
Sediment	Sediment – monitor sand bar	MO 2:	IN 2.3	3	5	R&M
Sediment	Cultural - monitor terraces	MO 2:	IN 2.4	2	3	M
Sediment	Sediment - bar & backwater	MO 2:	IN 2.5	3	3	R&M
Sediment	Sediment - bar, backwater and camp	MO 2:	IN 2.6	6	8	R&M
Sediment	Sediment - bar & backwater	MO 2:	IN 2.7	2	5	R
Sediment	Flow - spillway impacts on bed and	MO 2:	IN 2.8	1	1	R&M
Sediment	Backwater distribution: '90-91, 96-97	MO 3:	IN 3.1	4	3	R
Sediment	Backwater distribution: '90-91, 96-97	MO 3:	IN 3.2	3	2	R
Sediment	Sediment - bar & backwater	MO 3:	IN 3.3	3	4	R&M
Sediment	Sediment – linkage to biota	MO 3:	IN 3.4	7	8	R
Sediment	Backwater distribution: '90-91, 96-97	MO 3:	IN 3.5	2	3	R
Sediment	Backwater distribution: '90-91, 96-97	MO 4:	IN 4.1	6	6	R&M
Sediment	Sediment - model dam FX on bars,	MO 4:	IN 4.2	4	6	Admin.
Sediment	Sediment – assess dam FX on bars,	MO 4:	IN 4.3	5	5	Admin.
Sediment	Sediment - monitor inputs: Marble	MO 4:	IN NH1.	3	3	R&M
Sediment	Sediment – GCNRA high terrace	MO 4:	IN NH2.	1	1	R
Sediment	Sediment - monitor inputs: GCNRA	MO 4:	IN NH3.	2	2	R
Sediment	Sediment – GCNRA high terrace	MO 4:	IN NH4.	2	1	R&M

Sediment	Sediment – GCNRA bed morphology	MO 4:	IN NH5.	2	4	R
Sediment	Sediment – GCNRA grain size	MO 4:	IN NH6.	1	1	R
Sediment	Sediment – historic distribution & flow	MO 4:	IN NH7.	0	2	R&M
Sediment	Sediment – historic distribution & flow	MO 4:	IN NH8.	2	3	R&M
GIS	GIS - map topography, geology, soils	MO 1:	IN 1.1	1	1	R
GIS	GIS - data archival and storage	MO 1:	IN 1.2	0	2	Admin.
Recreation	Recreation – experience	MO 1:	IN 1.1	4	9	R&M
Recreation	Recreation – monitoring and research	MO 1:	IN 1.2	2	5	R
Recreation	Recreation – mitigate negative flow FX	MO 1:	IN 1.3	4	10	Admin.
Recreation	Recreation – angler satisfaction, use	MO 1:	IN 1.4	2	3	R&M
Recreation	Water - heavy metal impacts on fish	MO 1:	IN 1.5	0	0	R
Recreation	Recreation – camp	MO 2:	IN 2.1	1	10	R&M
Recreation	Recreation - dam FX on camp	MO 2:	IN 2.2	6	8	Admin.
Recreation	Recreation – develop campsite	MO 2:	IN 2.3	1	3	Admin.
Recreation	Recreation – model flow FX on	MO 2:	IN 2.4	2	2	R
Recreation	Recreation safety - boating: GCNRA	MO 3:	IN 3.1	1	3	R&M
Recreation	Recreation safety - boating: all	MO 3:	IN 3.2	3	3	R&M
Recreation	Recreation safety - boating: Grand	MO 3:	IN 3.3	2	1	R&M
Recreation	Ecosystem Assessment - FX of flows	MO 3:	IN 3.4	1	0	Admin.
Recreation	Recreation – Resource conflicts with	MO 3:	IN 3.5	2	1	Admin.
Recreation	Trout - flows RX for 100k trout	MO 4:	IN 4.1	2	7	R
Recreation	Waterfowl – hunter use, satisfaction,	MO 5:	IN 5.1	1	2	R
Lake Powell	Water - Lake Powell WQ	MO 1:	IN 1.1	10	14	R&M
Lake Powell	Water - dam FX on Lake Powell WQ	MO 1:	IN 1.1 (Biol)	5	12	R
Lake Powell	Water - Lake Powell, selenium	MO 1:	IN 1.2	1	0	R
Lake Powell	Water - water temperature impacts in	MO 2:	IN 2.1	1	9	R
Lake Powell	Lake Powell - dam FX on surface flux	MO 2:	IN 2.2	0	1	R&M
Lake Powell	Water - Lake Powell, selenium	MO 2:	IN 2.3	0	0	R
Lake Powell	Lake Powell – dam FX on advective	MO 2:	IN 2.4	0	1	R&M
Lake Powell	Lake Powell - fish: dam FX on pred-	MO 2:	IN 2.5	1	1	R
Lake Powell	Lake Powell - fish: dam FX on	MO 2:	IN 2.6	1	5	R
Aquatic foodbase	Fisheries – habitat distribution:	MO 1:	IN 1.7	1	3	R
Aquatic foodbase	GIS - aquatic habitat map by stage	MO 1:	IN 1.8	1	1	R
Aquatic foodbase	Fisheries - dam FX on habitat	MO 1:	IN 1.9	2	4	R
Aquatic foodbase	Aquatic foodbase - exposure FX	MO 1:	IN 1.10	2	3	R
Aquatic foodbase	Aquatic foodbase - dam FX on	MO 1:	IN 1.11	0	0	R
Aquatic foodbase	Water - selenium impacts on	MO 1:	IN 1.12	1	0	R
Native fish	FMS spawning hab. distrib. #1:	MO 8:	IN 1. (App.)	3	1	R&M
Native fish	FMS adult origins	MO 8:	IN 2. (App.)	2	2	R&M
Native fish	FMS spawning hab. distrib. #2: Glen	MO 8:	IN 3. (App.)	3	1	R&M
Native fish	FMS mechanisms of spawning failure	MO 8:	IN 4. (App.)	2	1	R
Native fish	Native fish - FMS dam FX on	MO 8:	IN 5. (App.)	3	2	R
Native fish	Native fish – spawning and trib.	MO 8:	IN 6. (App.)	2	1	R&M
Native fish	Aquatic foodbase - dam FX on	MO 8:	IN 7. (App.)	0	0	R&M
Native fish	Native fish - FMS habitat RX	MO 8:	IN 8. (App.)	1	0	R
Native fish	Native fish - FMS spawning hab.	MO 8:	IN 9. (App.)	1	0	R&M
Native fish	Native fish - MS spawning hab. distrib.	MO 8:	IN 10.	0	0	R&M
Native fish	Native fish - FMS population model	MO 8:	IN 11.	2	1	R

Native fish	Native fish - FMS habitat modification	MO 8:	IN 12.	1	0	Admin.
Native fish	Native/NN fish intrxns #4	MO 8:	IN 13.	2	0	R
Native fish	Water - selenium FX on native fish	MO 8:	IN 14.	0	0	R

APPENDIX 3

DRAFT PROSPECTUS FOR EVALUATING GCMRC MONITORING PROTOCOLS FOR THE COLORADO RIVER ECOSYSTEM

GCMRC-PEP Planning Team: T. Melis, Physical Scientist, M. Liszewski, Information Technologies Director, B. Gold, Biological Program, L. Stevens, Field Ecologist, F.M. Gonzales, Lead Surveyor/Hydrographer, R. Lambert, Cultural Program, L.D. Garrett, GCMRC Chief, W. Vernieu, Hydrologist, B. Ralston, Biologist/Review Coordinator

Part I. Proposed Strategy and Time Line for GCMRC Protocols Evaluation Program (PEP)

Following four planning meetings between the GCMRC's Chief, Physical Scientist, Information Technologies Director, Lead Surveyor/Hydrographer, and other staff, the following prospectus for the GCMRC protocols evaluation program (PEP), was drafted. The proposed strategy for implementation of the PEP is a staggered, multi-stage effort that investigates new technologies, as well as existing and past protocols used to monitor Colorado River Ecosystem (CRE). The geographical scope of the CRE covers a distance of 291 river miles (-15 to 276) between the forebay of Lake Powell and the western-most boundary of Grand Canyon National Park.

The monitoring protocols evaluated will include: 1) those related to physical resources, including tributary and mainstem sediment input, storage and transport; 2) streamflow and water quality below GCD to river mile 276; water quality in Lake Powell; biological resources, both aquatic and terrestrial; cultural resources in all categories; and a variety of remote sensing technologies (ground-based, airborne and hydrographic) appropriate for addressing stakeholder information needs in all of the above-mentioned areas.

The main goal of the PEP is to identify an optimal design for an efficient and effective long-term monitoring program for the CRE, to be implemented by the GCMRC. A highly effective long-term monitoring program is required to provide Glen Canyon Dam Adaptive Management Workgroup (and Technical Workgroup) members (stakeholders) with information needed to make recommendations to the Secretary of Interior (or designee) on management-action decisions and impacts of GCD operations under the existing Record of Decision (ROD)-imposed dam operations, initiated in December 1996. Although the PEP strategy will be generally followed regardless of individual protocol differences, the process will likely be tailored to meet program objectives of each resource area.

Individual resource-area PEP objectives will be accomplished through a multi-step process over two to three years in which systematic articulation, scoping, review and testing/evaluation efforts will identify the most effective and feasible methods of measuring CRE resource attributes and their long-term responses to GCD operations under the ROD. Following these steps, the most effective monitoring approaches will be identified and PEP results will be reported to the stakeholders. After final consultation with the Science Advisory Board (SAB) and the Technical Workgroup, GCMRC program managers and the Chief will implement changes to the long-term monitoring program as indicated by need, and allowed by cost and other considerations.

The proposed time line over which these evaluations will take place and be implemented in the GCMRC monitoring program is estimated to be Fiscal Year (FY) 1998 through FY02. Following the initial PEP, additional evaluations may need to occur as new information needs arise, new knowledge is gained, and as new techniques/technologies become available for monitoring riverine ecosystems. The PEP planning team also believes that a periodic review of the overall GCMRC monitoring program should be reviewed and evaluated at about five-year intervals to identify areas where improvements or small changes in focus are needed. Finally, the need for consistency in monitoring data sets for purposes of comparability is recognized as important as decisions to alter protocols are made by the GCMRC. The systematic nature of the PEP process will guarantee that paired tests leading up to changes in long-term monitoring are conducted in such a way as to ensure that data from past studies are comparable to future efforts.

PART II. Key Components of the PEP

In drafting this prospectus for the PEP, the GCMRC planning team considered the following issues to be important:

A) **Articulate Management Objectives/Information Needs, and Current Protocols** - Just as it is critical to identify details of new and existing monitoring protocols, it is also critical for PEP participants (external and internal) to have a clear and detailed understanding of present stakeholder-derived management objectives and information needs. Originally drafted in 1995 by the Glen Canyon Transition Workgroup, CRE management objectives were reviewed and revised by a sub-group of the Technical Workgroup, and the GCMRC Chief and his staff during a series of five scoping meetings in spring 1998. Information needs were originally stepped down from the draft objectives during summer 1996, and were reviewed and modified as needed in 1998. Information needs derived from the management objectives are the basis for procurement of CRE science activities by the GCMRC through its competitive RFP process.

In addition to describing information needs and objectives, past and presently used monitoring protocols need to be clearly articulated on the basis of existing literature and discussions with present/former project chiefs and PIs who conducted monitoring and research during phases I and II of the Glen Canyon Environmental Studies (GCES, 1983 through 1996). Information on existing protocols, including methods sections of reports and articles that describe various uses in the CRE or other rivers, must be reviewed and made available to external review panels and scoping workshop participants in advance of all PEP workshops/meetings. This information will be collected, compiled and distributed by program managers during the scoping phase of the PEP as they lead each of the individual protocol evaluations. Although the PEP will eventually address monitoring needs in all program areas, initial workshops held during the FY98 phase of the PEP will focus on the effectiveness of ground-based and airborne remote-technology sensing (GARST), and previously used protocols associated with physical resources, such as those used to monitor sediment transport and sand bar changes.

Outside experts, identified through GCMRC scoping activities, will also be invited to participate in review-oriented workshops. The GCMRC will solicit participation from experts qualified to provide external critical review of the PEP process, as well as those who may offer information and demonstrations on new technologies and methods from both private and public sectors.

B) **Define the Range of Optional Alternatives Under Existing Technologies** - Alternatives to existing protocols will be identified by in-depth GCMRC scoping of monitoring techniques that are presently used in other long-term programs for river ecosystems. Methodologies will also be considered that are presently used in monitoring of other ecosystems (i.e. near coastal marine settings, forests, etc.) where the protocols might be adapted to a large river, or technologies/methods that are still in developmental stages, but intended for large rivers.

The PEP scoping process is intended to be wide-ranging, and will glean information from multiple sources such as, reports, journal articles, professional presentations, displays at professional meetings. Attending national meetings frequented by ecosystem-monitoring experts, and conferences that attract technological innovators by GCMRC staff is encouraged as a means of conducting pre-workshop scoping activities. To increase the effectiveness of the PEP, the limitations and capabilities of new technologies of interest must be screened against information needs by the GCMRC/PEP planning team in advance of the first workshop. New technologies that hold great promise, but are mis-matched with stakeholder/GCMRC information needs should be easily identified. In cases where innovation has led to new approaches not been recognized by stakeholders, the PEP can act to update managers on areas where new information could be easily obtained. This will hopefully eliminate consideration of inappropriate new protocols early in the process. Agencies and private-sector firms identified through the scoping process will be invited to the workshop(s) for demonstration and discussions of new methods and technologies.

Regardless of the diversity of monitoring approaches considered, other topics such as replication, sampling interval and spatial distribution for a long-term monitoring program also need to be evaluated by CRE-resource category. For instance, during FY98, external review panels will also assist the GCMRC-PEP in reviewing and identifying ideal sampling strategies for existing efforts such as channel-storage changes, monitoring channel-bed grain-size evolution and bed coverage through time (SEDS), Lake Powell water quality monitoring (WETS), and for GARST. Information from recent high-flow experiments suggests that monitoring data on grain-size evolution of channel-stored sediment may significantly influence management decision making, but has not previously been a component of physical-resource monitoring.

The PEP process also recognizes that new information gained from experiments, such as controlled high releases from GCD, as well as evolving information needs, will likely drive additional new needs for monitoring methods of the CRE through time. Therefore, although the PEP may have formal start and end dates, the GCMRC mission will require program managers, stakeholders and the SAB to revisit the long-term monitoring strategy

(including individual protocols) on a periodic basis; perhaps as a five-year review.

C) **Evaluation/Selection of Protocols to be Implemented** - The PEP aims to identify which of the past, currently used or new, but untested protocols best meet the objectives of what a long-term monitoring program should accomplish for any ecosystem management program. Second, the program aims to design a river-monitoring program with protocols capable of assessing long-term ecosystem trends, as well as be able to document the impacts of discreet events, such as high-flows from GCD. Protocols must also be able to provide information to stakeholders in a timely manner useful for supporting the adaptive management process (recommendations to the Secretary of Interior). The selected protocols also must work within the unique settings of the CRE, be minimally intrusive to the environment, demonstrate cost effectiveness, stand as scientifically defendable, provide suitable accuracy/precision (depending on level of information need), and be highly repeatable and reproducible regardless of changes in contractors over time. Most importantly, the selected approaches must directly address the management objective-derived stakeholder information needs.

Where existing data occur in the databases of the GCMRC or its former/present cooperators, initial evaluations will be undertaken internally by staff members and scientists already involved in monitoring under existing agreements [Phase I]. However, existing data sets that may foster comparative assessment will only be analyzed after the articulation and scoping steps have been accomplished. In cases such as the FY98 evaluation of the SEDS, WETS and GARST, existing interagency and cooperative agreements will be modified during FY98-99 to enlist help in conducting paired test evaluations with collaborating scientists.

Any assessments conducted on existing data will be subjected to internal and external review and will be presented and discussed during initial workshop(s) held by GCMRC during spring/summer 1998, and beyond for other resource categories. The PEP external review panel(s) will be invited to attend the scoping workshop(s), and its members will be comprised of experts derived from the GCMRC list of reviewers established by discipline during the scoping phases. Membership will be determined competitively on the basis of expertise (initially, physical and remote sensing technologies), and on willingness and availability to participate in the scheduled time line of the PEP.

Following the articulation/scoping steps (phase I), committed PEP review panel members (3-5 persons per phase/program area) will be paid a stipend and travel for attending workshop(s), and will be required to provide individual and group reports on protocols evaluated, presentations/reports on assessments of existing data, results of field testing (phase II), and critical review of trial implementations (phase III). A key component of each report will consist of recommendations to the GCMRC Chief and the SAB on what changes in monitoring protocols are warranted. The results of each PEP evaluation will be reviewed by the SAB and comments will be forwarded to the GCMRC Chief for consideration before new or modified monitoring procedures are implemented by program managers through a competitive RFP-driven process.

For any given resource-program area, there will likely be at least three workshops held (minimum of one per year) throughout the PEP process. Although FY98 will be devoted mostly to scoping and evaluation of protocols relating to the GARST, WETS and SEDS, the PEP planning team intends that all protocols in all program areas be evaluated over a staggered schedule lasting 3-4 years [FY98 through FY02], as follows:

Part III. Proposed PEP Schedule

A) **General Schedule and Timing for PEP** - The GCMRC proposes that the PEP be staggered over three-four years, and fully realizes that the PEP process will and should vary somewhat in approach by individual resource-program areas. The basic approach will remain the same, but individual steps will likely vary based on each program manager's needs, budget constraints, etc. The PEP process begins in FY98 with articulation/scoping for GARST (headed by Ted Melis and Mike Liszewski, GCMRC's Physical Scientist, and Information Technologies Director, respectively), and protocols aimed at long-term monitoring of physical resources (SEDS and WETS, headed by Ted Melis and Dave Garrett, GCMRC's Physical Scientist and Chief, respectively).

The time line for preliminary reports on GARST, SEDS and WETS is September 1998 (see attachment 1 for a more detailed work plan and time line). Information gained from the initial phase of the process may be used in two ways: 1) where analyses of existing data have been suitable for comparison, and results/conclusions have been derived, the results will be externally reviewed in detail; 2) where scoping information has led to questions about the appropriateness of one protocol over another, but no existing data are available for analyses, the information will be used to develop RFP(s) intended to have specific protocols field tested and evaluated as

competitive research effort(s) in FY99 and beyond.

B) **Proposed Tasks and Timing for PEP - By Resource-Program Area -**

A) [FY98-99] A combined internal/external definition/scoping period, including initial peer review workshop(s) to evaluate past, present and possible new protocols that are relevant to stakeholder information needs; with the goal of review workshops being to identify one or more appropriate alternate protocols for field testing.

B) [FY99-2000] Field testing of the most effective and promising alternate protocol(s) through internal and external competitive research efforts.

C) [FY2000-2001] Trial implementation of the most promising alternative protocol(s), identified from field testing, evaluation and external review, through competitive RFPs.

D) [FY2000-2002] External review panel evaluation of monitoring information derived from the protocol(s) deemed most appropriate.

E) [FY2001-2002] Final selection of most-appropriate protocol(s) for incorporation into long-term monitoring program.

C) **Procedures for Accomplishing Tasks** - Scoping workshops and external review panels will be organized through the GCMRC by the PEP planning team and assistance from the GCMRC review coordinator (Dr. Barbara Ralston), beginning in spring/summer 1998. Resource areas and formerly/presently used physical/remote sensing protocols that have generated existing data sets will be compared as outlined above. Preliminary results of internal assessments will be presented at workshops, Technical Workgroup meetings, and will be reviewed and discussed at the GCMRC-sponsored workshops (see Attachment 1.).

Part IV. Proposed Time Lines for Individual Resource-Program Areas

Physical Resources and Remote Sensing - FY98-99 - *Scoping* [FY98] and *Field Testing Pilot Studies* [FY99],
FY2000 and Beyond - *Implementation* in GCMRC Monitoring Program through competitive RFP process;
Biological and Cultural Resources - FY99-2000 - *Scoping* [FY99] and *Field Testing Pilot Studies* [FY2000],
FY2001 and Beyond - *Implementation* in GCMRC Monitoring Program through competitive RFP process.

Evaluating Present and Alternative Airborne Remote-Sensing Technologies (GARST)
[Photography and Videography]

INTRODUCTION:

The GCMRC presently uses standard aerial photography/photogrammetry and color video for river corridor overflights. The following is a draft outline of tasks, responsibilities, deadlines, and budget information associated with the PEP pilot study; a process for ground-based and aerial photography/videography, termed here as Ground-Based and Airborne Remote-Sensing Technology (GARST), data collection protocols during FY98-99. This effort is intended to: 1) evaluate current aerial photography and videography protocols, 2) evaluate alternative airborne remote-sensing technologies, 3) propose an appropriate comparison of any new protocol with the existing protocols to evaluate the old vs. the new, and to ensure there is no discontinuity in the data set as a result of changing protocols, and 4) test the protocol evaluation process discussed above.

PLANNING PHASE:

Task I. Describe Current GARST Protocols Used by GCMRC to Monitor the Colorado River Ecosystem

Task I.a. (Mike Liszewski.) - Define the former and present remote-sensing protocols in terms of timing, scale, format, constant low-stage, method of deployment, etc.

Task I.b. (Program Managers and Staff) - Describe and define the types of data required and desired to address the present monitoring information needs set down by stakeholders (R. Lambert for cultural, B. Gold, L. Stevens, B. Ralston and -M. Yard for biological, T. Melis for physical, D. Garrett, W. Vernieu and S. Hueftle for Lake Powell, M. Liszewski for information technologies). A few examples of general needs might include: sandbar and sediment-related features, terrestrial vegetation (including chlorophyll-A), cultural site erosional/depositional changes. In describing the data requirements, the program managers and staff must address scale/resolution, as well as acceptable levels of error (precision/accuracy) associated with remote-sensed data.

Task I.c. (Program Managers and Staff) - Provide Mike L. with detailed information on: 1) how past airborne-collected data have or are presently being used? 2) What is being done with the data presently to achieve information needs defined by stakeholders? 3) Do the present protocols effectively provide data needed to answer information needs?
Due Date for Tasks I.a-c: March 6, 1998 - ACHIEVED

[NOTE: Several potentially interesting conferences happen to coincide with the initial phase of the PEP with respect to physical/remote sensing topics, such as the ASCE Wetlands Conference in late March 1998 [Denver, CO]; a national meeting sponsored by the USGS-WRD to present new technologies for measuring sediment in rivers in February in St. Petersburg, FL will also provide information on new technologies. Another conference on new technologies and developments in remote-sensing will be convened in late March, 1998 [Tampa, FL] that may also potentially provide new information and contacts on CRE resource monitoring approaches.]

Task II. Identify Expert Review Panel and Alternative Protocols to be Evaluated

Task II.a. (Program Managers) - Develop list of names of potential expert review panel members, review list and identify individuals to be invited to sit on the expert review panel (plus alternates), and invite individuals to join the expert review panel.

Task II.b. (Mike L. and Ted M.) - Identify alternative GARST protocols that may be evaluated by the expert review panel and subsequently recommended for evaluation through potential paired comparisons (e.g., field testing during the anticipated 1998 Labor Day overflight) or other means.

The following are approaches that the GCMRC (headed by Mike L. and Ted M.) will utilize to scope appropriate expertise and alternative technologies: 1) telephone and face-to-face interviews with program managers and research-group leaders from major agencies that work with remote sensing technologies and databases; especially those who focus on river, lake or near coastal ecosystems; 2) literature review, 3) attendance of the national remote-

sensing conference set for Tampa, FL in late March; 4) internal scoping and discussions with survey personnel (Gonzales and others) who have already identified interesting new remote-sensing technologies.
Due Date for Tasks II.a-b: April 10, 1998 - ACHEIVED

[NOTE: In future PEP efforts, the GCMRC would involve the Science Advisory Board (SAB) in the scoping process, as well as in external review panel meetings and workshops to the greatest extent possible. At the very least, the SAB should be involved in the scoping process and asked to review the decisions to conduct paired field tests, as well as final decisions on changes in protocols for implementation in the long-term monitoring program.]

FIRST REVIEW PHASE:

Task III. Convene GARST Expert Review Panel for Critical Evaluation of Existing and Potentially Useful Protocols - COMPLETED

Task III.a. (Mike L. and Ted M.) - The external review panel for GARST will be convened May 26-28, 1998. Mike L. and Ted M. will organize the meeting in Flagstaff, AZ at the USGS, Building 3 conference room. Expert review panel members will be supplied with information developed from Task I (above), and any alternative protocols identified from Task II (above).

Reviewers will have at least three weeks to prepare for the meeting (their ability to work within this time window will be one additional requirement for their selection).
Due Date for Task III.a: COMPLETED

Task III.b. (Mike L. and Ted M.) - At the review panel meeting, the panel will be introduced to the PEP process in general (Ted M. and Dave G.). This will be followed by a brief presentation on the existing protocols and data requirements. Discussions as to the appropriateness of the former/existing protocols for meeting presently defined information needs, as well as evaluation of alternatives identified by the GCMRC will be held. In addition, the reviewers will be asked to provide their own recommendations on other alternatives that may not have been identified through the GCMRC scoping process. Hopefully, through this combined process, the GCMRC will identify all of the appropriate GARST options for consideration and possible testing.
Due Date for Task III.b: May 28, 1998 - COMPLETED

Task III.c. (Expert Review Panel) - The expert review panel will be asked to provide the GCMRC will individual summary reports, and a group report on their evaluations of the protocols discussed during the meeting, and their recommendation(s), if any, on other GARST protocols should be considered for paired field testing during the Labor Day 1998 aerial overflight. On the basis of their report(s), the GCMRC (Mike L.) will implement the annual overflight and possibly a paired test, pending available funding ability to procure any alternatives that might be identified for a test comparison.
Due Date for Task III.c: COMPLETED

[NOTE: Whatever evaluation approach is recommended, the selection and implementation of a new protocol for airborne remote sensing must be implemented in such a manner as not to yield a discontinuity in data collection.]

PROCUREMENT PHASE:

Task IV. Labor Day 1998 Overflight (with Possible Paired or Triple Field Testing)

Task IV.a. (Mike L.) - The GCMRC Information Technologies Director will have all of summer 1998 to procure the standard overflight for Labor Day still photography and videography, and any additional protocols that were identified through the scoping and review panel process for paired field testing. The present contractual agreement for aerial photography may be used to procure additional protocols for testing during the overflight, depending on the contractor's willingness and ability to provide them directly or subcontract for them through another party within the designated time frame. Standard videography may be conducted by the Bureau of Reclamation with permitted helicopter deployment, and additional videography formats may also be used for testing purposes using existing cooperative and interagency agreements.
Due Date for Task IV.a: August 31, 1998

Task IV.b. (Mike L. and GCMRC's Contractor(s)) - Over the Labor Day weekend airborne remotely

sensed data will be collected. The processed data will be delivered to the GCMRC Information Technologies Director no later than mid-October 1998.
Due Date for Task IV.b: October 15, 1998

EVALUATION PHASE:

Task V. Paired-Test Evaluation by GCMRC, Cooperator(s), and Expert Review Panel

Contingency Task V.a. (Cooperator/Contractor procured through competitive RFP process) - In the event that comparitive testing is recommended by the expert review panel (May meeting), and and that alternative data sets are obtained from protocols other than standard aerial photography over Labor Day '98 overflight, then the GCMRC Information Technologies Director may decide to procure assessment(s) of the data from outside sources. If the RFP was released in summer 1998, then it is assumed that the performance period of the assessment would be at least one year, beginning October 1, 1998. Under this schedule, the draft report on the assessment would likely be due on August 15, 1999 and the final report would be completed on or before September 30, 1999.
Draft Report Due on August 15, 1999

SECOND REVIEW PHASE:

Task V.b. (Expert Review Panel and GCMRC) - The results of the paired test (databases) would be evaluated by the reviewers and the GCMRC staff at a second review panel meeting held in the fall of 1999 (date is dependent on how soon the data and evaluation are available). On the basis of this second review, the GCMRC would prepare a draft report on the PEP process, results of testing, and review results for distribution and comment by the Technical Workgroup in late summer 1999.
Due Date for Task V.b: October 1, 1999

DECISION-MAKING AND IMPLEMENTATION PHASE:

Task V.c. (Dave G.) - On the basis of review and comment by GCMRC staff, the SAB and the TWG, a decision would be made by the GCMRC Chief as to whether additional scoping, review and testing is required, or whether a protocol change(s) is warranted for implementation in to the GCMRC long-term monitoring program beginning in FY99 and beyond.

The following is an outline of the proposed time line, tasks, and estimated budget to conduct the GARST evaluation during FY98-99.

BUDGET AND TIMELINE, PEP-I:

Section VI. GARST - Time Line, Budget, and Assignments

A - Articulation:	2/1/98 through 3/6/98	Mike L. and Staff	COMPLETED
B - Scoping:	3/7/98 through 4/10/98	Mark G. + Ted M.	COMPLETED
C - External Review:	4/15/98 through 5/25/98	Mike L. + Ted M.	COMPLETED
D - First Meeting:	5/26 through 5/28/98	Mike L. + Ted M.	COMPLETED
E - Procurement:	6/16/98 through 9/3/98	Mike L.	COMPLETED
F - L.D. Overflight:	9/5/98 through 9/7/98	Mike L.	COMPLETED
***G - Data Processing:	9/9/98 through 10/15/98	Contractor(s)	TBA

NOTE ON ITEM G: [The period required to process and evaluate the data collected during the Labor Day '98 overflight will depend on the recommendations of the Expert Review Panel convened at the May 26-28,1997 meeting in Flagstaff, AZ. The minimum requirement for time and assessment by GCMRC could be 4-6 weeks (conventional photography versus digital imagery. This time period could be extended to as much as a year in the event that completely new GARST protocols are flown that generate significantly new and different data sets from those previously captured. HENCE THE REMAINDER OF THE TIMELINE ONLY APPLIES TO THE FIRST CASE, NOT THE LATTER.]

H - External Review:	6/15/99 through 7/15/99	Mike L. + Ted M.	TBA
I - Second Meeting:	Late July 1999	Mike L. + Ted M.	TBA
J - SAB Review:	August 1999	Mike L.	TBA
K - Draft Report:	8/15/99	Mike L.	TBA

***LABOR DAY 1999 AERIAL OVERFLIGHT [At minimum, standard aerial photography will be procurred]

L - Draft to TWG:	9/1/99, Discuss at Sept. TWG	Mike L.	TBA
M - Draft to AMWG:	October 1999	Mike L.	TBA
N - Present to AMWG	January 2000 Meeting	Dave G. + Mike L.	TBA
O - Chief's Decision:	Spring 2000	Dave G.	TBA
P - Implement Change(s):	Labor Day 2000	Mike L.	TBA

End GARST Component of PEP Assessments

OR,

Continue the PEP process for GARST, Phase II in FY2001 and beyond with additional scoping, field testing and SAB and external expert reviews, workshops, etc.

Evaluating Present and Alternative Physical Resources Monitoring Protocols (SEDS)
[System-Wide Monitoring and Modeling - Sediment and Flow]

INTRODUCTION:

The GCMRC presently uses standard aerial photography/photogrammetry and color video for river corridor overflights. The following is a draft outline of tasks, responsibilities, deadlines, and budget information associated with the PEP pilot study; a process for ground-based and aerial photography/videography, termed here as Ground-Based and Airborne Remote-Sensing Technology (SEDS), data collection protocols during FY98-99. This effort is intended to: 1) evaluate current aerial photography and videography protocols, 2) evaluate alternative airborne remote-sensing technologies, 3) propose an appropriate comparison of any new protocol with the existing protocols to evaluate the old vs. the new, and to ensure there is no discontinuity in the data set as a result of changing protocols, and 4) test the protocol evaluation process discussed above.

PLANNING PHASE:

Task I. Describe Current SEDS Protocols Used by GCMRC to Monitor the Colorado River Ecosystem

Task I.a. (Mike Liszewski.) - Define the former and present remote-sensing protocols in terms of timing, scale, format, constant low-stage, method of deployment, etc.

Task I.b. (Program Managers and Staff) - Describe and define the types of data required and desired to address the present monitoring information needs set down by stakeholders (R. Lambert for cultural, B. Gold, L. Stevens, B. Ralston and -M. Yard for biological, T. Melis for physical, D. Garrett, W. Vernieu and S. Hueftle for Lake Powell, M. Liszewski for information technologies). A few examples of general needs might include: sandbar and sediment-related features, terrestrial vegetation (including chlorophyll-A), cultural site erosional/depositional changes. In describing the data requirements, the program managers and staff must address scale/resolution, as well as acceptable levels of error (precision/accuracy) associated with remote-sensed data.

Task I.c. (Program Managers and Staff) - Provide Mike L. with detailed information on: 1) how past airborne-collected data have or are presently being used? 2) What is being done with the data presently to achieve information needs defined by stakeholders? 3) Do the present protocols effectively provide data needed to answer information needs?
Due Date for Tasks I.a-c: March 6, 1998 - ACHIEVED

[NOTE: Several potentially interesting conferences happen to coincide with the initial phase of the PEP with respect to physical/remote sensing topics, such as the ASCE Wetlands Conference in late March 1998 [Denver, CO]; a national meeting sponsored by the USGS-WRD to present new technologies for measuring sediment in rivers in February in St. Petersburg, FL will also provide information on new technologies. Another conference on new technologies and developments in remote-sensing will be convened in late March, 1998 [Tampa, FL] that may also potentially provide new information and contacts on CRE resource monitoring approaches.]

Task II. Identify Expert Review Panel and Alternative Protocols to be Evaluated

Task II.a. (Program Managers) - Develop list of names of potential expert review panel members, review list and identify individuals to be invited to sit on the expert review panel (plus alternates), and invite individuals to join the expert review panel.

Task II.b. (Mike L. and Ted M.) - Identify alternative SEDS protocols that may be evaluated by the expert review panel and subsequently recommended for evaluation through potential paired comparisons (e.g., field testing during the anticipated 1998 Labor Day overflight) or other means.

The following are approaches that the GCMRC (headed by Mike L. and Ted M.) will utilize to scope appropriate expertise and alternative technologies: 1) telephone and face-to-face interviews with program managers and research-group leaders from major agencies that work with remote sensing technologies and databases; especially those who focus on river, lake or near coastal ecosystems; 2) literature review, 3) attendance of the national remote-

sensing conference set for Tampa, FL in late March; 4) internal scoping and discussions with survey personnel (Gonzales and others) who have already identified interesting new remote-sensing technologies.
Due Date for Tasks II.a-b: April 10, 1998 - ACHEIVED

[NOTE: In future PEP efforts, the GCMRC would involve the Science Advisory Board (SAB) in the scoping process, as well as in external review panel meetings and workshops to the greatest extent possible. At the very least, the SAB should be involved in the scoping process and asked to review the decisions to conduct paired field tests, as well as final decisions on changes in protocols for implementation in the long-term monitoring program.]

FIRST REVIEW PHASE:

Task III. Convene SEDS Expert Review Panel for Critical Evaluation of Existing and Potentially Useful Protocols - COMPLETED

Task III.a. (Mike L. and Ted M.) - The external review panel for SEDS will be convened May 26-28, 1998. Mike L. and Ted M. will organize the meeting in Flagstaff, AZ at the USGS, Building 3 conference room. Expert review panel members will be supplied with information developed from Task I (above), and any alternative protocols identified from Task II (above).

Reviewers will have at least three weeks to prepare for the meeting (their ability to work within this time window will be one additional requirement for their selection).
Due Date for Task III.a: COMPLETED

Task III.b. (Mike L. and Ted M.) - At the review panel meeting, the panel will be introduced to the PEP process in general (Ted M. and Dave G.). This will be followed by a brief presentation on the existing protocols and data requirements. Discussions as to the appropriateness of the former/existing protocols for meeting presently defined information needs, as well as evaluation of alternatives identified by the GCMRC will be held. In addition, the reviewers will be asked to provide their own recommendations on other alternatives that may not have been identified through the GCMRC scoping process. Hopefully, through this combined process, the GCMRC will identify all of the appropriate SEDS options for consideration and possible testing.
Due Date for Task III.b: May 28, 1998 - COMPLETED

Task III.c. (Expert Review Panel) - The expert review panel will be asked to provide the GCMRC will individual summary reports, and a group report on their evaluations of the protocols discussed during the meeting, and their recommendation(s), if any, on other SEDS protocols should be considered for paired field testing during the Labor Day 1998 aerial overflight. On the basis of their report(s), the GCMRC (Mike L.) will implement the annual overflight and possibly a paired test, pending available funding ability to procure any alternatives that might be identified for a test comparison.
Due Date for Task III.c: COMPLETED

[NOTE: Whatever evaluation approach is recommended, the selection and implementation of a new protocol for airborne remote sensing must be implemented in such a manner as not to yield a discontinuity in data collection.]

PROCUREMENT PHASE:

Task IV. Labor Day 1998 Overflight (with Possible Paired or Triple Field Testing)

Task IV.a. (Mike L.) - The GCMRC Information Technologies Director will have all of summer 1998 to procure the standard overflight for Labor Day still photography and videography, and any additional protocols that were identified through the scoping and review panel process for paired field testing. The present contractual agreement for aerial photography may be used to procure additional protocols for testing during the overflight, depending on the contractor's willingness and ability to provide them directly or subcontract for them through another party within the designated time frame. Standard videography may be conducted by the Bureau of Reclamation with permitted helicopter deployment, and additional videography formats may also be used for testing purposes using existing cooperative and interagency agreements.
Due Date for Task IV.a: August 31, 1998

Task IV.b. (Mike L. and GCMRC's Contractor(s)) - Over the Labor Day weekend airborne remotely sensed data will be collected. The processed data will be delivered to the GCMRC Information Technologies Director no later than mid-October 1998.
Due Date for Task IV.b: October 15, 1998

EVALUATION PHASE:

Task V. Paired-Test Evaluation by GCMRC, Cooperator(s), and Expert Review Panel

Contingency Task V.a. (Cooperator/Contractor procured through competitive RFP process) - In the event that comparitive testing is recommended by the expert review panel (May meeting), and and that alternative data sets are obtained from protocols other than standard aerial photography over Labor Day '98 overflight, then the GCMRC Information Technologies Director may decide to procure assessment(s) of the data from outside sources. If the RFP was released in summer 1998, then it is assumed that the performance period of the assessment would be at least one year, beginning October 1, 1998. Under this schedule, the draft report on the assessment would likely be due on August 15, 1999 and the final report would be completed on or before September 30, 1999.
Draft Report Due on August 15, 1999

SECOND REVIEW PHASE:

Task V.b. (Expert Review Panel and GCMRC) - The results of the paired test (databases) would be evaluated by the reviewers and the GCMRC staff at a second review panel meeting held in the fall of 1999 (date is dependent on how soon the data and evaluation are available). On the basis of this second review, the GCMRC would prepare a draft report on the PEP process, results of testing, and review results for distribution and comment by the Technical Workgroup in late summer 1999.
Due Date for Task V.b: October 1, 1999

DECISION-MAKING AND IMPLEMENTATION PHASE:

Task V.c. (Dave G.) - On the basis of review and comment by GCMRC staff, the SAB and the TWG, a decision would be made by the GCMRC Chief as to whether additional scoping, review and testing is required, or whether a protocol change(s) is warranted for implementation in to the GCMRC long-term monitoring program beginning in FY99 and beyond.

The following is an outline of the proposed time line, tasks, and estimated budget to conduct the SEDS evaluation during FY98-99.

BUDGET AND TIMELINE, PEP-I:

Section VI. SEDS - Time Line, Budget, and Assignments

A - Articulation:	2/1/98 through 3/6/98	Mike L. and Staff	COMPLETED
B - Scoping:	3/7/98 through 4/10/98	Mark G. + Ted M.	COMPLETED
C - External Review:	4/15/98 through 5/25/98	Mike L. + Ted M.	COMPLETED
D - First Meeting:	5/26 through 5/28/98	Mike L. + Ted M.	COMPLETED
E - Procurement:	6/16/98 through 9/3/98	Mike L.	COMPLETED
F - Overflights:	9/5/98 through 9/7/98	Mike L.	COMPLETED
***G - Data Processing:	9/9/98 through 10/15/98	Contractor(s)	TBA

NOTE ON ITEM G: [The period required to process and evaluate the data collected during the Labor Day '98 overflight will depend on the recommendations of the Expert Review Panel convened at the May 26-28,1997 meeting in Flagstaff, AZ. The minimum requirement for time and assessment by GCMRC could be 4-6 weeks (conventional photography versus digital imagery. This time period could be extended to as much as a year in the event that completely new SEDS protocols are flown that generate significantly new and different data sets from those previously captured. HENCE THE REMAINDER OF THE TIMELINE ONLY APPLIES TO THE FIRST CASE, NOT THE LATTER.]

H - External Review:	6/15/99 through 7/15/99	Mike L. + Ted M.	TBA
I - Second Meeting:	Late July 1999	Mike L. + Ted M.	TBA
J - SAB Review:	August 1999	Mike L.	TBA
K - Draft Report:	8/15/99	Mike L.	TBA

***LABOR DAY 1999 AERIAL OVERFLIGHT [At minimum, standard aerial photography will be procured]

L - Draft to TWG:	9/1/99, Discuss at Sept. TWG	Mike L.	TBA
M - Draft to AMWG:	October 1999	Mike L.	TBA
N - Present to AMWG	January 2000 Meeting	Dave G. + Mike L.	TBA
O - Chief's Decision:	Spring 2000	Dave G.	TBA
P - Implement Change(s):	Labor Day 2000	Mike L.	TBA

End SEDS Component of PEP Assessments

OR,

Continue the PEP process for SEDS, Phase II in FY2001 and beyond with additional scoping, field testing and SAB and external expert reviews, workshops, etc.

Appendix 4

DRAFT RESEARCH AND MONITORING PLAN FOR BEACH/HABITAT-BUILDING FLOW FROM GLEN CANYON DAM, JUNE TO JULY 1999

INTRODUCTION

Beach/habitat building flow (s) (BHBF) of 45,000 cfs from Glen Canyon Dam may be considered by the Adaptive Management Work Group for June-July 1999. This "experiment" would be used to confirm and test existing and new hypotheses surrounding the use of dam releases to manage sediment distribution and ecosystem resources in Glen and Grand Canyons. This document outlines the research, monitoring and flow-related synthesis activities planned before, during and after the BHBF event, and the budget associated with those activities.

The duration, magnitude and ramping of the BHBF hydrograph are subject to discussion by the Technical Work Group (TWG) and the Adaptive Management Work Group (AMWG). Based upon information developed from the 1996 BHBF, 2 to 4 days of high flows are expected to be sufficient to balance benefits to sediment, biological and cultural resources (Figure 1). Prior and subsequent constant flows are recommended for aerial photographic purposes, at the lowest normally achieved level of pre-event fluctuating flows. Field studies are planned prior to, during and immediately after, and six months following the BHBF.

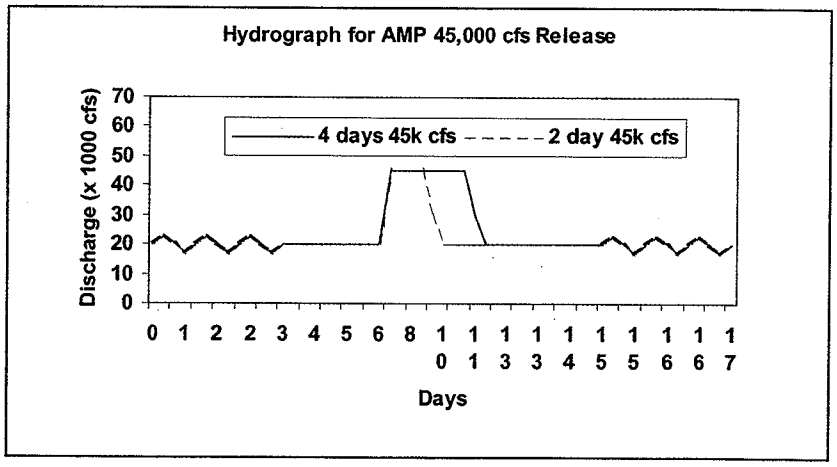

Figure 1

The duration of the BHBF should be established on the basis of a hypothesis related to the 1996 test results (lower limit for response) in sediment transports and deposition. On-going monitoring efforts will be incorporated to minimize the research costs associated with the 1999 BHBF. Research and monitoring activities will be coordinated and logistically supported by GCMRC, pending discussions by the TWG and AMWG, and approval of proposals. Given the short time frame surrounding planning and implementation of research activities for a BHBF defined by the

flow triggering criteria, GCMRC will not pursue a competitive funding approach to accomplish research and monitoring tasks, but will use a variety of mechanisms, including modification of existing contracts and in-house expertise.

OBJECTIVES

The objective of the BHBF is to test hypotheses related to duration and timing of BHBFs. Results of the 1996 test flow are the primary basis for design and development of the 1999 BHBF plan. The overall monitoring and research objectives of the 1999 BHBF plan are to advance scientific understanding on the best use of controlled floods for river ecosystem reousrce enhancement and mitigation from Glen Canyon Dam. Specific objectives include:

1. Verify results of the 1996 test, particularly those related to BHBF duration with respect to sediment responses.

    a. Determine the extent to which altered antecedent resource conditions and timing influence the outcome of a BHBF.

    b. Determine and verify the rate and mechanisms of bar development during high flows.

    c. Document grain-size and suspended sediment patterns in the mainstem and above and below the LCR confluence.

2. Monitor BHBF impacts on selected biological resources associated with Biological Opinion actions (KAS, SWIFL, native fish at the LCR other tributaries and mainstem).

3. Monitor and evaluate effects of BHBF on identified physical, biological and cultural resources.

The monitoring and research activities presented in this document will ensure sufficient information to assess the effects of this hydrograph, and advance scientific understanding of the potential for resource mitigation or enhancement by 45,000 cfs flows(s). Each monitoring study should address the question, "What is the status of the resource, how does this status compare to objectives for the reousrce?" Each research project should address the question "Will the results of this research enable predictions to be made about future resource responses to alternative flows?" In other words, how will the research results be used to help design future flows?"

In addition, each project undertaken here will include a review and analysis of flow impacts (high or low, constant or fluctuating) on each resource category. Collectively, this information will be used in a review of flow impacts on resources, and used to plan subsequent research on flow impacts.

The studies proposed here involve both monitoring and research activities. Stakeholder objectives have been revised and are presently in draft form, but may provide guidance to determine whether resource conditions, as well as flow criteria, indicate the need or potential benefit of one or more BHBFs.

1999 BHBF MONITORING AND RESEARCH

The following monitoring and research studies are suggested by the GCMRC. As was stated above, the studies are based on verifying previous BHBF objectives, assisting in biological opinion evaluations and evaluating the effects of operations of Glen Canyon Dam on downstream resources. The studies are divided into the four existing program areas currently operating within GCMRC: physical, biological, cultural/socioeconomic, and information technology. The costs associated with the latter program are in support of the other three programs (e.g., survey support, aerial photography). For each project an objective, hypothesis, data to be collected and collection site, and costs are provided.

I. INFORMATION TECHNOLOGY

1. Event Documentation: Determine BHBF impacts on the river ecosystem.

a) *Aerial Photography*: Fixed-wing black and white aerial photography will be conducted before and after the BHBF at a 1:4800 scale, according to the standard flight lines and protocols used in past photographic studies. Color photographs will be take of selected sites for vegetation analysis. Analysis of these photographs will provide a permanent, system-wide documentation of stage level, alteration of rapids, sandbar distribution, and backwater habitat distribution, and riparian vegetation, and will allow assessment of the extent to which the 1999 BHBF produces results similar to the 1996 BHBF test.

Fixed wing photography will be conducted at a constant flow level equal to the lowest release during the preceding 90 days. It is preferable from a scientific standpoint to have aerial imagery of the river corridor at a constant flow. A 15,000 cfs constant flow would provide the opportunity for calibration of 8,000 cfs flows photography, which has been the standard up to this time. Alternatively, the TWG may opt for a constant flow stage slightly above the lowest stage regularly achieved during the month prior to the BHBF.

Videography—The use of digital geo-reference videography will be explored if feasible. Cost estimates for this work are still being worked out, but will be at least $90,000.

2. Survey Support

GCMRC will provide survey support for sediment monitoring and Kanab ambersnail habitat measurements. Support will consist of providing equipment (total station set ups, superhydro) and the personnel to operate the equipment.

II. PHYSICAL RESOURCES

The following monitoring and research efforts are intended to address the following objectives:

1. Provide new information on the fine-sediment budget of the Colorado River ecosystem below Glen Canyon Dam (BHBF-induced sand bar and eddy storage versus export);

2. Document the impact of reducing the duration of a BHBF from 7 to 3.5 days;
3. Study effects on newly built sand bars of high-constant dam releases anticipated to follow the BHBF under a 1.5 or greater MAF release month;
4. Document changes in recently aggraded debris fans and rapids (reworking) that result from controlled flooding.

a) Pre-BHBF Activities (for at least three days, within two weeks prior to BHBF)

Question: *What is the pre-BHBF antecedent condition of fine-sediment storage throughout the mainstem channel of the Colorado River ecosystem, and how does it compare with those existing prior to the 1996 BHBF-Test?*

Work Efforts - Characterize antecedent streamflow and mainstem sediment conditions – including 1) Unit-value streamflow and selected water quality (including turbidity) data at four mainstem and two tributary USGS gages (Lees Ferry, Desert View, Grand Canyon, Diamond Creek, Paria River, and Little Colorado River near Cameron); 2) Daily sampling of suspended-sediment concentration and grain-size distribution at above mainstem sites, plus one temporary site near river mile 39 (mid-Marble Canyon); 3) Channel-bed grain-size and topography sampling at sites where suspended sediment are collected; 4) Baseline topographic surveys of selected eddies and terrestrial sand bars (including channel-margin bars) within the first 100 miles below Glen Canyon Dam; 5) Baseline textural and topographic characteristics of recently aggraded debris fans and rapids; 6) Document baseline conditions of topography, grain-size distribution and navigational conditions associated with recently aggraded (since April 1996) debris fans and rapids.

b) During-BHBF Flow and Sediment Research (daily to hourly sampling)

Questions: 1) *How does suspended-sediment transport vary throughout the given duration and magnitude of the BHBF at key mainstem sampling sites?* **2)** *How do site specific eddy deposition/erosion responses correlate with suspended-sediment concentrations and grain-size distributions?* **3)** *What size classes of sediment are transported away from recently aggraded debris fans and rapids and what is the rate at which transport occurs?*

Work Efforts - Characterize suspended-sediment transport, streamflow, sediment storage and related processes/rates – including 1) main channel measurements of channel-bed grain-size responses; 2) fine-sediment deposition and erosion responses at selected eddies and/or mainstem pools; 3) measure changing conditions of topography, grain-size distribution and navigational conditions associated with recently aggraded (since April 1996) debris fans and rapids under controlled flood conditions; 4) study bedload transport of coarse sediment under controlled flood conditions at recently aggraded debris-fan and rapids study areas.

c) **Immediate Post-BHBF Activities (three days, within two weeks prior to BHBF)**

Questions: 1) *Under reduced duration and different anticedent sediment conditions, did sand bars build to the same degree as during the 1996 BHBF-Test?* **2)** *On the basis of documented anticedent sediment-storage conditions, did suspended-sediment transport of the mainstem respond to following the BHBF in ways predicted (reduced export relative to pre-BHBF transport)?* **3)** *What was the volume of fine-sediment exported from the upstream critical reaches, and the entire system, versus the total estimated net storage increase?* **4)** *To what extent were recently aggraded debris fans and rapids reworked under controlled flood conditions?*

Work Efforts - Characterize immediate post-BHBF streamflow, suspended-sediment transport, and channel sediment-storage conditions – as described in part I-a, with additional measurement of fine-sediment flux from selected eddies back to the main channel (daily erosion rates) for a period of upto one week. Document post-flood conditions of topography, grain-size distribution and navigational conditions associated with recently aggraded (since April 1996) debris fans and rapids.

d) **Longer Post-BHBF Flow and Sediment Research**

Questions: 1) *What is the impact, following a BHBF (~45,000 cfs), of prolonged, of at least one month of steady flows of 25,000 cfs or greater on the fine-sediment budget and terrestrial sand bars of the Colorado River below Glen Canyon Dam?* **2)** *What are the textural characteristics of newly deposited sand bars relative to sediment-transport trends measured during the BHBF?*

Work Efforts - Characterize longer post-BHBF, suspended-sediment transport, streamflow and channel-sediment conditions following the anticipated high-constant dam releases associated with the 1.5 MAF or greater monthly forecast (1 or more months following the BHBF release in which dam releases are held above 25,000 cfs). The main emphasis of this work is measuring responses to high-constant flows on newly deposited terrestrial sand bars, eddy storage conditions, and changes to system-wide channel-bed storage in the mainstem channel.

PHYSICAL SCIENCE COOPERATORS: The research and monitoring associated with the BHBF will be accomplished by the GCMRC in cooperation with the U.S. Geological Survey - WRD (existing interagency agreements with principal investigators Hornewer and Webb), and the Geology Department of Northern Arizona University (existing cooperative agreement with principal investigator Parnell).

ESTIMATED PHYSICAL SCIENCE COSTS (Current Cooperators):

a. NAU Sand Bar Surveys $150,000 (~logistics costs $35,000): $185,000

b. USGS Streamflow/Sediment Transport $265,000 (~logistics costs $40,000): $305,000

c. USGS Changes in Debris Fans and Rapids $40,000 (~logistics costs $20,000): $60,000

III. BIOLOGICAL RESOURCES

Work completed associated with biological resources includes biological opinion required elements and conservation measures, monitoring and research elements. These efforts are intended to address the following objectives:

1. Provide new information on the physical, chemical and biological elements of the reservoir and downstream water quality transported and exported as a result of the BHBF .
2. Document the impact of reducing the duration of a BHBF from 7 to 3.5 days on vegetation and the soil seedbank;
3. Study the recovery rate of aquatic food resources from reducing the duration and changing the timing of a BHBF;
4. Document impact of the timing of a BHBF on biological resources including endangered native fish and terrestrial species.

INTEGRATED WATER QUALITY

RESERVOIR MONITORING

Objective: to determine the effect of withdrawal from jet-tubes on lake stratification, and downstream water quality.

Ho: the pattern associated with stratification will be similar to 1996. Water quality values discharged through the dam will also be similar.

Study Sites: Lake Powell Reservoir and tailwaters.

Duration of Sample Collection: 5 days prior to release, data collection during release, 5-7 days after release.

Project Cost: $50,000 **Logistic Costs: $10,000** **Total Costs: $60,000**

DOWNSTREAM MONITORING

A. Nutrient Flux

Objective: to determine the export of dissolve nutrients associated with BHBFs.

Ho: Large flood events produce a significant impact on the concentrations of dissolved organic carbon (DOC), and dissolved, inorganic forms of Nitrogen and Phosphorous in Colorado River water.

Study sites: Three locations (Lees Ferry., 45 mile, Separation Canyon). Simultaneous data collection by teams of 2 people/crew. Measure pH, temperature, conductance and DO, P and N.

Duration of Sample Collection: Collected 4-pre-flood sample, 8 rising limb samples, 9 flood crest samples, 10 falling limb samples and 4 post-flood samples.

Project Cost: $24, 804 **Logistic Costs: $10,000** **Total Costs: $34, 804**

B. Terrestrial Riparian Plant Communities

Objective: To determine the impact of high flows on soil seed bank and near-shore vegetation.

Ho: Seedbank depostion and composition will be similar to 1996 patterns

Study site: 11 vegetation study sites

Duration of Sample Collection : 1 downstream trip post flood

Project Cost: $35,000 **Logistic Costs: $14,000** **Total Costs: $50,000**

C. Aquatic Resources

Objective: To determine the impact of high flows on productivity.

Ho: Recovery rates will be similar to those values determined in 1996

Study Site: Glen Canyon, Lees Ferry, Paria, LCR, Diamond Creek.

Duration of Sample Collection: Collect drift will be monitored twice daily for 3 days prior to the BHBF, twice daily during the BHBF, 3 days following the BHBF and 6 months after the BHBF. Drift will be sampled at the base of GCD and at four mainstream cableways. Bulk ash-free dry mass of aquatic and terrestrial components will be sampled, without fine sorting and subsamples will be preserved for potential future detailed analyses. If the major tributaries are flowing above base level, limited collection of drift data from the Paria and LCR is recommended.

Project Cost: $94,000 **Logistic Costs: $56,000** **Total Costs: $150,000**

a. Native Fish: Based partially on the results of the 1996 BHBF test, and depending the timing of the 1999 BHBF, high flow impact on native fish, particularly endangered humpback chub, may include impacts on larval and young individuals. In contrast, high flow impacts on subadult and adult individuals are probably undetectable.

1). Ponding: Larval HBC and other native fish may be ponded during a high flow, and the rate of accumulation in tributary mouth pool areas and different size classes may be lost from the mouth of pools as flows subside. This process should be documented at the Paria and LCR confluences.

2) Displacement: Young HBC and other native fish may be swept out of rearing habitats (shoreline, return channels) as flow levels increase, alternatively non-native larvae may also become displaced and may these habitats may become more available to native fish following the BHBF. Data collection efforts coupled with on-going monitoring efforts should help clarify aspects of timing and native-non-native competitive interactions associated with shoreline habitat.

3) Habitat Changes: An analysis of backwater and near-shore habitat changes associated with a BHBF will be coordinated with on-going syntheses of Backwater habitat availability using aerial photography.

Project Cost: $100,000 Logistic Costs: $56,000 Total Costs: $156,000

b. Trout

1) Population: Trout population changes will be determined by electroshocking before and after the BHBF as well as creel censuses, incorporating existing monitoring schedules and protocols to the greatest extent possible.

2) Redd Distribution: Depending on the timing of the BHBF, active redd distribution will be monitored before and after the BHBF.---In this case, this is unlikely to be necessary.

3) Trout Diet: Trout diet analyses are recommended to determine linkage between alteration of the foodbase and fish foraging success.

Project Cost: $24,000 Logistic Costs: $10,000 Total Costs: $34,000

D. Terrestrial Resources

a) Endangered Kanab Ambersnail

1) KAS monitoring and mitigations: Kanab ambersnail (KAS) habitat and population monitoring and mitigation is required, pending discussion with Reclamation and FWS. The KAS habitat and population will be monitored before and after the BHBF. Moving KAS that exist in the flood zone to augment 2nd populations and zoo populations as well as to higher stage elevations is recommended to mitigate BHBF impacts on the populations. The movement of KAS will be

overseen by the FWS. Population and habitat recovery will be monitored in accord with the existing monitoring schedule.

2) **Endangered Southwestern Willow Flycatcher**: Depending on the timing of the BHBF, southwestern willow flycatcher (SWWF) habitat and population monitoring is likely to be required, pending discussion with Reclamation and FWS. Historical nesting areas will be monitored using aerial photography and site mapping. Observers will be place on site to document BHBF impacts on distribution and behavior before, during and after the BHBF because the event occurs during breeding season.

Project Cost: $40,000 **Logistic Costs: $32,000** **Total Costs: $72,000**

IV. CULTURAL AND SOCIO-ECONOMIC RESOURCES

Archaeological Resources:

A. Geomorphic Studies:

Objective: To determine the affects of BHBFs on deposits of fine-grained sediments in terrace and arroyo deposits at locations where archaeological materials have been identified. Sediment deposition at terraces and arroyos occurred under the 1996 BHBF; however, a shorter duration BHBF and different antecedent sediment storage may results in different sedimentation patterns during 1999 BHBF. Understanding these dynamics will contribute to understanding the role of dam management in the protection of archeological sites. Some of this work can be undertaken using exiting NPS monitoring schedules, but detailed information should be collected before during and after the BHBF.

Hypothesis: Differing flow regimes affect the deposition and retention of fine-grained sediments at archaeological site locations.

Study One: Pre-BHBF surveys of surface sand deposits and gage placement. During BHBF observation of selected modeling locations, and post BHBF resurvey of locations. Survey locations are above and below Lava Chuar, below Basalt Canyon and the Cardenas area.

Project Cost: $5,500 **Logistics Costs: $3,000** **Total Costs: $8,500**

Study Two: Topographic mapping at five catchment locations to determine sediment gain or loss due to the BHBF. Four locations (Nankoweap Creek, Palisades Creek, Lower Tanner Creek area, Upper Unkar area) will be surveyed as part of study one above. The fifth location (122 Mile Canyon) will be mapped during this study. A sample of catchments from the geomorphic type settings throughout the Canyon will be assessed from aerial photograph for comparison.

Project Cost: $10,000 **Logistics Costs: $5,000** **Total Costs: $15,000**

Study Three: Photographic monitoring of selected terraces with archaeological deposits within the Glen Canyon Reach. Continuation of existing photographic monitoring upstream at Lee's Ferry area and minus 9 mile terrace. Image frequencies will be adjusted to record affects of up and down ramping rates and the high flows under the BHBF.

Project Cost: $2,000 **Logistics Costs:** $ 500 **Total Costs:** $2,500

B. Traditional Cultural Properties:

Objective: Monitoring of traditional cultural resources and sites will be undertaken by the cooperation of Native American tribes. Additional tribal resource monitoring may be required depending on the scheduling of the BHBF. Tribal monitoring described below is for a BHBF in 1999 only. Other resources may be identified by other tribal groups different years.

Hypothesis: Flow regimes under a BHBF may affect the health of the traditional resources. Changes in duration of the proposed BHBF from the 1996 experimental flow may affect these resources differently.

Study One: Monitoring of the Goodding Willow, a traditional cultural resource, during the BHFB to determine the affects of the flows on the health of the resource. Monitoring will be done by the Hualapai Tribe and the Southern Paiute Consortium at the Granite Park area.

Project Cost: $3,000 **Logistics Costs:** $3,500 **Total Costs:** $6,500

C. Recreational Resources:

Objective: Recreational safety analyses may be desired, particularly if the BHBF takes place in June or July. Interviews of river runners and observation of accidents at major rapids before, during and after the BHBF may be conducted.

Hypothesis: High flows represent no danger to the visiting public.

Study One: Assessment of water safety at selected river rapids during the BHBF through interviews with boating guides and river raft patrons.

Project Cost: $10,000 **Logistics Costs:** $3,000 **Total Costs:** $13,000

Hypothesis: High flows from BHBF may affect recreational activities and associated economics. Assessment of impact to the commercial trout fishing industry may be determined for the Glen Canyon Reach.

Study One: Assessment of Hualapai camping beaches during the BHBF to determine and monitor the affects of the flow regimes on this resource. Monitoring conducted by the Hualapai Tribe.

Projects Costs: $8,000 **Logistics Costs:** $2,000 **Total Costs:** $10,000

Study Two: Assessment of selected recreational beaches to determine the affects of the BHBF on beach morphology. Beach surveys are combined with sandbar study conducted within the physical resource program.

Project Cost: $20,000 **Logistics Costs:** $5,000 **Total Costs:** $25,000

Study Three: Assessment of the affects of the BHBF on trout fishing within the Glen Canyon Reach through interviews and other methods.

Project Cost: $10,000 **Logistics Costs:** $1,000 **Total Costs:** $11,000

Study Four: Economic assessment of the impacts of the BHBF on recreational activities, and recreational enterprises. Study will compare economic affects of proposed BHBF with 1996 experimental flows.

Project Costs: $15,000 **Logistics Costs:** $1,000 **Total Costs:** $16,000

V. FLOW IMPACTS REVIEW

Each participant in the BHBF program will be required to provide a review of flow impacts on the resources associated with that persons expertise. Guidelines will be developed by GCMRC and the TWG to focus this review process. Results of the reviews will be compiled by the GCMRC for each research category and presented as an integrated assessment.

VI. LOGISTICS

Pending finalizations of projects, work plans and schedules, a comprehensive logistics plan will be developed. The permitting and scheduling challenges associated with a short planning horizon are numerous. The logistics budget and schedule will require refinement following authorization to conduct the BHBF and proceed with research planning.

Figure 2.1 PEP SCHEDULE

PEP/DATE	2000 JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2001 JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SEDS[1]	—	—	—	RFP	—	—	—	—	—	LTM[2]	—	—	—	—	—	—	—	—	—	—	—	—	—	➤
Aquatic Foodbase	—	—	—	—	—	—	—	—	—	PEP	—	—	REPORT	—	—	RFP	—	—	—	—	—	LTM	—	➤
Lees Ferry Trout	—	—	—	PEP	REPORT	—	RFP	—	—	—	—	—	—	LTM	—	—	—	—	—	—	—	—	—	➤
Native Fish	—	—	—	—	—	—	—	EVAL TRIP	—	PEP	—	—	REPORT	—	—	RFP	—	—	—	—	—	LTM	—	➤
Terrestrial Veg	—	—	PEP	—	REPORT	—	RFP	—	—	—	—	—	LTM	—	—	—	—	—	—	—	—	—	—	➤
Kanab Ambersnail	—	—	PEP	—	REPORT	—	RFP	—	—	—	—	—	LTM	—	—	—	—	—	—	—	—	—	—	➤
Avifauna	—	—	PEP	—	REPORT	—	RFP	—	—	—	—	—	LTM	—	—	—	—	—	—	—	—	—	—	➤
IWQP	—	—	—	—	—	—	—	—	—	PEP	—	—	REPORT	—	—	RFP/ In-House	—	—	—	—	—	LTM	—	➤
Cultural / PA	—	—	PEP	—	—	REPORT	—	—	—	—	EVALUATE PEP RECOMMENDATIONS		—	—	—	—	—	—	—	—	—	—	—	➤
Recreation - Fishing	CONDUCTED AS PART OF THE LEES FERRY TROUT PEP																							
Recreation - Camping Beaches	NOT SCHEDULED																							
Economics	NOT SCHEDULED																							
Remote Sensing[3]	ONGOING EVALUATIONS. PEP SCHEDULED FOR FY 2002																							

[1] Two PEP workshops were held for SEDS, the first on August 1998 and the second in August 1999. Draft reports were produced following each of these workshops. The final PEP report was received in October 1999. All reports of the SEDS PEP are available on the GCMRC website.

[2] Five-year contracts will be issued for LTM. In year 5, another PEP will be convened to see if any modifications are required to the existing long-term plan. RFPs will be issued in time to ensure continuity in the monitoring program.

[3] A PEP for remote sensing was held in May 1988 and the report of that panel was received in June 1999. That report was used to develop the strategy which will guide the evaluation of remote sensing technologies for FY2000 through FY2002. A second PEP will be convened in FY2002 to provide recommendation for the remote sensing protocols to be implemented by GCMRC. Activity in FY2000, 2001, and 2002 will consist primarily of field testing potential technologies and evaluating the value of the products resulting from the deployment of those technologies.