FISCAL YEAR 1998

ANNUAL MONITORING AND RESEARCH PLAN

by

THE GRAND CANYON MONITORING AND RESEARCH CENTER

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TABLE OF CONTENTS

CHAPTER 1

ANNUAL PROGRAM PLANS AND

THE LONG-TERM STRATEGIC PLAN

INTRODUCTION

The Fiscal Year 1998 Annual Monitoring and Research Plan (Annual Program Plan) represents the first year of implementation of the Long-Term Monitoring and Research Strategic Plan (Long Term Plan). The two plans taken together are the required instruments for implementing science programs of the Grand Canyon Monitoring and Research Center (GCMRC).

The Long-Term Plan, drafted for fiscal years 1998-2002, will be reviewed by the Adaptive Management Work Group (AMWG), as specified under the Grand Canyon Protection Act and Glen Canyon Dam EIS. The Long-Term Plan and associated funding will be approved by the Secretary of Interior for implementation.

The Long-Term Plan recommends monitoring and research strategies to determine the effect of the Secretary's actions on the natural, recreational, and cultural resources of Grand Canyon National Park and Glen Canyon National Recreation Area. General strategies outlined in the Long-Term Plan must be made more definitive by drafting specific monitoring and research proposals to be implemented within a given year or across several years of the Long-Term Plan. The centers Annual Program Plan accomplishes the goal of specifying

individual monitoring and research projects that will be used to accomplish objectives and information needs specified by the stakeholders and outlined in the Long-Term Plan.

LINKING THE LONG-TERM PLAN AND FY98 ANNUAL PROGRAM PLAN

The FY98 Annual Program Plan is best understood in the complete context of the Long-Term Plan. Although some elements of the Long-Term Plan are not contained in the FY98 Annual Program Plan, all the major resource areas of investigation, as well as programs on information technology are included.

The following summary of the long-term plan provides a brief introduction to the plan, as well as an overview of each major element of the plan.

AN OVERVIEW OF THE LONG-TERM PLAN: 1998-2002

The Long-Term Plan is designed to implement new concepts of adaptive management and ecosystem science called for in the Grand Canyon Protection Act and Glen Canyon Dam Environmental Impact Statement. The areas of monitoring, research, and information technology outlined for physical, biological, cultural and socioeconomic resources will be implemented over a five-year period. Annual Program Plans are required to assure appropriate progress on critical elements of the Long-Term Plan.

All elements of the Long-Term Plan, and all monitoring programs, research projects and information technologies drafted into Annual Program Plans incorporate the ecosystem science paradigm and are developed cooperatively with the Adaptive Management Work Group, utilizing adaptive management and science procedures. All programs proposed relate to determined or potential resource impacts in the riverine corridor associated with the USDI

Secretaries decisions and Glen Canyon Dam operating criteria specified in the Record of Decision (ROD) and EIS.

Independent reviews of past research in the Grand Canyon have concluded that several accomplishments need to be developed to ensure progressive future monitoring and science programs that will associate changes in critical resources to dam operations. These include:

1. Development of an adaptive management and science process to permit close interaction of science and management in applying potential new management criterion and evaluating impacts of that criterion in shorter time periods.
2. Development of a conceptual model of Grand Canyon riverine ecosystems which can be used to more clearly define critical attributes within resource categories, critical attribute linkages across resource categories, and interdependencies of resource attributes.
3. An extensive synthesis of all past knowledge associated with original baseline resource conditions in the Colorado River, riverine resource changes associated with construction of the Glen Canyon Dam, and changes associated with differing operating criteria at Glen Canyon Dam.
4. Ecosystem analyses to permit improved understanding of the most critical attributes that drive individual resources and groups of resources, and the interdependencies of attributes within and across resources.
5. Development of predictive models of ecosystem function and interaction under differing dam operating criteria.

PURPOSE AND SCOPE OF THE CENTER AND THE LONG-TERM PLAN

The Grand Canyon Protection Act and Glen Canyon Dam EIS directs the Secretary of 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 and goals of this Long-Term and Annual Program Plans are to determine short- and long-term ecosystem resource impacts of alternative Dam operation criteria and other information needs specified by the Adaptive Management Work Group and Secretary of Interior.

Long-term monitoring will occur in all resources of concern to determine changes in resource attributes from some desirable level. Research will be used to interpret and explain trends observed from monitoring, to determine cause and effect relationships and research associations, and to better define interrelationships among physical, biological and social processes. In addition to monitoring and research activities, the Center will develop information technologies to assure information archiving and transfer to managers and stakeholders and science organizations.

The physical scope of the research area to be investigated by the Center includes the Colorado River mainstem corridor and associated riparian and terrace zones from the forebay of Glen Canyon Dam to the upper reaches of Lake Mead, normally identified as Separation Canyon, a distance of approximately 278 river miles. The research scope does include limited investigations into some side tributaries such as the Little Colorado and Paria Rivers. It also includes, in general, resource impacts of dam operations up to inundation levels associated with a water flow of 100,000 cfs.

An assessment of dam operation impacts to water quality in Lake Powell will be completed in FY97, and any future monitoring and research investigations in either Lake Powell or Lake Mead must be directly associated with impacts contributed by Glen Canyon Dam operating criteria.

STAKEHOLDER INFORMATION NEEDS AND CRITICAL RESOURCE ATTRIBUTES

The long-term strategic monitoring and research plan is by design established to respond to the general objectives and information needs managers and stakeholders have regarding the Canyon and its resources. Objectives and information needs of stakeholders are specified in nine differing resource areas including hydropower, water, sediment, fish and aquatic, vegetation, threatened and endangered species, terrestrial wildlife, cultural resources, and recreation.

Within each of the above resource areas specific objectives have been developed cooperatively by the Bureau of Reclamation, and representatives of the AMWG and are specified in Appendix A. Detailed information needs for various objectives and resource areas were then defined by representatives of the AMWG working cooperatively with the GCMRC (Appendix B), and are also presented in Appendix A.

PROPOSED MONITORING AND SCIENCE PROGRAMS

Monitoring and science programs proposed in the long-term plan include significant activities in the following:

1. Synthesis of existing knowledge.
2. Physical resource program.
3. Cultural resource program.

4. Biological resource program.

5. Socioeconomic resource program.

6. Information technology program.

Each of these areas represent components of the long-term program from which developed information will be important in responding to objectives and information needs specified by stakeholders.

Synthesis of Existing Knowledge

The synthesis of existing knowledge has two primary components, and will be completed in the first two to three years of the first five-year plan. The first component is development of a conceptual model of Colorado River ecosystems of concern, and the various resource attributes that respond to variable operating criteria of Glen Canyon Dam. The second component of the synthesis program are detailed assessment of all past research associated with the riverine corridor's resources before and after Dam construction, as well as other western riverine corridors yet undamed, and of similar character and structure to the Colorado River mainstem. These synthesis are addressed in the individual resource program areas.

Completion of this comprehensive in-depth synthesis is critical to understanding this riverine ecosystem and associated impacts from differing operating criteria of the Dam. It includes extensive integrated data assessment and interpretation, as well as the first major comprehensive transfer of information technology to stakeholders regarding the potential impacts of differing operating criteria on ecosystems and associated resources.

Physical Resources Program

Water and sediment are the two primary resources of concern in the physical resources area. Monitoring and research efforts will concentrate on four aspects of these physical resources as follows:

1. Dam discharges and instream flows.
2. Sediment balance and processes.
3. Interrelationship of mainstem water and sediment and side channel inflows.
4. Interaction of mainstem water and sediment and Lake Mead resources.

The Biological Resources Program

Monitoring and research activity for biological resources is intended to develop information about the structure and function of the Grand Canyon ecosystem, as well as the impacts of a range of alternative dam operations on the ecosystem and associated flora and fauna.

Programs will evaluate the status and trends of native fish populations in the Grand Canyon ecosystem and seek to collect data that can be used to assess the native and non-native fish communities response to alternative operation criteria. Native fish species of concern are the humpback chub, razorback sucker, flannel mouth sucker, blue head sucker and speckled dase.

Monitoring of the non-native trout fisheries in the Lees Ferry reach will concentrate on growth, survivorship, and changes in population structure, including the contribution from natural reproduction over time.

Changes in the three primary riparian zones along the river will be monitored including, the old high water zone, new high water zone, and near shoreline wetland communities.

Monitoring of faunal assemblages will be aligned to sampling of riparian vegetation habitat changes.

Monitoring and research of terrestrial invertebrates along the riverine corridor will continue to be critical with the changing composition, structure, and densities of riparian vegetation.

Monitoring of vertebrates will require large study sites at which full descriptions of vegetation, soils and topography must be determined. Spot sampling at other locations might also be required to expand the monitoring database.

Avafauna inventory monitoring should emphasize listed species such as the Bald Eagle, Southwestern willow flycatcher and Peregrine Falcon.

The Cultural Resources Program

This program will accommodate both ongoing programs of the programmatic agreement, and new programs proposed to address information needs of the AMWG. Monitoring and research information needs and activities from the programmatic agreement are expected to be a major component of the Long-Term Plan.

The cultural resources program for the Center will accommodate three primary components: **a core program, a tribal projects element, and a cooperative** programming aspect. Objectives and information needs specified by the stakeholders have been utilized to incorporate the following monitoring and research proposals in the Long-Term Plan.

1. Develop data and monitoring systems to assess impacts.
2. Develop data to assess risk of damage and loss of cultural resources from varying flow regimes.
3. Develop tribal monitoring programs for evaluation of impacts to cultural resources.
4. Develop a predictive model of geomorphic processes that are related to archeological site erosion.
5. Develop mitigating strategies related to documented dam impacts to size by monitoring assessments.
6. Characterize resource values through scientific study.

The Socioeconomic Resources Program

There are many socioeconomic resources associated with the Grand Canyon riverine environment including recreation, electric power and water. In recreation, the objectives of long-term monitoring and research will be to determine whether recreation is enhanced and safety improved over impacts resulting from historical dam operations.

Camping beach evaluations will be determined by monitoring changes in beach areas using primarily remotely sensed data and cooperative programs with boating guides and their associations.

Hydropower generation will be monitored on a hourly basis as input to assessing the consequences of dam operations on power economics.

In research, a Cost Benefit Analysis (CBA) model is proposed, to accommodate evaluation of all associated market and non-market costs and benefits, including intrinsic or existence values of key resources.

Information Technology

Extensive data and information currently exists in the GCMRC database relating to resource levels, quality, and relationship to other resources. Potentially equal amounts of data and information exists within museums, universities, agencies, etc. However, much of this information has not been evaluated, especially relating to the interrelationship of differing resource attributes under differing dam operating criteria.

Several areas of focus will be implemented in the information technology programming, including the following:

1. Development of protocols for data collection, processing and use.
2. Development of extensive databases across all resources and a database management system.
3. Development of a robust geographic information system to accommodate multiple layers associated with all resources of interest to stakeholders.
4. Development of databases associated with remotely sensed data, here to date not incorporated in the GCES database system.
5. Stakeholder direct access to selected data and information in the database management system and GIS.

6. Development of outreach programs to transport data and information to stakeholders and train stakeholders in utilization of data and models incorporated in the information technologies program.

SCHEDULE AND BUDGET

The strategic plan outlined in this document addresses monitoring and research for a five year period: fiscal year 1988 to 2002. Each year in May, an annual operating plan will be drafted to guide implementation of specific elements of this strategic plan. It will be reviewed by the AMWG before approval by the Secretary of Interior.

This Plan is designed to guide specific monitoring and research through three fundamental science phases.

1. Development of conceptual ecosystem models, synthesis of existing knowledge, and determination of key attributes associating resource impacts to dam operations.
2. Definition of integrated impact of key attributes within a resource set and across all resources.
3. Development of decision support guidelines and models to assist managers and interested stakeholders to understand resource interactions, impacts of dam operations on resources and procedures for mitigating impacts.

Budget for this five year strategic plan is anticipated at approximately seven million dollars per year. Of the total seven million dollar per year annual budget allocation, approximately 5.3 million will be placed into on the ground research programs. Approximately one-half million is required by the upper Colorado region of BOR to

administer the adaptive management program, and approximately 1.2 million is required to operate all the center's administrative and service programming including logistics and computer support.

CHAPTER 2

DEVELOPING STAKEHOLDER INFORMATION NEEDS

DEVELOPING STAKEHOLDER OBJECTIVES

In 1996 the Bureau of Reclamation worked with a subgroup of the Transition Work Group to develop stakeholder objectives to guide future monitoring and research programs of the GCMRC. This group was disbanded with release of their July, 1996[1/] recommendations.

The objectives developed lie in nine resource areas (Figure 1). All of the objectives are listed in Appendix A.

DEVELOPING INFORMATION NEEDS

A series of meetings were held between May and October 1996 to define information needs (research, monitoring) of stakeholders who are involved with protection, management, and use of resources in the riverine environment of Grand Canyon National Park and Glen Canyon National Recreation Area. The group of stakeholders involved were identified as a Planning Group[2/] to the GCMRC. An average of 20 stakeholders attended eight six-hour workshops to develop the information needs specified in Appendix A and summarized below.

[1/] Adapted from *Glen Canyon Dam Management Objectives*, Bureau of Reclamation memorandum UC-205, ADM-1.10, July 1996, to Transition Work Group members.

[2/] The Planning Group, a cross section of representatives (Appendix B) from the Transition Work Group developed the information needs specified. The workshops held by the Planning Group were facilitated by the GCMRC.

Figure 1. Objectives resource areas identified for research and monitoring.

IDENTIFIED INFORMATION NEEDS

A synopsis of the information needs by resource area are presented in the following text. These expressed needs are the primary basis for developing Fiscal Year 1998 monitoring, research, and information transfer programs for the GCMRC.

Water Resources

- Monitor changes in the physical and chemical characteristics over time.
- Monitor concentrations of chemical constituents with established EPA/state standards.
- Measure water composition and temperature and their changes over time.

Sediment Resources

- Characterize sand-bar, backwaters, and return channel target structures.
- Define target backwater ecosystems and associated flow regimes.
- Define character and structure of all beaches and backwaters in system after 1996 test flows.
- Define historical and current (character and structure) levels of river stored sediment in system and associated flow regimes.
- Determine baseline conditions.

Cultural Resources

- Develop data and monitoring systems to assess impacts to cultural resources.
- Develop predictive model of geomorphic processes related to archaeological site erosion including:

  Types of degradation

  Rates of degradation

Define immediacy of threats to resources

Protection methodologies

Protection, monitoring and research costs

- Characterize through scientific study and data development all assumed historical and current values of resources to tribal nations and to general public.
- Characterize historic and current religious associations of all sites associated with impacts of dam operating criteria.
- Characterize all cultural resource sites as to the specific associated management/research needs, i.e.; preservation, stabilization, documentation, etc.; under alternative operating criteria.
- Develop Tribal monitoring programs for evaluation of resource impacts.
- Develop mitigation strategies relative to documented site impacts.

Fish And Aquatic Resources

- Monitor adult humpback chub populations and evaluate population level trends.
- Determine historic and current character and structure of species populations.
- Develop criteria for self sustaining populations of humpback chub.
- Monitor harvested and field sampled rainbow trout to determine the contribution of naturally reproduced fish to the population.
- Define areas and conditions of current and future existing and potential interactions between native and non-native species.
- Define current and historic food base character and structure.

- Using monitoring and research programs to evaluate all test flows in RPA and potential impacts to threatened and endangered fisheries.

Riparian And Terrestrial Vegetation Resources

- Determine historic natural composition of riparian and upland communities.
- Characterize normal range of variation and ecology of species.
- Monitor impacts of dam operating criteria on the succession processes of natural vegetation communities.
- Evaluate impacts of dam operations on establishment of and impacts from exotic plant species.
- Evaluate impacts of vegetation communities of alternate dam operating criteria.
- Determine historic and current distributions, range of variation and ecology of T&E and special status species.
- Establish ecosystem requirements of special status species and determine probable impacts of proposed flow regimes.
- Monitor population changes in special status species.

Native Terrestrial Wildlife Resources and Habitat

- Define and specify ecology of native faunal components, especially threatened and endangered species.
- Determine species' natural ranges (pre and post dam).
- Define food chain associations, interdependencies, requirements, etc., for native species population targets.
- Characterize historic and current use of expected use of area by species.

- Characterize historic and current populations of Kanab Ambersnail and their locations.
- Determine range of natural variability/ecology and ecosystem requirements of wildlife occupying the Canyon.

Socio-Economic Resources

- Determine criteria and aspects that are important to or detract from wilderness experience.
- Determine adequate beach quality, character and structure for camping throughout the system.
- Determine if operating criteria maintains safe and adequate powercraft navigability in Glen Canyon and upper Lake Mead.
- Determine flow regimes necessary to maintain fish populations on 100,000 adult Trout (age class II plus).
- Define pattern of waterfowl and other wildlife use and conflicts to other uses.

CHAPTER 3

FISCAL YEAR 1998 MONITORING AND RESEARCH PROGRAM ACTIVITIES

INTRODUCTION

This chapter presents the FY1998 program activities to be conducted on the conceptual model and for the following resource areas:

- Physical
- Cultural
- Biological
- Socioeconomic
- Information Technologies

As part of the overall synthesis for each resource area scheduled for FY1998, a conceptual model will be designed to represent Colorado resource ecosystems, resources and resource attribute linkages. This system model will be used to guide monitoring and research planning, define attribute linkages, characterize key attributes, and make qualitative assessments of resource change from changing dam operations.

For each of the above resource areas, we address three criteria to define projects for FY1998. First, we review the FY 1996-97 interim monitoring program to determine which elements of the program need to be continued. This includes both monitoring and research activities ongoing through the two-year period. Second we review objectives and information

needs to assure that those specified are appropriately incorporated in the FY1998 Annual Program Plan. Third, we evaluate the Long-Term Plan to assure that FY1998 monitoring and research proposed is in fact fully supportive of programs planned and time schedules proposed in the Long-Term Plan.

THE PHYSICAL RESOURCES PROGRAM

The focus of the physical resource program is on water and sediment resources, and how they act independently and together upon other resources under alternative dam operations. Much of the monitoring and research efforts focus on critical attributes of each, such as their physical and biological properties, i.e.; water temperature, nutrients in sediment, etc.

The FY1996-97 Monitoring and Research Program

The FY1996-97 monitoring and research program activities were, in large part, an extension of activities established in the 1990-1995 period. Projects ongoing since October 1, 1995 and planned to continue until October 1, 1997 include the following:

- Determine the processes of rapid erosion and the effects on evolution and longevity of channel margin deposits.
- An Assessment of dam operation impacts on Lake Powell Water Quality.
- Maintenance of streamflow gaging network throughout the Grand Canyon.
- Monitoring sand inputs from Paria and Little Colorado Rivers.
- Measurement and processing of data from monumented cross sections.
- Computation of volumes of sand-storage changes.
- Completion of report on sand-transport algorithm for Colorado River above Little Colorado River.

- Completion of report on bed materials and resurvey of selected reaches.
- Evaluation of backwater rejuvenation along the Colorado River in Grand Canyon, AZ.
- Continuation of the monitoring of sand bars along the Colorado River; includes maintenance of the daily photographic records and sand bar surveying.
- Integration and evaluation of Glen Canyon Environmental Studies Research Findings: Biological and chemical components of Grand Canyon riverine ecosystem.
- Integration of the Glen Canyon Environmental Studies Research Findings: Sediment transport and geomorphology.

Evaluations of the above components of the FY1996-97 program reveal that the following research studies which are scheduled to end October 1, 1997 should be terminated.

- Determine the processes of rapid erosion and the effects on evolution and longevity of channel margin deposits.
- An Assessment of dam operations impacts on Lake Powell Water Quality.
- Completion of report on sand-transport algorithm for Colorado River above Little Colorado River.
- Completion of report on bed materials and resurvey of selected reaches.
- Evaluation of backwater rejuvenation along the Colorado River in Grand Canyon, AZ.

- Integration and evaluation of Glen Canyon Environmental Studies Research Findings: Biological and chemical components of Grand Canyon riverine ecosystem.
- Integration of the Glen Canyon Environmental Studies Research Findings: Sediment transport and geomorphology.

These research/inventory projects provided timely and needed input to both the scientific and management community as noted above. Monies allocated to these projects will be moved to new physical resource projects that provide synthesis in other needed areas.

Several areas of monitoring and one inventory project were included in the FY1996-97 programs and need to be evaluated for the manner in which they will be continued in FY1998. These include the following:

- Maintenance of streamflow gaging network throughout the Grand Canyon.
- Monitoring sand inputs from Paria and Little Colorado Rivers.
- Measurement and processing of data from monumented cross sections.
- Computation of volumes of sand-storage changes.
- Monitoring of sand bars along the Colorado River - includes maintenance of the daily photographic records and sand bar surveying.

Maintenance of stream flow data is important to monitoring long-term assessments of water flux in the canyon. However, new protocols need to be investigated. The existing monitoring system is proposed as a control for the next two years. A 50% budget reduction is proposed for this effort. A call for proposal (CFP) will be released to determine how budget reductions will be accommodated while maintaining at least one half of traditional water flux monitoring.

The above savings will be used to conduct a synthesis of all water flux knowledge for the canyon and development and piloting of new monitoring designs that provide acceptable levels of information needs and accuracy, are less intrusive, provide greater information for resource linkage, and are more cost effective.

Four areas of monitoring and one survey program addressed sediment flux in the canyon in FY 1997. These efforts track suspended sediment, sediment dynamics, and sediment deposition. The research program used to evaluate sandbar changes is only indirectly linked to other monitoring efforts and needs to be directly linked.

The total budget for those four monitoring and one research project will be reduced to 50% of FY1997 funding. In FY1998, a call for proposal will be released to merge all of these efforts into one project that :

1. Maintains information needs and accuracy.
2. Improves cross linkage needs to other resources.
3. Has less site intrusive protocol.
4. Is less expensive.

Responding To Information Needs

The information needs specified in 1996/97 for the FY1998 Physical Resources Program is presented in the following synopsis.

Water Resources

- Monitor changes in the physical and chemical characteristics of water flux over time.
- Monitor concentrations of chemical constituents with established EPA/state standards.

- Measure water composition and temperature and their changes over time.

Sediment Resources

- Characterize sand-bar, backwaters, and return channel target structures.
- Define target backwater ecosystems and associated flow regimes.
- Define character and structure of all beaches and backwaters in system after 1996 test flows.
- Define historical and current (character and structure) levels of river stored sediment in system and associated flow regimes.
- Determine baseline conditions.

The FY1988 Physical Resource Program

The FY1998 Physical Resources Program structure is developed to respond to the Long-Term Strategic Plan, which is structured around objectives and information needs of stakeholders. The Long-Term Strategic Plan, and this plan addresses information needs in four areas:

- Water Flux in System.
- Sediment Flux in System.
- Side Channel Interaction with Mainstem Resources.
- Mainstem Water and Sediment Flux impacts to upper Lake Mead.

Water Flux Monitoring and Research will continue in FY1998 with the following projects:

- Monitoring water flow unit values through the Grand Canyon (Lees Ferry, Grand Canyon, Diamond Creek) and LCR and Paria Rivers using traditional

monitoring and research approaches of FY1996-97. (Funding levels will be at 50% of FY1997 levels).

- Synthesis of all past monitoring of water flux in Grand Canyon, and development and pilot test of new protocols for water monitoring. (Funding level at 50% of FY1997 water monitoring).

Sediment Flux Monitoring and Research will focus on synthesis of past efforts, developing improved monitoring methodology and development of linkages to other resources. Individual projects are as follows.

- A synthesis of all past sediment flux research in the Grand Canyon with the objectives of development of attribute associations between sediment flux and flow regimes.
- A synthesis of all historical information (pre and post dam) related to sandbar dynamics. Develop associations of flow regimes and bar formation and degradation.
- A synthesis of all science and information (pre and post dam) related to sediment balance in the riverine system by reach. Focus is on integrating information on bars, flux and storage to provide a method for determining sediment balance.
- Continue the sediment monitoring of FY1997 (in cross sections, flux). However, merge all monitoring into one project, eliminating duplication, and establishing protocols so as to provide best time and space assessments of parameters in a given reach. Also, merge sandbar research and mapping

programs into this new more comprehensive sediment monitoring approach and link to camping area monitoring in socioeconomic program..

- Develop a new sediment monitoring protocol by reach that relates all mainstem channel dynamics related to sediment and flow. The intent of the new protocol is to develop base information for developing future algorithms and associated information to evaluate changes in sediment balance by reach through time.

Side Channel Water and Sediment Interaction with mainstem resources is an area where considerable knowledge needs to be generated regarding water quality, sediment flux and nutrient levels. Following are FY1998 proposed projects.

- Synthesis of all research and monitoring of marsh, back channel, and back water and areas below side channel confluence and their relationships to dam operations associated sediment flux and interactive side channel and mainstem dynamics of differing flow regimes.
- Synthesis of information associating sediment nutrient level in reaches below side channels to variable flow regimes.
- Continuation of current unit value monitoring protocols for LCR and Paria, but at 50% budget levels.
- Development of new monitoring protocols for at least two side channels, LCR and Paria and pilot new protocol.

Mainstem Water and Sediment Flux impacts to upper Lake Mead have never been determined for differing dam operations criteria. Significant confounding results in the system due to the length of the river segment between Glen Canyon Dam and upper Lake

Mead, and operations of Boulder Dam which impounds Lake Mead. If the riverine segment were short, and Boulder Dam operations were constant, impacts of Glen Canyon Dam operations could be easily monitored in upper Lake Mead.

Two efforts are proposed for the upper Lake Mead interface as follows:

- Resurvey of Lake Mead sediment delta through BOR cooperative agreement. Use protocol of 1962 delta survey.
- Synthesis of existing knowledge relating changes in sediments in upper Lake Mead to variable dam operations criteria and then associated changes in flora and fauna.

CULTURAL RESOURCES

The FY 98 cultural resources annual plan includes activities that address information needs that have been identified by stakeholders. Activities proposed for this year address many of these needs; activities that respond to other needs will be conducted in the following years. Scheduling of activities is a function of available information, resource priorities and funding.

The FY1996-97 Monitoring and Research Program

The cultural resources activities specified in the FY 96 and FY 97 programs are required under the Programmatic Agreement (PA) that has been in place since 1994. This program is a separate, but complementary program, to the GCMRC cultural program. The PA program is a legal requirement of the Bureau of Reclamation (BOR) and the National Park Service (NPS) for compliance with the NHPA. The activities that have conducted under the PA program include monitoring of specific cultural resources identified during field inventories by the agencies and the Native American tribes. Monitoring techniques include

photographic documentation, instrument mapping, and testing of culture resources that are currently deteriorating. The PA activities for FY 96 and FY97 have been approved and funded by the BOR. On-going projects since October 1, 1995 through September 30, 1997 include:1) archaeological monitoring in the Grand and Glen Canyon areas by the NPS; 2) Hopi Tribal monitoring trips; 3) Paiute ethnobotanical monitoring; and 4) cultural resource monitoring by the Hualapai, Navajo, and Zuni tribes. An evaluation of these activities indicates that they need to be continued under the PA program.

At the request of the PA parties, who are acting as members of the Adaptive Management Work Group (AMWG), PA activities proposed for FY 98 may be included within the GCMRC annual plan. Requests from the PA parties will be directed through the AMWG process to become part of the GCMRC directives. At the present time, activities that will be channelled by the PA parties into the AMWG process have not been specified for FY 98. However, it is anticipated that some of the activities currently being undertaken will be proposed and incorporated into the FY 98 annual plan.

Stakeholder Objectives and Information Needs

Several objectives and information needs have been identified by stakeholders for cultural resources. The stakeholder objectives include: 1) Preserve *in situ* of all the downstream cultural resources and take into account Native American cultural resources concerns in the Colorado River corridor; 2) If *in situ* preservation is not possible, design mitigative strategies that integrate the full consideration of the values of all concerned tribes with scientific approach; 3) For participating Native American tribes, protect and provide physical access to cultural resource properties for religious purposes within the river

corridor; and 4) Develop appropriate research strategies which maximize data collection from mitigation and monitoring efforts for understanding human use and occupation in the canyon.

Specified Information Needs Addressed in FY 98 Annual Plan

Information needs have been identified by the stakeholders to address the above objectives. Portions of many of the information needs are addressed in the proposed activities for this FY 98 annual plan. The information needs that are included within this plan are: 1) Develop data and monitoring systems to assess impacts; 2) Develop data to assess risk of damage and loss from varying flow regimes; 3) Develop tribal monitoring programs for the evaluation of impacts to cultural resources; 4) Develop a predictive model of geomorphic processes that are related to archaeological site erosion; 5) Design and develop integrated relational data systems to support management and research program goals; 6) Develop technology / procedures for providing relevant/ protected data to appropriate groups/tribes; and 7) Ensure confidentiality of data regarding location of cultural sites.

Specified Information Needs Not Addressed in FY 98 Annual Plan

Some information needs are not included in the FY 98 annual plan. Activities that address the needs not included in this plan will be scheduled in the following years because implementation is contingent upon information generated from other activities. These information needs include: 1) Develop mitigation strategies related to documented dam impacts to sites by monitoring assessments, and 2) Characterize resource values through scientific (research)study.

FY1998 Cultural Resources Monitoring and Research Activities

Four activity areas are proposed for the FY 98 Annual Plan. These activities respond to the information needs identified by stakeholders and the Long-Term Strategic Plan

developed by the GCMRC and stakeholders. In addition, these activities form the basis for projects that may be proposed in subsequent years.

1. Synthesize existing data

Monitoring data has been collected on cultural resources by the NPS and the tribal groups for approximately four years. In part, this information has been partitioned into areas where different entitities have jurisdiction. The existing information needs to be compiled into the GCMRC's study area and synthesized. The objectives of this effort are: 1) determine if baseline information is sufficient for sites that have the potential of being impacted by dam operations; 2) determine if existing monitoring data are sufficient and evaluate it relative to the baseline information; 3) organize data base relative to site classes (such as structures featuures scatters, prehistoric, historic, TCPs, rock art sites, monitoring frequency, monitoring techniques, monitoring history, etc.; 4) identify resources that are experiencing impacts; 5) evaluate data base relative to classes of impacts identified in the monitoring assessments (i.e., physical and visitor-related impacts); 6) determine if additional information is necessary. Finally, data on isolated occurrences (IOs) must also be synthesized. IOs may represent the last remains of site materials, or they may consititute the first exposures of buried sites. IO data need to be analysized to understand site formation (and degradation) processes relative to dam operations.

2. Develop a risk assessment for cultural resources from varying flow regimes

The objective of these efforts is to understand the potential risks to cultural resources from various flow stages and the related erosional processes and their impacts to the resources. Some examples of these impacts include inundation of resources and bank slumpage and lateral retreat resulting in erosion of sediments with archaeological deposits. Flow regimes at various

stages will be mapped in combination with resource locations to determine the likelihood of inundation risks.

The existing work on geomorphic process and archaeological site erosion needs to be assessed for the status of knowledge relative to site impacts resulting from dam operations. This assessment should evaluate the baseline and monitoring data base developed above against the information available in current models. In addition, sediments recently deposited from the beach/habitat building flow need to be mapped and compared to past deposits and resource locations. This information should provide a basis to determine the possible extent of resources that may be impacted by these large flood episodes. Together, this information should provide data to formulate hypotheses to test the geomorphic model for predictive benefits to both locate additional sites and develop site mitigation strategies to conserve resources.

Finally, the ability of high flows to stabilized predam terrace deposits needs to be investigated. These objectives can be accomplished through the mapping of the "spike flow" deposits in selected areas where archaeological resources have been mapped at tight contour intervals.

3. Develop tribal programs to assess resource impacts

Tribal cultural programs are an important component of the GCMRC resource assessments. These programs supply different information on resource impacts that complement conventional assessments; they help to provide information on the full range of important qualities of the resource. Tribal programs also provide important technical information about the group's resources.

Although specific tribal proposals have not been developed by the tribes as yet, the GCMRC proposes efforts in three areas. These include: 1) a cultural and natural resource

assessment with the Hualapai Tribe that will be co-funded by the GCMRC and an outside foundation; 2) a tribal GIS resource mapping project that will incorporate general areas of resource concerns and facilitate consultation with tribal groups; and 3) a student intern program that will utilize students from participating Native American tribes to conduct necessary studies and activities.

4. Develop appropriate data systems and related technology

Cultural resource data require systems and technology that addresses the confidential and restricted nature of the information. The GCMRC proposes to develop data systems and technology that support management and research program goals while providing relevant, but sensitive, data to the appropriate tribe. In order to achieve these objectives, the GCMRC proposes to develop protocols with tribal representative concerning sensitive and confidential data. Protocols will be developed in a series of workshops that address tribal and agency concerns for the appropriate treatment and storage of sensitive data. Efforts to address data concerns will begin in early Spring.

BIOLOGICAL RESOURCES

Program Goals

The synthesis, inventory, monitoring and research activities for biological resources is intended to develop information about the structure and function of the Colorado River ecosystem in Glen and Grand Canyons (the ecosystem), as well as "... the effects of the Secretary's actions..." on the ecosystem. The effort will provide the knowledge base required to implement ecosystem management strategies within an adaptive management framework.

The development of a fundamental information base on the structure (components) and function (processes) of the ecosystem is a prerequisite to prediction of ecosystem effects from

"the Secretary's actions." It is key that relationships between the biotic and abiotic components of the ecosystem be addressed, for without an understanding of these relationships, one will not be able to predict the effects of "the Secretary's actions" on critical biological resources and the ecosystem, in general. Knowledge regarding the effects of natural and anthropogenic factors on biodiversity and ecosystem dynamics, and the adaptation of communities and organisms to those factors, is needed in order to propose management alternatives for achieving specified management objectives.

The FY 1996-97 Biological Resources Interim Program

Monitoring and research studies initiated in FY 1996, as part of the experimental flood have been continued with minor modifications in funding for FY 1997. Studies being conducted in FY 1997 are listed below.

FY 1997 Monitoring and Research Activities

I. Aquatic Food Base

-- Monitor the effects of flows on the aquatic food base in the Colorado River downstream from Glen Canyon Dam, AZ (Dean Blinn, PI)

-- Continuation of the standardized monitoring of the aquatic food base in the Lees Ferry reach. Includes determination of the standing crop of algae and invertebrates, as well as species composition and drift of algae and invertebrates. (William Persons, PI)

-- Aquatic productivity of the Colorado River in Cataract Canyon, UT (Dean Blinn, PI).

[Note: This contract is funded through outside funds related to the Selective Withdrawal Studies.]

II. Fish (native and non-native)

-- Arizona Game & Fish Department (AGFD) monitoring and research program, including sampling backwaters, mainstem, nearshore and tributary mouth habitats to assess fishery resources and habitats in Glen and Grand Canyons (William Persons, PI).

-- Continuation of AGFD standardized hoop net monitoring of humpback chub spawning population in the lower 1200 m of the Little Colorado River (William Persons, PI)

-- AGFD monitoring the status of the trout fishery in the Lees Ferry area and evaluate current sampling programs and protocols (William Persons, PI)

-- Back-water temperature study (Jeannie Korn, PI)

III. Riparian Vegetation

-- Second year transition monitoring of riparian plant habitats in Glen Canyon National Recreation Area and Grand Canyon National Park, AZ (Mike Kearsly, PI and John Spence)

-- Transition monitoring of the riparian plants and beach habitat building in Grand Canyon National Park (Mike Kearsley, PI)

-- Coordination of the riparian vegetation studies in the lower Grand Canyon corridor below National Canyon to Lake Mead (Hualapai Tribe, Kerry Christensen, PI)

-- Backwater and marsh rejuvenation (Larry Stevens, PI)

IV. Native Terrestrial Wildlife Resources and Habitat

-- Monitoring of riparian birds along the Colorado River from Glen Canyon Dam to Lake Mead - 1997 (Jim Petterson, John Spence, Kerry Christensen, PIs)

-- Monitoring of riparian birds along the Colorado River from Glen Canyon Dam to Lake Mead - 1997 (John Spence, PI)

V. Endangered and other special status species

-- Continuation of integrated program for monitoring southwestern willow flycatchers along the Colorado River (Jim Petterson, PI)

-- Assess, mitigate and monitor the impacts of an experimental high flow from Glen Canyon Dam on the endangered Kanab Ambersnail at Vasey's paradise, Grand Canyon, AZ (Larry Stevens, Dennis Kubly, Jim Petterson, PIs)

-- Support for Implementation of the Glen Canyon Dam Biological Opinion (Owen Gorrnan, PI)

-- Coordination of the aquatic resource studies in the lower Grand Canyon corridor below National Canyon to Lake Mead for Transition Monitoring and Endangered Species Act requirements (Hualapai Tribe, Ben Zimmerman, PI)

-- Kanab Ambersnail coordination (Larry Stevens, PI)

-- Monitoring and evaluation of the population recovery of the endangered Kanab Ambersnail at Vasey's Paradise (Vicky Meretsky, PI)

[Note: To provide technical support to the NPS, FWS, AGFD, and BOR on the statistical evaluation of the Kanab Ambersnail population recovery at Vasey's Paradise. Due to Dr. Meretsky's transfer to Indiana University.]

VI. Synthesis and Integration

-- Integration and evaluation of Glen Canyon Environmental Studies Research Findings: Biological and chemical components of Grand Canyon riverine ecosystem (Duncan Patten, PI)

-- Grand Canyon data integration project - endangered fish (Steve Carothers, PI)

These monitoring and research studies provided timely and needed input to both the scientific and management community. Draft reports on the FY 1996 activities have only recently been received and are currently being reviewed for their contribution to the goals and

objectives described in the DRAFT GCMRC long-term monitoring and research strategic plan. As noted above, with minor modifications in funding, these activities have been continued in FY 1997. Activities scheduled to be completed in FY 1997 will be reviewed regarding decisions on whether or not to continue those activities and monies associated to monitoring and research activities which are terminated will be reallocated to new biological resource projects that provide synthesis in needed areas.

The Biological Resources Program intends to award its FY 1998 monitoring and research studies through a competitive request for proposals process, as discussed in the long-term plan.

Responding to Stakeholder Objectives and Information Needs

Consultation with Stakeholders from May though August 1996, led to the development of a set of Stakeholder Objectives and corresponding Stakeholder Information Needs. These are shown in Appendix C. Subsequently, meetings were held with scientists from August through October, 1996 to step the Stakeholder Information Needs down into a knowledge base (i.e., scientists' knowledge & scientists' need to know), and potential elements of a monitoring and research program (i.e., scientists' monitoring statements & scientists' research questions). These DRAFT resource sheets (Appendix A) are still undergoing review and revision, primarily with respect to the knowledge base and potential monitoring and research activities.

The FY 1998 biological resources program is based on (1) the DRAFT Long-term Monitoring and Research Strategic Plan, which calls for an emphasis on synthesis activities and the development of a conceptual systems model, (2) the stakeholder objectives and information needs shown in Appendixes A and C, and the monitoring statements and research questions contained in the DRAFT resource sheets (Appendix A).

The FY 1998 Biological Resources Program

For FY 1998 synthesis, monitoring and research activities are proposed in several different areas in response to stakeholder objectives and information needs. These include the aquatic food base, humpback chub and other native fish, trout, riparian vegetation, and selected threatened and endangered species (i.e., Kanab ambersnail, Southwestern Willow Flycatcher, Bald eagle, and Peregrine Falcon).

It is anticipated that the biological resources program will be level funded at FY 1997 levels. The need to engage in synthesis and modeling activities implies that one will need to carefully evaluate the support of needed monitoring and research efforts.

Aquatic Food Base

Many wildlife species, especially fishes, depend on the aquatic food base for their survival. Fluctuations in the aquatic food base resulting from dam operations or other factors may trigger changes in some or all of the populations of native and non-native fish species. Recognizing its importance, the stakeholders have clearly stated as an objective the maintenance or enhancement of the aquatic food base in Glen and Grand Canyons.

In response to this stakeholder objective, the FY 1998 program will include a synthesis of existing information, both published and unpublished, concerning the aquatic food base in Glen and Grand Canyons, its likely response to alternative dam operations, and its importance to the trophic dynamics of the ecosystem, especially native and non-native fishes. Following this synthesis, specific research needs will be developed and prioritized.

Development of an appropriate aquatic food base monitoring scheme will need to address the why, where, when, and how sampling should be conducted. Parameters which should be considered for monitoring include standing stock, productivity, and species composition and

dominance of algae, macrophytes, and aquatic invertebrates in Glen and Grand Canyons and their associated tributaries. In addition one should consider monitoring the export of algal clumps downstream and the overall contribution of detritus to the trophic dynamics of the ecosystem.

Complementary with the biotic sampling we will call for the measurement of such abiotic parameters as water temperature, dissolved oxygen, pH, and conductivity. Also, substratum microhabitats, nutrient concentrations, Secchi depth, water velocity, and/or stage and water depth should be considered for monitoring.

Fish

Fish are an important part of the ecosystem because of their trophic role, their important recreational value, and because some are listed as threatened or endangered species. Changes in the structure or function of the ecosystem resulting from alternative dam operations could have either harmful or beneficial effects on fish populations. The stakeholders have recognized the importance of fish by developing six stakeholder objectives and twenty-nine stakeholder information needs to specifically address native and non-native fish concerns.

Humpback chub and other native fishes

As part of the FY 1997 program, a data integration project is being conducted on humpback chub and other endangered fishes. The main focus of this effort is to identify factors that limit reproduction, development, recruitment, or survival of humpback chub and other native fishes. The interim results of this effort which should be available in late February, 1997 will be used as the basis for deciding if additional synthesis work is needed, and what types of research projects should be considered. It is hoped that this work will bring more clarity to the importance of water temperature, water clarity, role of tributaries, availability of backwaters,

suitability of irregular shoreline habitats, differing flow regimes, food availability, habitat and dietary requirements of very young fish, and competitive and predatory interactions with non-native fish to the maintenance or enhancement of existing populations of humpback chubs and other native fishes.

For a population of fish to remain viable, it must have successful recruitment. The three major factors thought to influence successful fish recruitment are: hydrology and transport, food production and availability, and larval fish quantity. In general for fish, the timing of reproduction must coincide with local food production cycles, and larvae must be transported to a favorable nursery habitat for there to be successful recruitment. Food production and availability, habitat quality and availability, and competitive interactions can all affect with slower growth rates potentially increasing the duration of high risk life stages, which can result in increased mortality and reduced recruitment.

Pilot monitoring activities developed as part of the FY 1998 program will be aimed at understanding the links among dam operations and the resulting flow regimes, spawning, larval transport, trophic dynamics, and recruitment. Data will be collected that provides information regarding the status and trends of humpback chub and other native fish species. Parameters to be considered for monitoring will include appropriate estimates of abundance, species composition, age structure, reproduction, recruitment and growth, as well as habitat condition and availability, food availability and diet, disease and condition, and competitive and predator-prey interactions with non-native fishes.

Development of an appropriate humpback chub and native fish monitoring scheme will need to address the why, when, where, and how of sampling, with appropriate recognition of the

long- or short-lived nature of the species being monitored, as well as their special (i.e., threatened or endangered) status, if any.

Trout

Trout were first introduced into tributaries of the Colorado River in Glen and Grand Canyons in the 1920s. Following the construction and closure of Glen Canyon Dam in 1963, trout have become an important recreational resources in the 25 km Lees Ferry reach below Glen Canyon Dam. This is primarily due to the high primary productivity resulting from the high water clarity, the presence of coarse substrates, the maintenance of significant populations of benthic macroinvertebrates, the reduced water temperatures, and the regular stocking and management of the recreational trout fishery.

Alternative dam operations and the resulting flow regime can affect the food base for trout, as well as the mortality of adult, juvenile, and larval fish through stranding, dewatering, and displacement.

A synthesis of existing information (both published and unpublished data) concerning the trout fishery and its likely response to alternative dam operations will be conducted. Following this synthesis, specific research needs will be developed and prioritized.

Pilot monitoring activities developed as part of the FY 1998 program will focus on growth, survivorship, and changes in population structure, including the contribution from natural reproduction. Parameters to be considered for monitoring will include appropriate estimates of abundance, age structure, reproduction, recruitment and growth, as well as habitat condition and availability, food availability and diet, and disease and condition.

Development of an appropriate trout monitoring scheme will need to address questions of the why, when, where, and how, of sampling and should concentrate on growth, survivorship,

and changes in population structure, including the contribution from natural reproduction over time in the Lees Ferry reach.

Reasonable and Prudent Alternative and the Biological Opinion

The stakeholder identified work related to the reasonable and prudent alternative as an important objective. Following consultation with the U.S. Fish and Wildlife Service and the Bureau of Reclamation, GCMRC will evaluate how its proposed FY 1998 fish and aquatic resources activities relate to the reasonable and prudent alternative and the biological opinion. Where needed, appropriate revisions will be proposed.

Riparian Vegetation

The riparian vegetation communities along the Colorado River were changed drastically by the installation of Glen Canyon Dam. Today the riparian zone is composed of three nearly distinct communities: (1) the old high water zone (OHWZ), (2) the new high water zone (NHWZ), and (3) the near shoreline wetland communities. These riparian communities are important for stream bank stability, fish and wildlife habitat, and aesthetic and recreational values. Their importance is recognized by the stakeholders objective to preserve or restore riparian communities affected by dam operations.

A synthesis of existing information (both published and unpublished data) concerning the riparian vegetation zone, its likely response to alternative dam operations, functional relationships of the organisms in the riparian zone, and the resulting impacts on associated riparian species will be conducted. Following this synthesis, specific research needs will be developed and prioritized.

Pilot monitoring activities developed as part of the FY 1998 program will focus on the monitoring of species composition, abundance, and their spread or contraction. Development of

an appropriate riparian vegetation monitoring scheme will need to address questions of the why, when, where, and how of sampling.

Native and special status species

The stakeholders have recognized in their development of objectives the importance of native and other special status species. Specifically, they have called attention to the Kanab ambersnail, Southwestern willow flycatcher, Peregrine falcon, and Bald eagle. They have called for information which will help protect, restore, or enhance the survival of native and special status species. This includes a focus on appropriate age-class distributions, food availability, and habitat needed to ensure the sustainability of these populations.

In each case, the FY 1998 biological resources program will call for a series of monitoring and research activities directly linked to providing information that can contribute to these objectives. As with the previous areas, GCMRC will begin with a synthesis of existing information and the initiation of pilot monitoring activities. In the case of the Kanab ambersnail, specific activities will be focused on addressing the requirements of the biological opinion, as appropriate.

Other studies

Given the limited amount of funds available for the FY 1998 program little work is anticipated on the remaining stakeholder objectives. Limited scoping studies to better define appropriate monitoring and research activities may be considered.

The Contribution of the FY 1998 Program to the Long-Term Plan

The FY 1998 program is clearly linked to the stakeholder objectives and information needs. The information gained from the proposed synthesis, monitoring and research activities when combined with the results of the conceptual modeling effort will make significan

contributions to our undersatnding f the key componenst and processes which structure the Colorado River ecosystem in Glen and Grand Canyons. This information is likely to result in significant revisions and improvements to the development of the long-term monitoring and research plan. It is anticipated that further pilot monitoring activities will be initiated in FY 1999 and as a result of these efforts, the development of a conceptual systems model, and associated synthesis and research activities, a sound long-term monitoring and research program can be in place by FY 2000.

THE SOCIO ECONOMIC RESOURCES PROGRAM

There are many socio-economic resources associated with the Grand Canyon riverine environment including recreation (i.e., boating, fishing, hiking, sightseeing), electric power, and water. Further, due to the biological and geologic distinctiveness of the Grand Canyon, the park has acquired national and international recognition, and all of the resources in the canyon are considered to be significant to the public.

The FY 1996-97 socio-economic resources program was reduced from the FY 1994-95 program, where significant effort occurred on evaluating non-market impacts of alternative dam operations. Although several projects in other resource areas have linkages to socioeconomic parameters and resources, (i.e., trout, sandbars, birds) only two projects were specifically oriented to socioeconomic assessments of alternative dam operations as follows:

- Transition monitoring of the riparian plants and beach habitat building in Grand Canyon National Park.
- Beach camping area changes resulting from the beach habitat building flow.

Both of these projects relate to changes in recreation benefit resulting from a modified flow regimes. Both projects are scheduled for completion in FY 1997, and will be terminated. However, after a synthesis project in FY 1998 they will be redesigned for implementation in FY 1999.

Information needs specified for this resource area cover issues of camping, beaches, water safety, sports fishing and wildlife (waterfowl) viewing and hunting. Following are a synopsis of specified information needs.

- Determine criteria and aspects that are important to or detract from wilderness experience.
- Determine adequate beach quality, character and structure for camping throughout the system.
- Determine if operating criteria maintains safe and adequate powercraft navigability in Glen Canyon and upper Lake Mead.
- Determine flow regimes necessary to maintain fish populations on 100,000 adult Trout (age class II plus).
- Define pattern of waterfowl and other wildlife use and conflicts to other uses.

The FY 1998 Program will emphasize several areas through monitoring and research projects as well as cooperative and volunteer programs as follows:

- Develop synthesis of camping beach changes through time associated with differing flow regimes, i.e.; camping area, vegetation changes, etc.
- Monitor trout anglers use and satisfaction through creel census and cooperative monitoring program with fishing guides and trout unlimited.

- Develop new monitoring protocol for long-term assessments of camping beach change from differing flow regimes. Implement pilot.

The Long-Term Plan proposes several areas of assessments for camping beach changes, angler attitudes, boater safety, cost benefit analysis model, user attitude surveys, etc. The proposed projects are considered most critical for implementation in FY 1998.

INFORMATION TECHNOLOGIES

Extensive data and information currently exists in the GCMRC relating to resource levels, quality, relationship, to other resources, etc. Further, potentially equal amounts of data and information exist within museums, universities, agencies, etc. This information represents a valuable resource to researchers, managers and interested stakeholders, yet, much of it has not been analyzed. Its potential utility for problem solving, formulating improved management guidelines, modeling relationships, or increasing understanding of the various resources and system under study, justify an aggressive program in information technologies.

FY 1996 and 1997 programs in information technology were not specifically in GCES plans. However, programs did exist in DBMS and GIS, as well as information transfer to stakeholders. Significant on demand activity was occurring in cultural resources and on information needs relating to the biological opinion.

Information Needs have not been explicitly defined for the information technologies area. However, significant needs in this area can be interpreted from the four major resource areas. The FY1998 information technologies program has, therefore been defined from these defined information needs, until explicit needs can be specified.

1. Development of protocols for data collection, processing and use.

2. Development of extensive databases across all resources and a database management system.

3. Development of a robust geographic information system to accommodate multiple layers associated with all resources of interest to stakeholders.

4. Development of databases associated with remotely sensed data, here to date not incorporated in the GCES database system.

5. Stakeholder direct access to selected data and information in the database management system and GIS.

6. Development of outreach programs to transport data and information to stakeholders.

FY1998 Information Technologies have been defined for four areas; Database Management Systems, GIS, Increasing stakeholder access to data and technology, and outreach programs.

A general principle for database management is that all data will be freely available. However, is some cases, such as archaeological-site data, data that Indian Tribes define as sensitive, or information on localized endangered species, a level of confidentiality will be necessary. Explicit protocols will be developed to ensure confidentiality. Specific projects proposed are:

- Revise/develop Mega-data protocols and DBMS protocols to expand current system capability.
- A centralized, integrated database will be developed to facilitate exchange of information among projects. Portions of the system will be distributed. Monitoring, inventory and research data will be included.

- Protocols will be developed to cross-reference files from centralized to distributed systems.
- Develop direct access to DBMS for managers/stakeholders.

Geographic Information Systems (GIS) will be used for data storage analysis with transfer to users. In FY1998 two efforts are proposed.

- Revision of GIS protocols to expand system.
- Movement of priority information needs into GIS where appropriate.
- Develop GIS access for managers/stakeholders .

Two primary information technology thrusts are planned to give greater information access to stakeholders.

- Develop home page access for stakeholders.
- Develop and implement programs for direct access and use of GCMRC Lake Powell data and Colorado River water and sediment flux data.
- Develop and implement a training program for stakeholders on the GCMRCDBMS.
- Develop and implement a training program for stakeholders on ARC view for existing GIS data.

CHAPTER 4

PROGRAM ADMINISTRATION

ORGANIZATION STRUCTURE

The GCMRC is restructuring to accommodate the challenges of both the Long-Term Plan and the FY1998 Annual Program Plan. Three program managers (physical, biological, and cultural) will manage the individual resource areas and together with the chief focus on evaluation of ecosystem resource interactions and integration under differing dam operations. An information technologies director will oversee an extensive program of data analysis and management, GIS technology and transfer.

Positions that will be critical to stakeholders are defined in the following text as to their primary roles.

Logistic Coordinator. The GCMRC has decided to conduct all logistics for its programs internally in FY1998-99. This effort is to effect a 30% reduction in logistics costs. All logistics river trips, air photography, rescue, etc, will be programmed by the logistics coordinator. An annual logistics plan will be drafted, incorporating workshops for principal investigators, and published guidelines for permitting and reporting. All logistics will be controlled at this point.

Coordinator of Reviews. All competed proposals, PI reports, GCMRC reports, cooperative programs, etc. will be subjected to specific independent review protocols of the center. Monitoring and research projects to be subjected to competitive reviews and awards

will be specified each year in the Annual Program Plan. This program, under the associate center chief will be managed by a coordinator. The coordinator can be contacted by PIs and/or their organizations, managers and other stakeholders to access critical documents detailing GCMRC programs.

A Programmatic Agreement Task Group is proposed to be linked to the Cultural Resource Program it will consist of the GCMRC Cultural Program Manager and BOR and NPS program managers. This group would address responsiveness of the center to critical elements of the programmatic agreement mandated to NPS and BOR.

A Biological Opinion Task Group will be linked to the Biological Resources Program Managers office. It will assure the center responds to the monitoring and research needs of the BOR and USFWS.

Coordinators will be specified for Data Base Management, GIS and technology transfer programs. These positions will assure critical timely support to managers and other stakeholders in their interactions with the GCMRC, especially in their requests for information.

Although the center will not utilize a senior scientist position after FY1997, it will select a Science Advisory Board. A group of six prominent scientists will be selected to provide guidance to the center on long-term and annual plans, program structure and information technology. The group will meet annually with center staff to provide council on overall program direction.

PROGRAM SCHEDULE

The schedule for implementation of the FY1998 Annual Program Plan is as follows:

March 1, 1997	Secretary Approval of Plan
April 1, 1997	Release of CFPs
June 1, 1997	Award of Proposals
July 1, 1997	Approval of NPS permits
August 1, 1997	Release of Logistics Plan for FY1998 program
April 1, 1998	First Progress Report due
July 1, 1998	Second Progress Report due
September 1, 1998	Final Draft Report due
October 1, 1998	Final Report due with all contract deliverables

All research proposed by GCMRC program managers and scientist with annual salary/operating expenses greater than $20,000 will also require an external review and be included in the Annual Program Plan for secretary approval. Such projects, if one year in nature, will also conform to the above reporting schedule.

BUDGET

The FY1998 budget for the Adaptive Management Program was proposed in the 1996 BOR budget process at approximately $6.9 million. The GCMRC feels the budget level will accommodate the FY1998 Annual Program Plan, if the plan is approved without significant changes.

Following are the potential budget allocations toward the FY1998 Adaptive Management Program.

BOR Budget	000 of $
• BOR Administration of AMP GCMRC budget	350
• Overhead Services BOR	350
• Overhead Services MSGS	220
• Personnel (PFT, term, contract)	1,200
• Information Technologies	425
• Logistics	480
• Biological Resources Science	1,600
• Physical Resources Science	850
• Cultural Resources Science	1,400
• Socioeconomic Resources Science	250
	$ 7,125,000

APPENDIX A

RESOURCE SHEETS

Note: The resource sheets reflect changes resulting from comments submitted to the GCMRC as of January 21, 1997.

Monitoring and Research Planning
Water Resources #1

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' Need To Know	Scientists' Monitoring Statements	Scientists' Research Questions
General Goal: The Secretary Shall operate Glen Canyon Dam in a manner fully consistent with the preferred alternative and subject to the Grand Canyon Protection Act of 1992, the Colorado River Compact, the Upper Colorado River Basin Compact, the Water Treaty of 1944 with Mexico, and the provisions of the Colorado River Storage Project Act of 1956, and the Colorado River Basin Project Act of 1968 that govern allocation, appropriation, development, and exportation of the waters of the Colorado River Basin.					
Maintain chemical and physical characteristics of water at levels appropriate to support physical, biotic, and human resource needs of various ecosystems.	1. Determine changes in the physical and chemical characteristics over time. 2. Determine concentrations of chemical constituents in comparison with established EPA/state standards.	1. Canyon water characteristics are a function of Lake Powell water. 2. Lake Powell water release characteristics are a function of dam operations and they are variable over time. 3. Conductance at several sites in the Canyon is known. 1. Past daily average discharge are known for: 1. Lees Ferry 2. Grand Canyon 3. Paria 4. LCR-Cameron 2. Discharge routing model exists that predicts discharges to 45,000 cfs in all canyon reaches.	1. Ability to predict downstream water temperatures in mainstem and back water from dam release on basis of season and stage. 2. Influence of flow variables on aquatic biota, especially temperature and sediment. 3. Long-term phosphorus changes are not known and not predictable. 4. Levels of phosphorus, nitrogen and salinity for comparisons to standards. 5. Interactive relationship between tributaries and springs and mainstem water temperature. 6. Physical and chemical water trends, such as salinity, relative to dam operations.	1. Monitoring temperature through canyon corridor. 2. Monitor water temperature to determine aquatic productivity. 3. Monitor dissolved nutrient changes from dam to Lees Ferry. 4. Monitor nitrogen and phosphorus levels in stored sediment and sediment being deposited. 5. Determine appropriate water quality standards & evaluate water quality against established standards. 6. Monitor bacteria levels. 1. Monitor unit values of stage and maintain stage discharge relations at: • Lees Ferry • above LCR • Grand Canyon • Diamond Creek • Paria	1. Determine effect of dam discharge on temperature. 2. Determine and model longitudinal rate of water temperatures increase throughout the canyon. 3. Determine the relationship between flow and temperature. 4. Determine temperature variation in backwaters. 5. Determine changes in phosphorus salinity levels and their association to dam operations. 7. Determine Lake Powell water quality changes due to dam operations. 1. How do reach average water velocity at very low flows affect the accuracy of the discharge routine model?

Monitoring and Research Planning
WATER RESOURCES #2

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' Need To Know	Scientists' Monitoring Statements	Scientists' Research Questions
		3. Hourly dam releases completed from power generation data are available. 4. Reach average water particle velocity at steady 15,000 and 45,000 cfs and unsteady releases with daily mean of 15,000 cfs. 5. Know average water particle velocity in Glen Canyon reach at steady 5,000 cfs. 6. Past stage at 30-50 sties for various releases regimes. 7. Some information on flow from ungaged springs.	7. Relationship of dam operations to bacterial levels, especially MLIS. 8. Effects of variability in water quality in Lake Powell to forebay/discharge quality. 1. Unit values (15 min. values) of discharge at: Lees Ferry, above LCR, Grand Canyon, Diamond Creek, lower LCR reach, Paria. 2. Reach average water velocity at low flows. Frequency of flooding from ephemeral tributaries (important for aquatic food base modeling). Ability to calculate stage at a given location and time. (Model needs to be widely available).	2. Monitor stage and discharge at base flow below Blue Springs area for temperature, discharge, and chemical, physical characteristics to mainstem T&E species. 3. Monitor unit values of stage and discharge in LCR near Cameron. Hourly hydrograph of lower LCR (Cameron gauge is of limited value to fisheries biologists). 4. Monitor base flow discharge on • Diamond Creek • above Kanab Creek • Havasu Creek • possibly Spencer Creek for T&E species. Use event recorders (e.g., daily camera) monitor flows at the mouths of the four large tributaries (Paria, LCR, Kanab Creek, Havasu). Fisheries need.	Contingency plans for rapid study of unpredictable events (floods, debris flows, fish kills, exception releases, etc.)

Monitoring and Research Planning
SEDIMENT RESOURCES #1

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' need to know	Scientists' Monitoring Statements	Scientists' Research Questions
1. The overall resource management target is to maintain a range of sediment deposits over the long-term, including an annually flooded bare sediment (unvegetated) active zone, a less frequently flooded vegetated zone, terraces (within the 45,000 cfs river stage), and backwater channels. The goal of managing sediment resources will be on a reach scale basis. Should significant and localized adverse impacts occur, site specific mitigation would be considered along with possible modifications to dam operations.					
As a minimum for each, maintain the number and average size of sandbars between the stages associated with flows of 8,000 and 45,000 cfs and the number and average size of backwaters at 8,000 cfs that existed during baseline conditions.	1. Characterize sandbar, backwaters, and return channels target structures. 2. Determine changes in sediment storage and define balances and hydraulic processes necessary to maintain target sandbar levels. 3. Evaluate historical sandbar change. 4. Develop methods for predefining change in sandbar character structure under alternative dam operating criteria. 5. Determine a baseline.	1. Enough sediment exists in the system under current regime to match sandbar formation under interim flows, but insufficient sediment exists for regimes of the 1880s. 2. Data base exists for sandbar changes during post dam operations. 3. Can predict amount and area distribution of sand deposition from tributaries in mainstem channel and sandbars. 4. Sand channel monitoring sediment transportation modeling accurately monitor sand in channel.	1. Where sand in the Glen Canyon reach comes from. 2. Monitor number, size and morphology of sandbars and backwaters at various flow regimes. 3. Synthesize and evaluate sand bar data from mid 1970s to present.	1. Monitor flow and sediment input from the Paria and LCR tributaries. Establish observer system to monitor occurrence and size of debris flows. 2. Monitor sand stored in the channel bed and sandbars in the Glen Canyon, Marble Canyon, and Grand Canyon reaches. 3. Monitor sand in sand pools below main side streams (i.e., LCR). Monitor physical occurrence of backwaters and shallow channel side waters suitable for young fish, including HBC fishery needs.	1. Analyze historic debris flows and their effect on the ecology of the riverine system under low flow regimes. 2. Estimate sediment contributions from ungaged tributaries by debris flows. 3.Complete the development of debris flow prediction techniques. 4. Determine if current monitoring methods & networks for sandbars and channel bed sand should be modified to provide better correspondence between channel stored sand and sandbars. 5. Investigate methods for determination of depth to nonerodible material in the channel. 6. Map the channel geometry in any reaches where bed evolution predictions are needed. 7. If needed to improve accuracy of the discharge & sediment routing models, measure reach averaged flow velocity at low flow. 8. Test models currently being developed with data from the spring 1996 high releases and other available data to verify predictions of rates and amount and areal distribution of bed evolution. 9. Use well tested multidimensional bed evolution models to investigate the relation between the amount of sand available and size, duration of habitat building releases required to rebuild sandbars and backwaters of given size and character.

Monitoring and Research Planning
SEDIMENT RESOURCES #2

Increase the average size of sandbars above the 20,000 cfs river stage and number of backwaters at 8,000 cfs to the amount measured after the 1996 test of the beach/habitat building flow in as many years as reservoir and downstream conditions allow.	1. Define target backwater ecosystems and associated flow regimes. 2. Define historical variation in backwater number and character. 3. Determine changes in backwater character & structure associated with dam operating criteria. 4. Define all linkages, associations, interdependencies, etc.; of physical backwater resources to biotic entities. 5. Define processes necessary to maintain backwaters at target levels.	1. Know long-term changes in sand storage at Lees Ferry near Grand Canyon. Shorter term changes known at several locations.	1. Long-term trends in variability in sand storage. 2. Accuracy of model predicted rates of erosion and sand deposition.	1. Monitor sediment movement through system with model verified by cross sections. Monitor physical and temporal characteristics of sandbars (location area, volume, stability, etc.)	
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 downstream resources warrant and when Lake Powell water storage is high.	1. Define character and structure of all sandbars and backwaters in system after 1996 test flows. 2. Develop methodologies to define future operating alternatives to maximize benefit to sandbar and backwater character and structure.		1. Continued monitoring required to know changes & status of system. 2. Rate of change of sandbars & backwaters during major deposition events. 3. Optimum size & duration of releases to rebuild sandbars & reform recirculation zones for mainstem storage.	1. Measure and monitor suspended sediments at Lees Ferry at peak flow events.	
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.	1. Define historical and current levels of bottom sediment deposits in system. 2. Define minimal levels of bottom sediments necessary to maintain long-term sandbar, backwater, channel sediment deposits. 3. Develop procedures to monitor and predict impacts of alternative operating criteria on channel sediment deposits, and implication to sandbars and backwaters in selected reaches.	1. Sediment transport relationships are known.	1. Amounts of stored sediments in river bottom. 2. Minimum levels of stored sand required to maintain sand resources at target levels. 3. Accuracy of bed evolution models to predict sand transport bed evolution. 4. Ability to predict rapid erosion during high releases. 5. Depth of river bed and channel geometry at various locations.	1. Monitor sediment movement through system with model verified by cross sections.	
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 and 30,000 cfs.		1. Geomorphic/sandbar indicators and cross section indicators can be used to determine when there is enough sand for a flood. 2. Have tools to "predict" backwater formation re: discharge events	1. Do low flow velocities affect accuracy of discharge sediment routing models. 2. Sediment balance for entire system or parts of system. 3. Modeling approach to predict sediment balance, distribution, etc.; by reach.	1. Monitoring side canyon debris flows.	Investigate the significance of rapid erosion events and, if significant, develop methods for their perdition.

NRC Concerns

1. Development of alternative sampling methods within the National Park.
2. More emphasis on sediment quality.

Monitoring and Research Plan
CULTURAL RESOURCES #1

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' Need To Know	Scientists' Monitoring Statements	Scientists' Research Questions
Preserve in situ all the downstream cultural resources and take into account Native American cultural resources concerns in Colorado River corridor.	1. Develop data and monitoring systems to assess impacts to cultural resources. 2. Develop predictive model of geomorphic processes related to archaeological site erosion including: • Types of degradation; threats • Rates of degradation • Define immediacy of threats to resources • Protection methodologies • Protection, monitoring and research costs. 3. Develop tribal monitoring programs for the evaluation of impacts to cultural resources. • Identification and evaluation of tribal cultural resources • Management recommendations for tribal cultural resources 4. Assess potential affects from various flow regimes on cultural resources.	1. Locations of cultural resource sites identified in resource inventories. 2. Conditions of sites within various impact zones based on annual monitoring activities. 3. Definition of cultural resources varies by tribe and is held by tribes. 4. Archaeological sites defined as TCPs by tribes.	1. Area assessments, and probability model for location of additional sites is needed. 2. Resources of cultural importance to the tribes.	1. Assess existing data on isolated occurrences to determine adequacy of monitoring information. 2. Assemble data on resources of cultural importance to the tribes to establish effective monitoring programs.	1. Study isolated occurrences to determine their relationship to site formation or degradation processes. 2. Incorporate oral history with archaeological data to examine human occupation along river corridor. 3. Study methods to identify traditional use areas outside traditional site definitions (e.g. agricultural fields). 4. Design investigations to determine if certain temporal activity / occupation periods are obscured from archaeological record due to dam operations.

Monitoring and Research Plan
CULTURAL RESOURCES #2

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' Need To Know	Scientists' Monitoring Statements	Scientists' Research Questions
If in situ preservation is not possible, design mitigative strategies that integrate the full consideration of the values of all concerned tribes with scientific approach.	1. Characterize through scientific study & data development all historical & current values of resources to Tribal Nations and to general public. 2. Develop data systems to assess variable risk of damage / loss of differing resources / sites from dam operating criteria. 3. Evaluate flood terrace stability necessary to maintain cultural resources and terraces at pre-dam conditions. 4. Develop mitigation strategies related to documented site impacts and monitoring assessments. 5. Evaluate affectiveness of monitoring procedures. 6. Develop mitigation costs.	1. Geomorphology processes that promote erosion. 2. Some site stabilization techniques are known.	1. Factors governing rates of erosion need to be determined. 2. Additional site stabilization techniques needed.	1. Monitor existing stabilization techniques affected by high flow regimes.	1. Define long-term impacts of flows on streamside bank degradation (lateral bank retreat), arroyo headwall damage and model impacts to cultural resources and stabilization potentials.
For participating Native American tribes,, protect and provide physical access to cultural resource properties for religious purposes within the river corridor	1. Characterize historic & current religious associations of all sites associated with impacts of dam operations within the river corridor. 2. Develop tribal monitoring for evaluation of impacts to cultural resources including sacred sites.	Location of some traditional cultural sites is known by tribes; some are not yet discovered.	1. Location of tribe-identified traditional cultural sites needed if individuals will divulge locations. 2. Develop baseline cultural resource maps to facilitate tribal consultation for: • resource locations • risk of loss • resource study locations (including other resource studies) • plant & biological resource locations • sensitive physical / landform locations	1. Revise GIS resource maps as needed.	

Monitoring and Research Plan
CULTURAL RESOURCES #3

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' Need To Know	Scientists' Monitoring Statements	Scientists' Research Questions
Develop, appropriate research strategies which maximize data collection from mitigation and monitoring efforts for understanding human use and occupation in the canyon.	1. Characterize all cultural resource sites as to the specific associated management/research needs, i.e. preservation stabilization, documentation, etc. under alternate operating criteria. 2. Design and develop integrated relational data systems to support management and research program goals/designs. 3. Develop technology/ procedures for providing relevant/protected data to appropriate groups/tribes. 4. Ensure confidentiality of data regarding location of cultural sites.		1. Site formation processes of deposits not known.		1. Formulate research design to study the relationship of isolated occurrences to site formation or degradation processes and dam operations. 2. Evaluate specific locations to obtain site formation data for differing temporal occupation/activity periods. 3. Formulate pilot assessment of geologic history of terrace formations and their relation to past human occupations. 4. Establish and refine appropriate research designs to guide data collection and recovery, and contribute to an improved understanding of the human occupation and use of Glen and Grand Canyons.

NRC Concerns

1. Tribal studies should not be considered academic studies but rather applied studies focused toward specific objectives, that is, the protection of specific tribal cultural resources.
2. Develop a clear outline of criteria to be used in the selection of sites to be monitored.

Cultural Resource

The requirements specified in the Programmatic Agreement are the legal requirements of the Bureau of Reclamation and the National Park Service under Sections 106 and 110 of the National Historic Preservation Act of 1966, as amended. The long-term monitoring and research plan on the Grand Canyon Monitoring and Research Center represents a separate but complementary program with many similar activities although the purpose and scope of the programs are different. The elements of these programs are listed below.

Programmatic Agreement Program

1. Within three months of the execution of the Programmatic Agreement, BOR and the NPS, in consultation with the SHPO and Tribes, shall develop a plan for monitoring the effects of the Glen Canyon Dam operations on historic properties with the APE and for carrying out remedial actions to address the effects of ongoing damage to historic properties. Reclamation shall submit a draft of the Plan to the parties in this agreement for review and comment. Each party shall have 60 days from receipt of the Plan to comment.
2. Remedial measures shall be implemented to mitigate ongoing adverse effects and may include, but not be limited necessarily to, bank stabilization, check dam construction and data recovery, as appropriate.
3. Reclamation and the NPS shall incorporate the results of the identification, evaluation, and monitoring and remedial action efforts into a Historic Preservation Plan (HPP) for the long-term management of the Grand Canyon River Corridor District and any other historic properties within the APE.
4. The HPP shall establish consultation and coordination procedures, long term monitoring and mitigation strategies, management mechanisms and goals for long term management of historic properties with the APE.
5. Reclamation and the NPS shall take into consideration all comments received in their development of a final draft HPP, and submit the final draft HPP to the reviewing parties for a second review opportunity.

GCMRC Cultural Program

1. Core Program consists of monitoring and research activities to address stakeholder objectives and information needs.
2. Individual Tribal Projects to conduct activities related to this program.
3. Cooperative Projects to address education and outreach.

The GCMRC program will address cultural resource issues in an integrated manner with the programs in biological and physical areas through the incorporation of tribal perspectives on cultural resources.

Monitoring and Research
AQUATIC FOOD BASE #1

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' need to know	Scientists' Monitoring Statements	Scientists' Research Questions
Maintain and enhance the aquatic food base in Glen and Grand Canyon. Maintain continuously inundated areas to Cladophora and aquatic invertebrates at or above 5,000 cfs discharge Aquatic food base data needed for Grand Canyon beyond Glen Canyon.	FOOD BASE CHARACTER & STRUCTURE 1. Define current and historic food base character and structure. Define food base character, structure and requirements for maintaining target populations. 5. Define the species composition and the distribution of aquatic algae & macrophytes in Glen and Grand Canyons. EFFECTS OF CHANGES IN DAM OPERATIONS 2. Determine system changes to maintain/enhance food base. 3. Define impacts of alternative operating criteria, including thermal modification and low steady flows associated with native fish releases, on aquatic food base. 4. Define the species composition and density of macroinvertebrates in Glen and Grand Canyons. 5. Determine what thermal modification will do. 6. Determine if changes in the CR are due to dam operations or some other changes in the system not related to dam operations.	FOOD BASE CHARACTER & STRUCTURE • Food web energetics conceptual model. • Mainstem algae & macroinvert community structure, biomass, & seasonal variability; limited similar information for LCR & other tributaries. • Linkages between algae and primary consumers & detrital links; diatoms are key organic drift component. Know diet linkages of primary and secondary consumers. • Aquatic conversion to energy levels in mainstem. • Physical hard substrate (structural) habitat requirements for Cladophora. • Cladophora & Chara are best substrate for diatoms; diatoms are at base of rainbow trout food chain. • Photosynthetically Available Radiation (PAR) Model (Yard) relates suspended sediment to PAR • Structures known through corridor by seasons. •Know diet of rainbow trout in Lees Ferry reach.	FOOD BASE CHARACTER & STRUCTURE • The community structure interactions among algal species. • Phosphorus availability/ limitations. • How changes in nutrient regimes in Lake Powell change macrophyte communities. • Nutrient levels in side channels needed. EFFECTS OF CHANGES IN DAM OPERATIONS • Water velocity, state, & discharge limits for diatoms, Cladophora, & aquatic macrophytes & macroinvertebrates. • How does stage relate to proportion of algae exposed. The potential productivity (food base) loss at differing flows. • How does state relate to primary productivity (light, etc.). Determine quantitative estimate of benthic and drifting macro invertebrates in Marble and Grand Canyons. • What are links between benthic biomass/ productivity & how does temperature affect benthic communities & primary production. •How stage affects diatom abundance distribution. • What aquatic plant community changes might be expected as a result of changes in water temperature resulting from selective withdrawal or seasonally adjusted steady flows.	FOOD BASE CHARACTER & STRUCTURE Monitor food availability and fish food habits via drift and benthos assessments Monitor fish food availability. Monitor the species composition and distribution of aquatic algae and macrophytes in Glen and Grand Canyon. Monitor species composition and density of macroinvertebrates in Glen and Grand Canyons and tributaries. EFFECTS OF CHANGE IN DAM OPERATIONS Monitor aquatic food base in tributaries to determine if changes in the CR are due to dam operations or to landscape changes in the watershed. Monitor productivity, area, and standing crop of attached aquatic vegetation and associated invertebrates above Lees Ferry to distinguish between effects of dam operation and natural variation.	FOOD BASE CHARACTER & STRUCTURE Complete CR energetics model to determine if the system is nutrient and/or food limited. What factors affect sexual reproduction of Cladophora? What is the microbial contribution to organic processing? Need to inventory aquatic macroinvertebrate community. Fontanalis and Chara contributions to ecosystems. EFFECTS OF CHANGES IN DAM OPERATIONS Determine, in association with specific water releases (defined flows), the effects of flow rate (velocities) on primary producers in the Glen Canyon reach. Determine potential for invasion of other aquatic species, especially under low steady flows or selected temperature withdrawals; zebra mussels, fish parasites, etc.

Monitoring and Research
AQUATIC FOOD BASE #2

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' need to know	Scientists' Monitoring Statements	Scientists' Research Questions
		• Have limited information on diet of juvenile native fishes in LCR & mainstem backwater habitats. Have limited information on diet of adult humpback chub from mainstem in Grand Canyon. EFFECTS OF CHANGES IN DAM OPERATIONS • Know thresholds (temperature/water) of exposure for diatoms, Cladophora. • Know colonization and recovery rates of diatom and macrophytes. • Nutrient linkages (including ground water & tributary inputs) to primary producers.	• Linkages between discharge/aquatic invertebrates/fish. • Fontinalis & Chara contributions to ecosystems • The interactions among algal species? • Taxonomy of river and tributary invertebrates needs to be defined. • Nutrient linkages (including ground water 7 tributary inputs) to primary producers. •Are allochonous food imputs from arroyo flooding (animal and vegetable material) quantitatively significant food sources? • Aquatic food base data needed for Grand Canyon beyond Glen Canyon. • What factors affect sexual reproduction of Cladophora? • What is the microbial contribution to organic processing? • Inventory needs- Oligochaetes, flatworms, chironomids. • The potential productivity (food base) loss at differing flows. • Interactions of native fish and food base.		

Monitoring and Research Planning
Fish and Aquatic Resources
HBC#1

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' need to know	Scientists' Monitoring Statements	Scientists' Research Questions
Maintain or enhance the existing population of humpback chub at or above 1987 levels determined by April/May Loop-net monitoring in the lower 1,200 meter of the LCR. (Focused at fish greater than 200 MM, and should include fish health assessment.) Maintain levels of recruitment of humpback chub in the mainstem and Little Colorado River, as indexed by size frequency distributions and presence and strength at year-classes. (Focused at young of year and juvenile fish, and should include a fish health assessment.) Verify the status of and manage for healthy, self sustaining populations of native fish in Glen Canyon based upon the capability of the habitat to support those fishes.	1.1 Determine adult humpback chub population levels and evaluate population level trends. 2. Determine levels of recruitment of humpback chub in the mainstem and the LCR 3. Determine quantity & quality of chub backwater habitat in mainstem. 5. Develop a backwater quality index, using existing data for humpback chub. 4. Determine and identify surrogate native or non-native fishes for evaluation of health factors for humpback chub. Evaluate impacts of sampling wetlands and recreation use on native fish population	1.1.1 Grand Canyon is one of six populations of humpback chub nationally; it is largest, centered at Little Colorado River (LCR) with successful reproduction in the LCR 1.1.2 Possible downward trend in LCR adult numbers over last 10 years derived from mark-recapture data; similar downward tend in mainstem population not noted. • Structure and location of nine existing aggregations of humpback chub in mainstem. Site fidelity in humpback chub. 1.1.5 Growth and survival of young chub into the spawning population (recruitment) is probably a weak link in maintaining and enhancing the adult population and is low in the mainstem CR. 1.1.6 Spates and late summer runoff in the LCR transport young chub into the mainstem CR where their survival is likely lower than in the LCR. 1.1.7 Growth and survival of young chub in the cold mainstem CR water is lower than in the warmer LCR. Young HBC use backwaters and other near shore low velocity habitats as nursery and rearing areas.	Recruitment of humpback chub into Little Colorado River and Colorado River aggregations 1.1.2 What proportion of adult humpback chub in the LCR are resident and what proportion move between the LCR and the mainstem CR 1.1.3 PIT tag mark and recapture information for all species marked, (i.e. GCMRC monitored data repository). • Genetics of humpback chub aggregations. • Ecology information (diet, cycles, requirements) for HBC. • Food availability for humpback chub throughout Little Colorado River. • Stomach contents analysis of pre-dam humpback chub from existing collections. • Non-lethal disease assessment procedures; or assessment procedures for surrogate species Is there successful recruitment of HBC at locations other than the LCR. • Effects of sampling efforts on fish populations.	Monitor humpback chubs in the LCR, mainstem CR, especially where population of interest are located. 1.1.1.1 Monitor adult humpback chub population levels and evaluate population level trends. Monitor size frequency distributions, presence, strength, and health status of year-classes. Information needs focus on young-of-year and juvenile fish. 1.1.1.2 Monitor recruitment into the adult humpback chub spawning population in the LCR and other known aggregations.	Evaluate food habits (gut contents) of HBC. Genetically characterize HBC and other native fish aggregations in the LCR, 30 mile, & Middle Granite Reach. Collect HBC tissue samples throughout canyon, extract DNA and bank for future studies. Test alternative methods for tagging HBC smaller than 150 mm. 1.1.1.3 Determine most efficient population estimation techniques for HBC. 1.1.1.14 Develop life tables for HBC. Determine cumulative effect of handling (research) on fish (stress, trap avoidance, etc.).

Monitoring and Research Planning
Fish and Aquatic Resources
HBC#2

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' need to know	Scientists' Monitoring Statements	Scientists' Research Questions
		1.1.8 Some adult HBC appear to reside in the LCR while other individuals move between the mainstem CR and the LCR. 1.1.9 Aggregations of HBC in the mainstem CR are comprised of large adults with few juvenile fishes. 1.1.10 The HBC is a long-lived species. 1.1.11 Spawning and rearing temperature, salinity, DO requires of humpback chub. • Swimming ability of juvenile humpback chub and flannelmouth sucker. • Which springs they feed near. (?) Humpback chub and rainbow trout use similar drift feed. Humpback chub seem to feed more on terrestrial than benthic components in lower canyon reaches. Young-of-year HBC (~30 mm) have been collected at a few scattered locations along the mainstem. • Have some conceptual "diagrams" of ecosystems requirement. • Some fish habitat requirements, i.e.; trout, humpback chub.			

Monitoring and Research Planning
Fish and Aquatic Resources
HBC#3

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' Need To Know	Scientists' Monitoring Statements	Scientists' Research Questions
Establish a second, self sustaining population of humpback chub by 2005 contingent on feasibility. Monitor for and determine the contribution of other existing spawning aggregations as one component of assessing feasibility.	1. Develop criteria for self sustaining populations of humpback chubs. 2. Assess feasibility of second population including other current aggregations.	See HBC#1.			Establish experimental populations of special status fishes for physiological studies, including temperature effects on larval fish and for potential brood stock. Evaluate the establishment of an experimental fish breeding program for mainstem reestablishment.

Monitoring and Research Planning
FISH AND AQUATIC RESOURCES
Other Native Fish #1

Stakeholder's Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' need to know	Scientists' Monitoring Statements	Scientists' Research Questions
Verify the status of and manage for healthy, self sustaining populations of flannelmouth sucker, bluehead sucker, and speckled dace in the mainstem Colorado River in Grand Canyon and its tributaries. Verify the status of and manage for healthy, self sustaining populations of native fish in Glen Canyon based upon the capability of the habitat to support those fishes. (Focused at young of year, juvenile, and adults to determine size frequency distribution, densities [via catch rates] and assessment of fish health.	1. Determine historic and current character and structure of species populations. 2. Determine historic & current life-history & habitat requirements of species. (Habitat, spacing, food source, interdependence, etc.) 3. Define impacts of alternative flow regimes on species population character and structure. 4. Determine requirements to maintain/enhance self sustaining populations of species.	• Spawning and rearing temperature, salinity, DO requires of humpback chub. • Possible downward trend in LCR adult numbers over last 10 years derived from mark recapture data; similar downward trend in mainstem not noted. 1.1.1 Have limited information on historic occurrence and distribution of native fishes and species composition of the community. 2.2.1 Know temperature regimes necessary for successful spawning and reproduction of most fishes. 2.2.2 Know diet, early life history requirements of most fishes. 2.2.3 Most native fish spawn in warm tributaries, larvae drift to the mainstem. Some larvae rear in larger warm water tributaries (LCR, Kanab). 2.2.4 Small juveniles rear in backwaters and tributaries, larger juveniles move to main channel near shore habitats. 2.3.1 Know species composition, size distributions, general life spans, sex ratios of fish communities. 2.4.1 Know fish need to successfully spawn, survive, grow, and recruit to the spawning population to maintain and enhance self sustaining populations of species.	• Ecology information (diet, habitat requirements, predation, etc.) for humpback chub in Little Colorado River. • PIT tag data repository for all of river system. •Energetics of T&E sensitive species. • Parasite, disease, life history and related interactions of native and nonnative fish. • Ecology information (diet, cycles, requirements) for flannelmouth suckers, blue headed sucker, speckled dace. • Validate all data on fish assemblages. • Structural and functional linkages of aquatic ecosystems, threatened and endangered and sensitive fishes. • Effects of temperature variation and effects on fisheries in Lake Powell and river. • Effects of rapid lake level drop on fisheries and endangered fish in Lake Powell. • How does stage relate to drying of spawning beds.	Monitor fisheries of Lake Powell, if selective withdrawal is implemented. 2.1.1.1 Monitor (numbers caught, catch per effort, length, weight, parasites, reproductive condition, PIT tag number) for all life stages of fish species in appropriate habitat types and locations. Establish and maintain a PIT tag data repository. Monitor flannelmouth sucker aggregations at tributary locations, including Paria, Kanab, Havasu, etc. Native species for monitoring include HBC, flannelmouth bluehead and razorback suckers, speckled dace. Match shoreline fish sites with shoreline vegetation	Test experimental enhancement of flannel mouth populations and other species through Paria River rearing ponds, including imprinting in Paria water. Determine the extent of food limitation on distribution and condition of native fish. Review potential diseases, parasites and other factors affecting fish length in the future. Evaluate food habits (gut contents) of flannelmouth sucker over time using non-lethal methods. Determine interrelationships between mainstem flow and backwater fish habitat (e.g. warming, geochemistry, food availability). Evaluate non-lethal methods for determining diet of adult native catostomids. Study of probable impacts of rapid drops in Lake Powell to biotic communities.

Monitoring and Research Planning
FISH AND AQUATIC RESOURCES
Other Native Fish #2

Stakeholder's Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' need to know	Scientists' Monitoring Statements	Scientists' Research Questions
		Temperature effects data for larval flannelmouth	2.1.1 Character and structure of fish assemblage. 2.2.1 Interactions of native fish and food base. 2..2.2 Determine life history requirements (spawning, rearing habitat, diet) for native fish assemblage. • Effects of sampling efforts on fish populations. 2.3.1 Define impacts of alternative flow regimes of species population character and structure.		

Monitoring and Research Planning
Fish and Aquatic Resources
Trout

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' Need To Know	Scientists' Monitoring Statements	Scientists' Research Questions
In Colorado River corridor below Glen Canyon Dam to the confluence with the Paria River, natural reproduced fish should compose at least 50% of the Age III rainbow trout. Sufficient suitable spawning habitat should be maintained to reach this objective. The total populations of rainbow trout (age II+) in this reach should be maintained at approximately 100,000 fish as determined by population estimation. Rainbow trout should achieve 18 inches in length by Age III with a mean relative weight (Wr) of at least 0.80.	1. Determine ecosystem requirements, population character and structure to maintain reproduced populations of Age II+ Fish at 50,000-100,000 population levels. 2. Determine changes in population character & structure. 3. Determine contribution of naturally reproduced fish to the population. 4. Determine availability and quality of spawning substrates in Glen Canyon reach. 5. Determine size of the population of Age II+ rainbow trout in Glen Canyon reach. 6. Determine growth and condition of rainbow trout in Glen Canyon. 7. Define criteria for healthy trout population.	Approximately 75% of field sampled and creeled trout are naturally spawned under interim flows. During pre interim flows, approximately 25% of the fish were naturally spawned with the other 75% comprised of hatchery stocked fish. Know locations of some spawning bars (primarily shallow bars), location of redds (Yard maps). Know species composition, fish sizes and distribution (related to population character and structure). Know angler pressure, catch, harvest rates and percent of harvest comprised on naturally spawned fish. Know that few stocked trout move downstream from the Glen Canyon reach (related to population character and structure) under existing flow regimes. 4.1.6 Know genetics of stocked trout (Bell-Aire strain). 4.3.1 Know growth rates of stocked fish that have been marked with coded wire tags. 4.4.1 Know condition and Wr of field sampled and creeled fish. 4.4.2 Know Goode fish health index ratings for field sampled fish. 4.4.3 Know that most trout carry parasitic trout nematode. 4.4.4 Selenium levels in trout flesh appear to be higher than normal. General knowledge at relationship between river stage and laying of trout redds.	• Food web energetics; re: how does algal mass relate to trout production. 4.1.3 What is quantity and availability of spawning gravels in the reach? 4.1.4 What is percentage of wild spawned fish under different flow regimes? 4.1.5 What is genetic character of wild spawned fish? 4.1.6 What are impacts of different regulations (slot limit, bag limits, gear restrictions) on character and structure of the trout population? 4.3.1 What is growth of naturally spawned fish? 4.4.1 What is status of disease and parasites in the fishery? 4.4.2 What is impact of high Se levels on reproduction of trout?	Monitor rainbow trout above Lees Ferry; reproduction, percent of population that is naturally spawned, downstream movement. 4.1.1.2 Monitor harvested & field sampled rainbow trout to determine contribution of naturally reproduced fish to the population. 4.1.1.3 Monitor changes in population character and structure. 1. Monitor temperature regimes and effect on recreational use of fishery.	Determine the extent of food limitation on distribution and condition of fish. Review potential for growth-limiting factors affecting rainbow trout in the future, including diseases, parasites, etc. Develop an energetic model for trout incorporating lower trophic components. Determine carrying capacity for trout under different flow regimes. What stocking rates are appropriate to meet Stakeholders Objectives? Evaluate slot and bag limits using existing growth and survival information. Develop effective remote sensing techniques to evaluate changes in spawning gravel composition.

Monitoring and Research Planning
Fish and Aquatic Resources
Native/Non-Native Fish Interactions

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' Need To Know	Scientists' Monitoring Statements	Scientists' Research Questions
Minimize to the extent possible, interactions between native and non-native fishes.	1. Define areas & conditions of current & future existing & potential native and non-native fish interactions. 2. Monitor key attributes associated with interaction. 3. Determine which methods for minimizing interactions through isolation can be achieved through dam operations. 4. Determine methods for minimizing interactions without isolation. 5. Provide ongoing information regarding species composition, relative abundance & size class structure of non-native fish in the Colorado River & important tributaries. 6. Identify existing & potential sources of interaction (predatory, competitive) between extant non-native and native fish of the Colorado River and important tributaries. 7. Evaluate effects of beach habitat building and habitat maintenance flows on the distribution & abundance of non-native fish in the Colorado River and important tributaries. 8. Identify potential alternative strategies to suppress problematic non-native species in the Colorado River and important tributaries.	Brown trout, rainbow trout, channel catfish prey on humpback chub and flannelmouth. Rainbow trout and humpback chub diets are similar. Channel catfish spawn primarily in the Little Colorado River. Brown trout spawn primarily in Bright Angel Creek area. Red shiners are abundant in Lake Mead inflow. Fathead minnow are present in tributaries. Carp are common throughout the system. Striped bass make annual spawning runs from Lake Mead. Walleye, largemouth bass, green sunfish, black bullhead are potential predators of native fish, but their numbers are currently low. Information on native and non-native fish interactions from work in the upper Colorado River basin.	Native versus non-native fish interactions must be defined by positive and negative linkages. Determine probable responses of all non-native species to selective withdrawal and steady summer flows. Verify extent of predation on native fish by brown trout, rainbow trout, channel catfish. Usefulness of recreational fishing to control exotic fish. How does trout management in Glen Canyon affect native species? Validate all data on fish assemblages. The affects non-native fish (carp, trout, catfish, minnows) have on larval and juvenile native fish in the Colorado River.	Monitor numbers and composition of all non-native fish populations. Important non-natives for monitoring include rainbow and brown trout, channel catfish, carp, fathead minnow, red shiner, Rio Grande killifish, striped bass. Monitor food habits of brown trout, rainbow trout, channel catfish, striped bass, walleye, carp. Monitor removal of channel catfish from Little Colorado River. Monitor removal of brown trout from Bright Angel Creek.	Test efficacy of experimental non-native fish control i.e.; the removal of non-native fishes and the response in the native fish population. How will populations of channel catfish and brown trout respond to removal? Determine potential for invasion of other aquatic species, especially under low steady flows or selected temperature withdrawals; zebra mussels, fish parasites, etc. Study native and non-native species interactions through controlled research (especially the impacts of various temperature regimes). Risk analysis of response by non-native fishes to selective withdrawal and steady summer flows. How do non-native fish affect the survival and recruitment of native fish.

Monitoring and Research Planning
Fish and Aquatic Resources
Reasonable & Prudent Alternative

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' Need To Know	Scientists' Monitoring Statements	Scientists' Research Questions
Evaluate through monitoring and research the reasonable and prudent alternatives specified by the US Fish and Wildlife Service.	1. Using monitoring & research programs evaluate all test flows in RPA and potential impacts to threatened and endangered fisheries. 2. Determine the benefits and impacts of installing selective withdrawal for thermal modification in the mainstem of the Colorado River downstream of Glen Canyon Dam.	Interim flows probably benefited native fish. Interim flows may also benefit non-native fish. Red shiners, fathead minnows, carp can thrive in warm river environments, e.g., upper basin. Temperature regime expected downstream of dam. Results of similar experiments at Shasta and Flaming Gorge Dams.	Risk analysis of selective withdrawal. Will the small increase in water temperature help native fish spawn in the mainstem and larvae to survive after entering the mainstem from the LCR. Determine the likelihood of shad, shiners, and stripped bass entering the system. Determine the affects on trout growth, primary productivity and invertebrates. Determine the likely changes in community structure and diversity among fish, invertebrates, and primary producers.	Establish baseline information regarding location and reproductive potential of non-native fish, in case selective withdrawal is implemented.	Risk analysis. Conduct study to relate probable changing temperature regimes to fisheries.

Needs Proposed in Biological Opinion

Attainment of riverine conditions that support all life stages of endangered and native fish species is essential to the Colorado River ecosystem.
The service believes that actions for one native species should be supportive of other native species in the ecosystem.
Reclamation and the Service will meet at least annually to coordinate reasonable and prudent alternative activities.
Determine humpback chub life history schedule for populations downstream of Glen Canyon.
Establish a second spawning aggregation of humpback chub downstream of Glen Canyon Dam.
Protect humpback chub spawning population and habitat in LCR by being instrumental in developing a management plan for this river.
Develop actions that will help ensure the continued existence of the razorback sucker.
Develop a management plan for the species in the Grand Canyon.

Monitoring and Research Planning

RIPARIAN AND TERRESTRIAL VEGETATION #1

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' Need To Know	Scientists' Monitoring Statements	Scientists' Research Questions
Preserve or restore (where possible) natural species composition & abundance within riparian and unplanned communities affected by dam operations.	1. Determine historical (pre-dam) natural composition of riparian and upland communities. 2. Characterize normal range of variation and ecology of species.	• Terrestrial vegetation divided into three zones: marsh, new high water, old high water. • Know extent of vegetated area and type of all vegetative communities. • GIS of some reaches; vegetation maps for reaches. • Cottonwoods are establishing. • Old high water zone vegetation is not reproducing. • Inundation levels and grain size control riparian vegetation in still water. • Conceptual successional model of marsh and sandbar vegetation. • Preferred alternative will reduce vegetation levels below current levels (elevation).	Information on changes to species composition, areal extent, and location of vegetation. Normal range of variation and ecology of species. • Quantitative successional vegetation models. • Nutrient dynamics in the inundation zone. • Groundwater/nutrients flows-how they relate to riparian vegetation.	Monitor species composition, abundance spread or contraction of vegetative communities below the dam. Monitor fate of old high water species (e.g. mesquite) in new riparian areas, under different flow regimes. Choice of locations for monitoring of riparian vegetation should partially be driven by other resource needs (wildlife, fisheries, sand bar erosion, campsites) and by existing datasets for 10 GIS geomorphic reaches. Monitor riparian habitat between Glen Canyon Dan and Lake Mead, as it is important to the Grand Canyon ecosystem.	Determine effects of management alternatives on riparian vegetation: steady summer flows, habitat building flows. Explore GIS modeling the impacts of alternative flow regimes on riparian vegetation.
	4. Evaluate impact of dam operations on establishment of and impacts from exotic plant species.	• 13% of riparian plant species in canyon are exotic; accounts for 40% of area coverage. • Some exotics have become important to target species for conservation (e.g. Tamarisk/Southwest Willow Flycatcher) and watercress for KAS.		Monitor spread of non-native vegetation, camelthorn, Lepium latifolium, Eragnostis cerrula, Tamarisk, Russian olive. Monitor changes in extent and relative abundance of Willow and Tamarisk.	Conduct basic life history studies of non-native vegetation: camelthorn, tree of heaven, Lepium lattifolium, Eragnostis cerrula.

Monitoring and Research Planning

RIPARIAN AND TERRESTRIAL VEGETATION #2

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' Need To Know	Scientists' Monitoring Statements	Scientists' Research Questions
Emphasize the preservation of unique plant communities and any special status species (federal, tribal, & state designations) to ensure their perpetuation within system.	1. Determine historic & current distributions, range of variation and ecology of T&E and special status species. 2. Establish ecosystem requirements of special status species & determine probable impacts of proposed flow regimes. 3. Determine population changes in special status species. 4. Determine impacts of operating criteria necessary to meet ecosystem requirements of special state species on other resources and ecosystems.	• There are no sensitive or endangered plant species listed along the river that are at risk.	• Linkage of terrestrial vegetation and aquatic food base for important T&E and specialists species. • Invertebrate productivity and relationships to vegetation and vegetation change.	• Match shoreline fish sites with shoreline vegetation Monitor location, size, number, and species composition of marsh habitats within riparian area. Monitor habitat for Willow flycatcher. Monitor distribution and abundance of vegetation needed by Kanab ambersnail	Determine, perhaps by GIS modeling, the extent of flooding riparian vegetation by river stage. Flooded riparian veg may be important fish habitat.

Monitoring and Research Planning

NATIVE TERRESTRIAL WILDLIFE RESOURCES #1

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' need to know	Scientists' Monitoring Statements	Scientists' Research Questions
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. Maintain native faunal components of the ecosystems for the benefit of T&E species.	1. Define and specify ecology of native faunal components, especially T&E species; including evolutionary & environmental changes, natural range of variation, linkages, interdependencies & requirements. 2. Evaluate species population to detect departures from natural range of variation. 3. Determine changes, declines in special status species & characterize ecosystem changes to benefit species.	Distribution and relative abundance of amphibians along the river corridor (surveys in 1970's). Distribution, abundance, age class distribution, habitat use, and genetic characteristics of isolated Leopard Frog population at RM-9 along the river corridor (surveys and research in 1994-1996). Distribution and relative abundance of reptiles along the river corridor (surveys in 1970's). Distribution, relative abundance, habitat affinities, and ecology of general bird community along the river corridor (surveys in 1970s-1900s). Food habits of selected insectivorous birds along the river corridor. Terrestrial-origin insects predominate in diet of these birds. Distribution, abundance, habitat affinities, and breeding ecology of the Southwestern Willow Flycatcher along the river corridor (surveys in 1980s-1990s). Also know the strong negative impacts of Brown-headed Cowbird nest parasitism on flycatcher productivity. Distribution, abundance, habitat use, human disturbance patterns, and feeding ecology of wintering feeding ecology of wintering Bald Eagles along the river corridor (surveys in late 1980s-1990s).	Evaluate changes in vertebrate species densities as a result of increase in riparian vegetation (e.g. Neotropical migrants). Are amphibians responding (population sizes and/or distribution) to past and future changes in aquatic. Is this isolated frog population viable in the long-term? How will future changes in aquatic and riparian systems particularly possible warming of fiver) effect this genetically distinct population? Are reptiles responding (population sizes and/or distribution) to past and future changes in riparian habitat? How ill bird community respond (population sizes and/or distribution) to future changes in aquatic and riparian habitats? Is this isolated population of Willow Flycatchers viable in the long-term? How will future changes in riparian habitats effect flycatcher distribution, abundance, and breeding ecology/ what is the source of the cowbirds that are parasitizing the flycatchers? Will changes n the aquatic system influence Bald Eagle use of the river corridor for winter foraging, particularly at trout spawning sites such as Nankoweap Creek.	Vegetation and bird monitoring should be closely linked. Monitor endangered birds, number, and habitat. Monitor Willow flycatcher in relation to vegetation community structure. Monitor distribution and abundance of riparian corridor amphibians. Monitor distribution, abundance, reproductive status/ success, and age-class distribution of Leopard Frogs at FM-9 site. Monitor distribution and abundance of riparian corridor reptiles. Monitor distribution and abundance of riparian corridor bird community. Monitor distribution abundance, and breeding success of riparian corridor bird community. Monitor distribution, abundance, and breeding success of breeding success of Peregrine Falcon. Monitor distribution and abundance of riparian corridor mammals. Monitor distribution and abundance of bats and bat roost sites along the riparian corridor	Willow flycatcher. How many territories? Where are they producing young? More attention should be placed on upper Lake Mead and tributaries of Lake Mead and tributaries of Lake Powell. Is Brown-headed Cowbird parasitism negatively affecting the abundance and/or distribution of other bird species? If so, what management alternatives can counteract this effect? What techniques are most effective for long-term monitoring of bird community? Is he flycatcher population along the river corridor genetically and reproductively isolated? To what other regional Willow flycatcher populations are these birds most closely related (genetically). What are the "sources" of cowbirds found parasitizing flycatcher nests along the river? What management actions can be taken to reduce or eliminate parasitism? How will increased water temperatures influence food base (fish) and foraging conditions?

Monitoring and Research Planning

NATIVE TERRESTRIAL WILDLIFE RESOURCES #2

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' Need To Know	Scientists' Monitoring Statements	Scientists' Research Questions
		Distribution, abundance (a very large population), habitat use, and feeding ecology of Peregrine Falcons along the river corridor (surveys in late 1980s-1990s). Distribution, abundance, and habitat use of wintering waterfowl along the river corridor above Lees Ferry (regular surveys in mid 1990s). Distribution, abundance, and habitat use of wintering waterfowl along the river corridor below Lees Ferry (opportunistic surveys in 1980s-1990s). Distribution and relative abundance of mammals along the river corridor (surveys in 1970s). Distribution and relative abundance of bats along the river corridor, with limited data on breeding and roost sites. Distribution and habitat affinities of terrestrial insects along the river corridor with limited data on ecology and relative abundance. Distribution, abundance, habitat affinities and general ecology of the Kanab Ambersnail at Vasey's Paradise (surveys and research in 1990s).	Will changes in the aquatic and riparian systems (as manifested in food base) influence Peregrine Falcon use of the river corridor particularly with regard to breeding? Needs met. The current understanding of waterfowl ecology suggests that external factors strongly dominate and influence local waterfowl abundance. Needs met. The current understanding of waterfowl ecology suggests that external factors strongly dominate and influence local waterfowl abundance. Are mammals responding (population sizes and/or distribution) to past and future changes in aquatic and riparian habitats? Identification of additional roost sites, with emphasis on maternal colonies. Increased understanding of ecology of bats, including movements, habitat use, and foraging needs and patterns. How are bats influenced by river operations (e.g. diet), visitation (e.g. disturbance at roost), etc. Species present, and their ecologies, particularly in regard to riparian vegetation. Is this isolated population of Kanab Ambersnails viable in the Long-term? How are snails affected by predation, parasitism, and disease?	Standardized invertebrate monitoring difficult and impractical. May eventually target keystone species. Monitor distribution and abundance of Kanab Ambersnails. Survey for new populations along the river corridor.	

Monitoring and Research Planning
NATIVE TERRESTRIAL WILDLIFE RESOURCES #3

Maintain a natural age-class distribution throughout the majority of their natural range in Glen and Grand Canyons, emphasizing the need to recruit into breeding age classes.	1. Determine species natural ranges (pre-post dam). 2. Determine historic age class distribution (pre-post dam). 3. Assess natural range & age class distribution,, changes, constraints, probable long term viability implications to species; assess alternate habitat, ecology associations (specifically age class); and ecosystem associations. 4. Monitor impacts of alternative operating criteria on ecosystem & ecology requirements of species.		Ecology in these settings not fully known.	Specific items noted under previous objectives identify monitoring needs for most species and groups.	Assessment of current knowledge on distribution abundance, and life history of riparian reptiles and mammals. Determine significance of post dam vegetated corridors to range extensions and interbreeding among previously isolated populations of amphibians and reptiles.
Evaluate the viability of food chains for native fauna, including the Peregrine Falcon, S.W. Willow Flycatcher, and other special status species.	1. Define food chain associations, interdependencies, requirements, etc.; for native species population targets. 2. Monitor impacts of alternative operating criteria on food chain associations.	Basic understanding of the feeding habitats and food base of most terrestrial vertebrates in the Canyon. Food does not appear to be a limiting factor to any known species, although local abundance of wintering eagles may be influenced by availability of spawning trout.	How does the food base / food chain affect the ecologies of bats, Kanab Ambersnails and other species of concern along the river corridor?	Monitor abundance of food organisms important to special status species.	Determine food habits of bats and Ambersnails. Determine potential and suitable alternative food sources for Ambersnails.
In as much as management is not deleterious to naturally occurring ecosystem components, consider & mitigate impacts to special status species that may use the river corridor opportunistically. Maintain self sustaining fish populations as forage to provide opportunities for bald eagles. Monitor for nesting.	1. Characterize historic and current use or expected use of area by species. 2. Determine habitat, forage, nesting, etc.; requirements based on current or future use.	Bald Eagle. May use river corridor in winter, but not historically occurring. Concentrated near Nankoweap drainage. This appears to be directed mainly at the Bald Eagle. Distribution, abundance, habitat use, human disturbance patterns, and feeding ecology of wintering Bald Eagles along the river corridor (surveys in late 1980s-1990s) already well known and understood.	will changes in the aquatic system influence Bald Eagle use of the river corridor for winter foraging, particularly at trout spawning sites such as Nankoweap Creek.	General avian community monitoring. Determine what species are breeding, relative abundance, etc. Monitor bat populations and habitats. Not applicable for Bald Eagle (unless selective withdrawal or other major changes to aquatic system are implemented).	How will increased water temperatures influence the Bald Eagle food base (fish) and foraging conditions? To what degree are Bald Eagles dependent on the trout resources at Nankoweap during the winter/

Monitoring and Research Planning
NATIVE TERRESTRIAL WILDLIFE RESOURCES #4

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' Need To Know	Scientists' Monitoring Statements	Scientists' Research Questions
The population of Kanab Ambersnail should be inventoried and maintained near current levels. Efforts to establish additional population center should be guided by the recovery plan for the species.	1. Characterize historical and current populations of Kanab Ambersnail and their locations. 2. Determine ecology & ecosystem related requirements for Kanab Ambersnail to enhance 1996 levels. 3. Monitor changes in populations, health, & character of Ambersnail. 4. Identify areas of possible future use.	Kanab Ambersnail populations.	Need second population of Kanab Ambersnail established.	Monitor Kanab Ambersnail for compliance. Monitor Kanab Ambersnail populations above 60,000 cfs. Monitor occurrence of Kanab Ambersnail trematode parasite. Monitor abundance and food habits of Peromyscus predator at Vaseys Paradise.	Determine definitive host of Kanab Ambersnail trematode parasite. Identify other areas of habitat potentially suited to KAS (within and outside of NPS areas).
Maintain a diversity of wildlife species associated with ongoing natural evolutionary and ecological processes, giving priority to native species.	1. Determine the historical and current wildlife occupying or using habitats in the Canyon. 2. Determine range of natural variability, ecology and ecosystem requirements of species. 3. Monitor impacts of operating criteria on wildlife with emphasis on special status species.	GIS map of upper Lake Mead, physical areas not delineated. Upper Lake Powell regarding riparian vegetation, neotropical migrant birds, native and nonnative fish. Know location and vegetation requirements of some mammals. Amphibian distribution is roughly known, not densities.	Reptile ecologies, densities, and diversity. Use of shoreline marshes by vertebrate (waterfowl, other birds, bighorn, deer, etc.). Need an assessment of current knowledge on distribution, abundance, and life history of riparian herptiles and mammals. Little is known, hard to determine effects of dam operations without an information base.	Distribution and abundance of large mammals should be determined at 5-year intervals. Distribution and abundance of reptiles and amphibians. Should be determined at 5-year intervals. Monitor abundance of RM-9 leopard frogs. Monitor bat populations and habitats.	Determine food habitat of terrestrial vertebrates and effects of and on changing vegetative communities: bighorn sheep and rushes, beaver and cottonwood. • Invertebrate inventory of GCNRA and GCNP.

NRC Concerns

1. Link biotic studies with each other, and integrate with hydrological and geomorphic studies that would make the essential connection to operations.

Monitoring and Research Planning
RECREATION #1

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' need to know	Scientists' Monitoring Statements	Scientists' Research Questions
Provide quality recreation experiences that do not adversely affect natural or cultural resources. Maintain or improve wilderness character of the recreational experience.	1. Determine criteria and aspects that are important to or detract from wilderness experience. 2. Characterize procedures to mitigate those aspects of flows that detract from wilderness character of river. 3. Determine the impact of scientific studies on wilderness character and experience.	1. Accident data on boating/fishing. 2. Discharge levels and related satisfaction of boaters.	1. Recreational expectations of Glen and Grand Canyon visitors.		1. Determine visitor knowledge, expectation, perceptions and experience related to wilderness river recreation.
Maintain flows and sediment processes that create adequate beach character and structure for camping.	1. Determine adequate beach quality character and structure for camping throughout system. 2. Evaluate impacts of operating criteria on establishing and maintaining adequate beaches and distribution of other resource, quality, character and structure. 3. Monitor beach character and structure changes. 4. Develop systems models to predict flow regimes for building & maintaining beaches.	1. Beach areas as related to interim flows, floods below Paria.	1. Beach area from interim flows and floods in Glen Canyon reach.	1. Compile and use aerial photography, videos, etc.; to evaluate flow regimes on camp size, quality and number. 2. Establish cooperative monitoring with boatman and fishermen on fisheries resource change.	1. Determine relationship of impacts through time of debris flows on sites of recreation campsites through models.
Maintain flows that do not preclude navigability by whitewater craft in the Grand Canyon and power craft in Glen Canyon and upper Lake Meade.	1. Determine if operating criteria maintain adequate power craft navigability in Glen Canyon and upper Lake Mead and safe access by recreational users. 2. Determine if operating criteria maintain white water raft navigation in Grand Canyon. 3. Define ecosystem & other resource impacts of flow regimes to maintain navigation. 4. Evaluate the affects of operations as prescribed in the preferred alternatives on recreational safety.	1. Glen Canyon discharge and related "accident" data such as boats and motors striking bottom. 2. Adequate flows for white water rapids.	1. Improved "accident" data (rates, locations). 2. Evolution of rapids in waterway and effects on navigation. 3. Visitor/boat carrying capacity of river corridor by reach.		1. Study of probable impacts of rapid drops in Lake Powell and the effects on recreational uses. 2. Using flight data, assess impacts of flow regimes on boating capacity in reaches with critical resources. 3. Using recreation study assessments completed, determine probable impacts to recreation expectations under different flow regimes.

Monitoring and Research Planning
RECREATION #2

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' need to know	Scientists' Monitoring Statements	Scientists' Research Questions
Maintain cold water fisheries opportunity (100,000 age adult II^{+}) in Glen Canyon.	1. Determine flow regimes necessary to maintain continuous access to quality of the angling opportunity. 2. Determine impacts of operating criteria on other resources and ecosystems.	1. Angler satisfaction and use at various flow levels.	1. Monitoring of angler use and satisfaction.	1. Establish cooperative monitoring with boatman and fisherman on fisheries resource change.	
Maintain sport hunting opportunities for waterfowl in Glen Canyon.	1. Define pattern of waterfowl use and conflicts to other uses. 2. Define pre- and post-dam waterfowl use. 3. Determine effects of flow regimes on waterfowl usage.	1. Waterfowl are highly mobile and population size is strongly affected by factors outside the parks.	1. Effects of dam operation on bird populations and sports hunting.		1. Assess potential effects of dam operations on important waterfowl species.

Monitoring and Research Planning
Hydropower

Stakeholders' Objectives	Stakeholders' Information Needs	Scientists' Knowledge	Scientists' Need To Know	Scientists' Monitoring Statements	Scientists' Research Questions
Maximize the value of long-term firm power and energy generation within the criteria and operating plans established by the Secretary under Section 1804 of the Grand Canyon Protection Act.					

APPENDIX B
PLANNING GROUP PARTICIPANTS

Name	Affiliation
Tom Moody	Grand Canyon Trust
Larry Riley	AGFD
Bill Persons	AGFC
Kerry Christensen	Hualapai Tribe
Steven Lloyd	US Bureau of Reclamation
Andre Potochnik	Grand Canon Rafters
Frank Ronco	N. AZ Flycaster
Norm Henderson	Nat'l Park Serv./Glen Canyon
Bill Davis	EcoPlan Assoc./CREDA
Mark T. Anderson	US Geological Survey
Don Metz	USFWS
Dave Cohen	T.V.
Ted Melis	USGS
Christine Karas	USBR
Barry Gold	GCMRC
Bill Vernieu	GCMRC
Ruth Lambert	
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Kurt Dongoske	Hopi Tribe
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Alan Downer	Navajo Nation
Rich Valdez	BIO/West
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Loretta Jackson	Hualapai
Clay Bravo	Hualapai Tribe
Dick Brown	NA Flycasters
Robert Forrest	EcoPlan Associates
L.D. Garrett	GCMRC
Julie Graf	USGS
Bill Liebreid	SWCA
Bruce Moore	Bureau of Reclamation

APPENDIX C - BIOLOGICAL RESOURCES PROGRAM
STAKEHOLDER OBJECTIVES AND INFORMATION NEEDS

I. FISH AND AQUATIC RESOURCES

Aquatic Food Base

S.O. 1: Maintain and enhance the aquatic food base in Glen and Grand Canyons. Maintain continuously inundated areas for Cladophora and aquatic invertebrates at or above 5,000 cfs discharge.

S.I.N. 1.1: Define current and historic food base character and structure
S.I.N. 1.2: Define food base character, structure and requirements for maintaining target populations
S.I.N. 1.3: Determine system changes to maintain/ enhance food base
S.I.N. 1.4: Define impacts of alternative operating criteria on ecosystem (food base)
S.I.N. 1.5: Monitor the species composition and the distribution of aquatic algae and macrophytes in the Colorado River
S.I.N. 1.6: Monitor the species composition and density of macroinvertebrates in the Colorado River

Humpback Chub

S.O. 2: Maintain or enhance the existing population of humpback chub at or above 1987 levels determined by April/May hoop-net monitoring in the lower 1,200 meters of the Little Colorado River. (Focused at fish >200mm, and should include a fish health assessment.) Maintain levels of recruitment of humpback chub in the mainstem and Little Colorado River, 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.)

S.I.N. 2.1: Monitor adult humpback chub populations and evaluate population level trends
S.I.N. 2.2: Monitor levels of recruitment of humpback chub in the mainstem and the LCR
S.I.N. 2.3: Monitor quantity and quality of chub backwater and near shore habitat in mainstem
S.I.N. 2.4: Determine and identify surrogate native or non-native fishes for evaluation of health factors for humpback chub
S.I.N. 2.5: Develop a backwater quality index, using existing data for humpback chub
S.I.N. 2.6: Evaluate impacts of sampling methods and recreation use on native fish populations

S.O. 3: Establish a second, self sustaining population of humpback chub by 2005, contingent on feasibility. Monitor for spawning and determine the contribution of other existing aggregations as one component of assessing feasibility.

S.I.N. 3.1: Develop criteria for self sustaining populations of humpback chub
S.I.N. 3.2: Assess feasibility of second population including other current aggregations

I. FISH AND AQUATIC RESOURCES (continued)

Other Native Fish

S.O. 4: Verify the status of and management for healthy, self sustaining populations of flannelmouth sucker, bluehead sucker, and speckled dace in the mainstem Colorado River in Grand Canyon and its tributaries. Verify the status of and management for healthy, self sustaining populations of native fish in Glen Canyon based upon the capability of the habitat to support those fishes. (Focused at young-of-year, juvenile, and adults to determine size frequency distributions, densities [via catch rates], and assessment of fish health.)

S.I.N. 4.1: Determine historic and current character and structure of species populations
S.I.N. 4.2: Determine historic and current ecosystem requirements (habitat, spacing, food source, interdependencies, etc.) of species
S.I.N. 4.3: Monitor and define impacts of alternative flow regimes on species population character and structure
S.I.N. 4.4: Determine requirements to maintain/enhance self-sustaining populations of species

Trout

S.O. 5: In the Colorado River corridor below Glen Canyon Dam to the confluence with the Paria River, natural reproduced fish should compose at least 50% of the Age III rainbow trout. Sufficient suitable spawning habitat should be maintained to reach this objective. The total populations of rainbow trout (age II plus) in this reach should be maintained at approximately 100,000 fish as determined from population estimation. Rainbow trout should achieve 18 inches in length by Age III with a mean relative weight (Wr) of at least 0.80.

S.I.N. 5.1: Determine ecosystem requirements , population character and structure to maintain reproduced populations of Age II plus fish at 50,000 - 100,000 population levels
S.I.N. 5.2: Monitor changes in population character and structure
S.I.N. 5.3: Monitor harvested and field sampled rainbow trout to determine the contribution of naturally reproduced fish to the population
S.I.N. 5.4: Monitor the availability and quality of spawning substrates in the Glen Canyon reach
S.I.N. 5.5: Monitor the size of the population of age II plus rainbow trout in the Glen Canyon reach
S.I.N. 5.6: Monitor the growth and condition of rainbow trout in Glen Canyon
S.I.N. 5.7: Define criteria for healthy trout population

I. FISH AND AQUATIC RESOURCES (continued)

Native / Non-Native Fish Interactions

S.O. 6: Minimize, to the extent possible, interactions between native and non-native fishes.

S.I.N. 6.1: Define areas and conditions of current and future existing and potential interactions
S.I.N. 6.2: Monitor key attributes associated with interaction
S.I.N. 6.3: Determine methods for minimizing interactions through isolation
S.I.N. 6.4: Determine methods for minimizing interactions without isolation
S.I.N. 6.5: Monitor the species composition, relative abundance, and size class structure of non-native fishes in the Colorado River and important tributaries
S.I.N. 6.6: Identify existing and potential sources of interaction (predatory, competitive) between extant non-native fishes and native fishes of the Colorado River and important tributaries
S.I.N. 6.7: Evaluate the effects of beach/habitat building flows and habitat maintenance flows on the distribution and abundance of non-native fishes in the Colorado River and important tributaries
S.I.N. 6.8: Identify potential alternative strategies to suppress problematic non-native species in the Colorado River and important tributaries

Reasonable and Prudent Alternative

S.O. 7: Evaluate through monitoring and research the reasonable and prudent alternatives specified by the US Fish and Wildlife Service.

S.I.N. 7.1: Using monitoring and research programs evaluate all test flows in RPA and potential impacts to threatened and endangered fisheries
S.I.N. 7.2: Determine the benefits and impacts of installing selective withdrawal for thermal modification in the mainstem of the Colorado River downstream of Glen Canyon Dam

II. RIPARIAN AND TERRESTRIAL VEGETATION

S.O. 1: Preserve or restore (where possible) natural species composition and abundance within riparian and upland communities affected by dam operations.

S.I.N. 1.1: Determine historical natural composition of riparian and upland communities
S.I.N. 1.2: Characterize normal range of variation and ecology of species
S.I.N. 1.3: Monitor impacts of operating criteria on the succession processes of natural vegetation communities
S.I.N. 1.4: Evaluate impacts of dam operations on establishment of and impacts from exotic plant species
S.I.N. 1.5: Evaluate impacts to vegetation communities of alternate aspects of operating criteria

S.O. 2: Emphasize the preservation of unique plant communities and any special status species (Federal, Tribal, and State designations) to ensure their perpetuation within the system.

S.I.N. 2.1: Determine historic and current distributions, range of variation and ecology of T&E and special status species
S.I.N. 2.2: Establish ecosystem requirements of special status species and determine probable impacts of proposed flow regimes
S.I.N. 2.3: Monitor population changes in special status species

III. NATIVE TERRESTRIAL WILDLIFE RESOURCES AND HABITAT

S.O. 1: 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. Maintain native faunal components of the ecosystems for the benefit of threatened and endangered species.

S.I.N. 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
S.I.N. 2: Monitor species population to detect departures from natural range of variation
S.I.N. 3: Monitoring changes, declines in special status species and characterize ecosystem changes to benefit species

S.O. 2: Maintain a natural age-class distribution through out the majority of their natural range in Glen and Grand Canyons, emphasizing the need to recruit into breeding age classes.

S.I.N. 2.1: Determine species' natural ranges (pre and post dam)
S.I.N. 2.2: Determine historic age class distribution (pre and post dam)
S.I.N. 2.3: Assess natural range and age class disruption, changes, constraints, probable long-term viability implications to species; assess alternate habitat, ecology associations (specifically age class); and ecosystem associations
S.I.N. 2.4: Monitor impacts of alternative operating criteria on ecosystem and ecology requirements of species.

S.O. 3: Evaluate the viability of food chain(s) for native fauna, including the Peregrine Falcon, Southwestern Willow Flycatcher, and other special status species.

S.I.N. 3.1: Define food chain associations, interdependencies, requirements, etc., for native species population targets
S.I.N. 3.2: Monitor impacts of alternative operating criteria on food chain associations

S.O. 4: In as much as such management is not deleterious to naturally occurring ecosystem components, consider and mitigate impacts to special status species that may use the river corridor <u>opportunistically</u> (Bald Eagle). Maintain self-sustaining fish populations as forage to provide opportunities for bald eagles. Monitor for nesting.

S.I.N. 4.1: Characterize historic and current use or expected use of area by species
S.I.N. 4.2: Determine habitat, forage, nesting, etc.; requirements based on current or future use

III. NATIVE TERRESTRIAL WILDLIFE RESOURCES AND HABITAT (continued)

S.O. 5: The population of Kanab Ambersnail should be inventoried and maintained near current levels. Efforts to establish additional population center should be guided by the recovery plan for the species.

S.I.N. 5.1: Characterize historical and current populations of Kanab Ambersnail and their locations
S.I.N. 5.2: Determine ecology and ecosystem related requirements for Kanab Ambersnail to enhance 1996 levels
S.I.N. 5.3: Monitor changes in populations, health, and character of Ambersnail

S.O. 6: Maintain a diversity of wildlife species associated with ongoing natural evolutionary and ecological processes, giving priority to native species.

S.I.N. 6.1: Determine primary and secondary predatory areas, standing crop of attached vegetation communities and associated invertebrate communities and monitor on a seasonal basis
S.I.N. 6.2: Determine the historical and current wildlife (special status and migratory species, including waterfowl) occupying or using habitats in the Colorado riverine corridor
S.I.N. 6.3: Determine range of natural variability, ecology and ecosystem requirements of species
S.I.N. 6.4: Monitor impacts of operating criteria on wildlife with emphasis on special status species