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DRAFT FISCAL YEAR 1999
ANNUAL MONITORING AND RESEARCH PLAN

by

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CHAPTER 1
ANNUAL PROGRAM PLANS
AND
THE LONG-TERM STRATEGIC PLAN

INTRODUCTION

The Fiscal Year 1999 (FY 99) Annual Monitoring and Research Plan (Annual Plan) represents the second year of implementation of the Long-Term Monitoring and Research Strategic Plan (Strategic Plan) for the Colorado River ecosystem.^{1/} The Colorado River ecosystem is defined as the Colorado River mainstem corridor and interacting resources in associated riparian and terrace zones, located primarily from the forebay of Glen Canyon Dam (GCD) to the western boundary of Grand Canyon National Park, a distance of approximately 293 river miles. The scope of the Grand Canyon Monitoring and Research Center's (GCMRC) activities also includes limited investigations into some tributaries (e.g., the Little Colorado and Paria Rivers). All projects proposed will relate to determined or potential resource impacts primarily in the Colorado River ecosystem related to dam operations. It also includes, in general, cultural resource impacts of dam operations for inundation levels associated primarily with flows up to approximately 300,000 cubic feet per second (cfs) as addressed in the Programmatic

^{1/}"Colorado River ecosystem" will be used throughout this document as the standard definition of the monitoring and study area for GCMRC.

Agreement^{2/}, and for physical, biological, recreational and other resources, impacts of dam operations for inundation levels associated primarily with flows up to 100,000 cfs. In between these levels, stakeholder concerns with respect to relict vegetation, endangered species, and cultural resources may require activities by the GCMRC.

The FY 99 Annual Plan represents only incremental changes from the FY 1998 Annual Plan. This follows the logic outlined in the Strategic Plan that monitoring activities should be considered long-term efforts and that significant change in monitoring and research activities would occur following completion of the FY 1998 conceptual modeling and synthesis activities.

GENERAL OBJECTIVES

The Grand Canyon Protection Act of 1992 (GCPA) and Operation of Glen Canyon Dam - Final Environmental Impact Statement (GCDEIS) direct the Secretary of the Interior to establish and implement long-term monitoring programs and related research and scientific activities that will ensure that GCD is operated in a manner consistent with Section 1802 of the GCPA. The GCMRC was established to facilitate these activities. The mission and goals of the GCMRC are to develop monitoring and research programs and related scientific activities that evaluate short- and long-term impacts of "...the effects of the Secretary's actions..."^{3/} on the biological, cultural, and physical resources of the Colorado River ecosystem. The GCMRC also provides

²The Programmatic Agreement is a legal agreement between federal and state agencies and tribal groups that specifies the responsibilities of the parties to comply with federal historic preservation legislation.

³As specified in the 1992 Grand Canyon Protection Act, the GCD Environmental Impact Statement (1995), and the Record of Decision (1996). The "Secretary's actions" include dam operations or alternative dam operating criteria as well as other authorized actions; and will be referred to in this document as "dam operations".

information to meet needs concerning resources of the Colorado River ecosystem specified by the Adaptive Management Work Group (AMWG), and the Secretary of the Interior.

Long-term monitoring of all resources of concern will occur to detect and quantify changes related to dam operations. Research efforts will focus on interpreting and explaining trends, determining causal relationships, and defining inter-relationships among physical, biological and cultural processes. In addition to monitoring and research activities, the GCMRC will develop an information management program to ensure information archiving and transfer to managers, stakeholders, and science organizations.

The Strategic Plan describes monitoring and research activities that will be implemented to determine the effect of dam operations on the natural, recreational, and cultural resources of Grand Canyon National Park and Glen Canyon National Recreation Area as specified in the GCPA. General strategies outlined in the Strategic 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 Strategic Plan. The GCMRC's FY 99 Annual Plan specifies individual monitoring and research projects that will be initiated in response to objectives and information needs specified by the stakeholders and outlined in the Strategic Plan. It is anticipated that the Strategic Plan will be revised following review by the AMWG and the National Research Council in FY 1998.

As a context for understanding the FY 99 Annual Plan a summary of the Strategic Plan and an overview of each major element of the plan is presented below.

AN OVERVIEW OF THE STRATEGIC PLAN: 1998-2002

The Strategic Plan is designed to implement the adaptive management and ecosystem science program called for in the GCPA and the GCDEIS. 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 will be developed to assure appropriate progress on critical elements of the Strategic Plan.

All elements of the Strategic Plan, and all monitoring programs, research projects, and information technologies drafted into annual program plans, will be developed in response to management objectives and information needs specified by the AMWG.

Key elements of the Strategic Plan that are intended to provide the information needed to ensure future monitoring and science programs will be effective at evaluating changes in critical resources associated with "the effects of the Secretary's actions" include:

1. Implementation of an adaptive management program to facilitate close interaction of science and management in evaluating potential new management criteria and the impacts of those criteria on specified management objectives and information needs.
2. Development of a conceptual model of the Colorado River ecosystem that describes critical attributes and linkages within and between resource categories.
3. Synthesis of existing knowledge associated with baseline resource conditions in the Colorado River ecosystem, riverine resource changes associated with

construction of Glen Canyon Dam, and changes associated with differing operating criteria for Glen Canyon Dam.

4. Specification by the AMWG of desired future environmental conditions that can serve as appropriate targets for the implementation and evaluation of the results of management actions.
5. Development of an annual report on the status of valued ecosystem components (VECs) within the Colorado River ecosystem that can be used to evaluate potential management actions to be undertaken in subsequent years.

MISSION AND SCOPE OF GCMRC AND THE STRATEGIC PLAN

Responding to continued concerns over potential impacts of Glen Canyon Dam operations on downstream resources, Congress in 1992, enacted the Grand Canyon Protection Act (P.L. 102-575, Title XVIII). The Act directs the Secretary of the Interior to “... *operate Glen Canyon Dam ... in such a manner as to protect, mitigate adverse impacts to, and improve the values for which Grand Canyon National Park and Glen Canyon National recreation Area were established, including, but not limited to, natural and cultural resources and visitor use*”. While not overturning or superceding existing law, this Act provides the basis for the adaptive management program prescribed in the Glen Canyon Dam Environmental Impact Statement by instructing that “... *the best and most recent scientific data.*” be used in making operating decisions and that appropriate consultation with stakeholders be undertaken. The Act also directs the Secretary to establish a long-term monitoring and a research program to, “... *determine the effects of the Secretary’s actions under section 1204c on the natural, recreational, and cultural*

resources of Grand Canyon National Park and Glen Canyon National Recreation Area.” The closest the Act comes to using the words “adaptive management” is to state in the report language which accompanies the Act, under the discussion of Section 1205, that the Secretary shall “... *respond to information developed under the long-term monitoring program by adapting [emphasis added] the operation of Glen Canyon Dam, ... as needed over time to protect the values for which Grand Canyon National Park and Glen Canyon National recreation Area were established.*” (U.S. Senate, Report 102-267, March 31, 1992).

The Grand Canyon Protection Act does not explicitly state how the Secretary of Interior is to implement the research and monitoring programs specified in the Act. However, in early 1993 EIS work groups began to develop ideas for an adaptive management program for Glen Canyon Dam. Competing proposals for developing an adaptive management program were put forward by the Bureau of Reclamation, the National Park Service, and the Hualapai and Navajo nations, among others. Following extensive debate an Adaptive Management Program was incorporated into the EIS, as the required process for developing scientific information which directly addresses stakeholder concerns and provides the basis for evaluating management options for operating Glen Canyon Dam within existing legal frameworks.

The Adaptive Management process specified in the EIS calls for continued interaction of managers and scientists, to both monitor “the effects of the Secretary’s actions”, primarily current dam operations, on the Colorado River ecosystem, and conduct research on new alternatives that increase protection of resources and improve natural processes.

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

An assessment of dam operation impacts to water quality in Lake Powell completed in FY 97 has resulted in a recommendation by the AMWG that GCMRC develop a monitoring and research program for Lake Powell associated with impacts of the operation of Glen Canyon Dam.

STAKEHOLDER INFORMATION NEEDS AND CRITICAL RESOURCE ATTRIBUTES

The Strategic Plan was established to respond to the general objectives and information needs of managers and stakeholders regarding Glen and Grand Canyon and their resources.

Objectives and information needs of stakeholders are specified in nine resource areas including: hydropower, water, sediment, fish and aquatic biology, vegetation, threatened and endangered species, terrestrial wildlife, cultural resources, and recreation (Figure 1).

Within each of the above resource areas, specific objectives were developed cooperatively by the Bureau of Reclamation (Reclamation) and representatives of the AMWG. Detailed information needs for various objectives and resource areas were defined by representatives of the AMWG working cooperatively with the GCMRC. These objectives and information needs

may be found in the Strategic Plan and will be reviewed and revised in FY 1998 to define a set of desired future environmental conditions and valued ecosystem components.

PROPOSED MONITORING AND SCIENCE PROGRAMS

Monitoring and science programs proposed in the Strategic Plan include the following:

1. Conceptual modeling and synthesis of existing knowledge.
2. Physical resource program.
3. Cultural resource program.
4. Biological resource program.
5. Socioeconomic resource program.
6. Information technology program.
7. Science Advisory Board

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

Conceptual Modeling and Synthesis of Existing Knowledge

The synthesis of existing data and information 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 the Colorado River ecosystem. The intent of the model will be to examine resource elements that respond to variable operating criteria of Glen Canyon Dam. The second component of the synthesis program is the critical analytical assessment of past research associated with the riverine corridor's resources after and possibly before Dam construction, as well as relevant data and information from other regulated and unregulated

western riverine corridors, that are of similar character and structure to the Colorado River ecosystem. These syntheses are addressed in the individual resource program areas.

Completion of these syntheses will provide an important tool for organizing our understanding of this riverine ecosystem and the impacts of flow regulation. Anticipated end products include a more integrated data assessment and interpretation of critical alternatives associated with resources of concern, and a major comprehensive transfer of information to stakeholders from GCMRC regarding the potential impacts of alternative operating criteria on riverine ecosystems and associated resources.

The Physical Resources Program

Hydrology and sediment are the two primary resources of concern in the physical resources area, although impacts from Glen Canyon Dam operations on these physical resources also extend to other resources, such as biological and cultural. For the most part, Fiscal Year 1999, monitoring and research efforts started in the FY98 program will continue to focus on four areas of impact from dam operations as follows:

1. Influence on mainstem flows,
2. Sediment balance and geomorphic processes, including those related to active sandbars used as camping areas and terrestrial and aquatic habitats, and pre-dam river terrace deposits containing cultural resources,
3. Inter-relationship between mainstem and tributary sediment and flows, with particular emphasis on inputs from the Little Colorado and Paria Rivers, and

physical impacts of tributary debris flows on mainstem geomorphology and related resources and processes,

4. Influences of dam releases and natural tributary inflows on mainstem hydrology and sediment transport with respect to impacts on Upper Lake Mead delta and related resources, such as southwest willow flycatcher habitat.

The Biological Resources Program

Monitoring and research relating to biological resources is intended to refine and further develop information about the structure and function of the Colorado River ecosystem in relation to dam operations. Linkages between the biological resources program and the physical resources program should be made to facilitate the understanding of the influence of abiotic factors on biotic resources (e.g., discharge and sediment on fish habitat).

Monitoring and research efforts will address the following areas:

1. Aquatic food base.
2. Native and non-native fish populations.

Programs will evaluate native and non-native fish population dynamics to assess the native and non-native fish communities' responses to alternative dam operations and criteria. Native fish species of concern are the humpback chub and flannelmouth sucker. Non-native species of current interest as predators/competitors of native fish include several species of Salmonidae, Ictaluridae, Cyprinidae and Percichthyidae.

Monitoring of the non-native trout fishery in the Lees Ferry reach will concentrate on growth, survivorship, recruitment, and changes in population structure, including the contribution from natural reproduction over time and angler use. Monitoring of other non-native fish populations will be carried out in conjunction with ongoing native and non-native fish monitoring activities.

3. Vegetation change with respect to species composition and area in the riparian zones along the river.

Changes in species composition and vegetative area in the three primary riparian zones along the river will be monitored including, the upper riparian zone, lower riparian zone, and hydro-riparian wetland communities.

4. Threatened and endangered species studies to address the population age structure, diet analysis, and habitat requirements of listed species, including the Kanab Ambersnail and Humpback Chub.

Monitoring of threatened and endangered species will remain a priority for GCMRC. For example, with respect to the Kanab ambersnail monitoring and research activities will address the population age structure analysis, diet analysis, and habitat requirements.

5. Avifauna monitoring that emphasizes the Southwestern Willow Flycatcher and general riparian avifauna surveys with respect to habitat conditions, and population censuses (e.g., riparian obligate species, resident non-obligate species, and migrant species).



Avifauna monitoring will emphasize the southwestern willow flycatcher and general riparian avifauna surveys (e.g., wintering and breeding waterfowl, riparian obligate species, resident non-obligate species, and migrant species).

The Cultural Resources Program

This program will address information needs of the AMWG relative to cultural resources at the direction of parties to the Programmatic Agreement (PA), who are also AMWG members. Activities that are a part of the ongoing PA program may be included. Monitoring and research information needs and activities from the PA are expected to be a major component of the Strategic Plan.

The cultural resources program for the GCMRC 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 Strategic Plan.

1. Assess existing and develop additional data and monitoring systems to assess impacts.
2. Assess existing and develop additional data to assess risk of damage and loss of cultural resources from varying flow regimes from 45,000 cfs to 100,000 cfs.
3. Assess existing and develop additional tribal monitoring programs for evaluation of impacts to cultural resources.
4. Assess existing and test local and reach-scale predictive model of geomorphic processes that are related to archeological site erosion.

5. Assess existing and develop additional mitigating strategies related to documented dam impacts determined by monitoring assessments.

6. Characterize resources through scientific study.

The Socio-economic Resources Program

There are many socioeconomic resources associated with the Colorado River ecosystem including recreation, camping beaches, electric power, and water delivery and water quality.

Areas of monitoring and research in the socioeconomic program will include the following:

1. Change in campsite beach area, number, location and quality.

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

2. Recreational safety.

3. Methods for and enhancement of the wilderness experience.

4. Changing user preferences.

Information Technology

Extensive data and information currently exist in the GCMRC collections relating to resource conditions, quality, and relationships to other resources. Potentially equal amounts of data and information exist within museums, universities, agencies, etc. However, much of this information has not been organized, managed or integrated into an analysis of the interrelationship among various resources and dam operations.

The following areas will be implemented in the information technology program:

1. Development of protocols for data collection, processing and use.
2. Development of extensive multi disciplinary databases and a database management system.
3. Development of a robust geographic information system (GIS) to accommodate multiple layers associated with all resources of interest to stakeholders.
4. Development of databases associated with remotely sensed data are not presently incorporated in the GCES database system.
5. ~~Develop stakeholder interface mechanisms to access selected data and information in the database management system and GIS.~~
6. Development of outreach programs including identification and quantification of needs, to transport data and information, and to educate stakeholders in use of data and models incorporated in the information technologies program.

SCHEDULE AND BUDGET

The Strategic Plan is designed to address monitoring and research for a five-year period 1998-2002. Each year in October, an annual plan will be drafted to guide implementation of specific elements of the Strategic Plan. It will have prior review by the AMWG and approval by the Secretary of the Interior. The Annual Plan outlined in this document addresses monitoring and research for Fiscal Year 1999, beginning October 1, 1998.

The budget for the FY 99 Annual Plan is programmed at \$7,300,000. Of the total \$7,300,000 budget allocation, approximately \$5,600,000 will be directed to GCMRC science

programs. Approximately \$400,000 is required by the Upper Colorado Region of BOR to administer the adaptive management program, and approximately \$1,300,000 is required to operate all GCMRC's administrative programming.

CHAPTER 2

STAKEHOLDER INFORMATION NEEDS

WHICH GUIDE THE FY 99 ANNUAL PLAN

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^{4/} recommendations.

The stakeholder objectives developed lie in nine resource areas (Figure 1). All of the stakeholder objectives may be found in the Strategic Plan. The AMWG has decided to review the stakeholder objectives in FY 1998. Review and revision of these stakeholder objectives will result a more definitive set of desired future environmental conditions for the Colorado River ecosystem and valued environmental components.

IDENTIFIED INFORMATION NEEDS

A synopsis of the information needs in each resource area is presented in the following text. These information needs were the primary basis for developing both Fiscal Year 1998 and Fiscal Year 1999 monitoring, research, and information transfer programs for the GCMRC. They are also the basis for continuation of FY1998 physical science activities with minimal

^{4/} Adapted from *Glen Canyon Dam Management Objectives*, Bureau of Reclamation memorandum UC-205, ADM-1.10, July 1996, to Transition Work Group members.

modifications through at least FY1999: In the cultural resource area, some information needs were predefined, based on ongoing activities within the Programmatic Agreement.^{5/}

Information needs specified by stakeholders are explicitly linked to stakeholder objectives. Generally, as new objectives are specified, they result in a new set of information needs. In Fiscal Year 1998 (spring 1998), new objectives will be defined by the TWG and approved by the AMWG, which will also require specification and approval of new information needs. Objectives and information needs will be specified for the Lake Powell program at that time. All new objectives and information needs will be used to define the FY 2000 program.

Water Resources

- 1) Monitor changes in water quality (physical and chemical characteristics such as temperature, salinity, nutrients, trace elements, etc.) over time and space,
- 2) Monitor concentrations of chemical constituents relative to historical levels, and with respect to identified Colorado River ecosystem requirements, and relative to established EPA/state and tribal standards,
- 3) Monitor water temperature changes throughout the Colorado River ecosystem over time and space with respect to influences of dam operations.

^{5/} The Programmatic Agreement is a legal cooperative agreement among the Advisory Council on Historic Preservation, National Park Service, Upper Colorado Region of Bureau of Reclamation, Arizona State Historic Preservation Office and seven tribes as follows: Havasupai, Hopi, Hualapai, Kaibab Paiute, Navajo, San Juan Southern Paiute, Shivwits Paiute and Zuni.

Sediment Resources

- 1) Monitor fine-grained sediment deposits, including pre-dam river terraces, active sandbars used by recreationists as camping areas, and aquatic habitats related to return-current backwater channels,
- 2) Monitor changes in backwater habitats relative to dam operations under the Record of Decision (ROD),
- 3) Define character and structure of pre-dam river terraces associated with cultural resources, and all other fine-grained sediment deposits, including camping beaches and backwater habitats found throughout the Colorado River ecosystem immediately following the 1996 test flow,
- 4) Define historical and current (character and structure) levels of channel-stored sediment throughout the Colorado River ecosystem and associated dam operations,
- 5) Determine baseline conditions of fine-sediment storage throughout the river ecosystem.

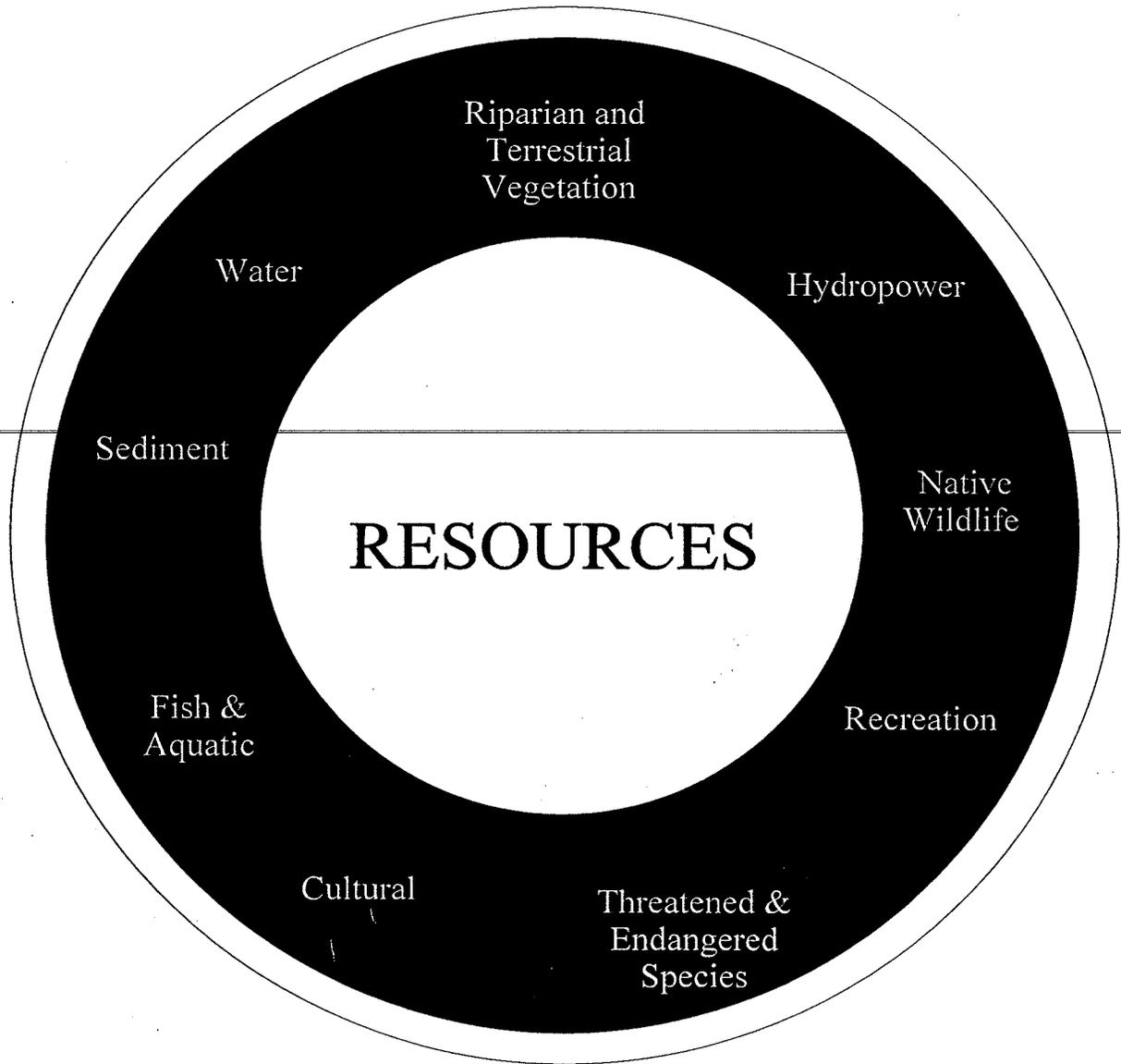


Figure 1. Objectives resource areas identified for research and monitoring.

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 defined 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

- Improve monitoring protocol for adult Humpback Chubs and evaluate population trends.
- Determine historic and current character and structure of species populations.

- Conduct studies of temperature, habitat availability and use of mainstem and tributary habitats by native fish.
 - Determine importance of backwaters to native fish.
 - 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.
 - Determine impacts of dam operations on trout redds.
 - 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.
 - Design and test an experimental program of steady flows to verify an effective flow regime and quantify, to the extent possible, effects on endangered and native fish.

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 successional processes of natural vegetation communities.
- Evaluate impacts of dam operations on establishment of and impacts from exotic plant species.
- Evaluate impacts of alternate dam operating criteria on vegetation communities.
- 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, where possible, species' natural ranges (pre and post dam).
- Define food chain associations, interdependencies, requirements, etc., for native species population targets.

-
- Characterize historic and current expected use 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 power craft 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.

Information needs were not specified for Lake Powell for FY 1998. In FY 1997, an assessment was requested by the AMWG to define Lake Powell water quality impacts related to Glen Canyon Dam operations. The assessment revealed impacts from dam operations and resulted in the AMWG proposing continuation of current monitoring programs in FY 1998, until new objectives and information needs could be specified for Lake Powell in FY 1998. As noted, these new objectives and information needs will be used to develop Lake Powell monitoring and research programs for FY 2000.

CHAPTER 3
FISCAL YEAR 1999 MONITORING AND
RESEARCH PROGRAM ACTIVITIES

INTRODUCTION

This chapter presents the FY 99 program activities to be conducted for the following program areas:

- Conceptual modeling and synthesis

- Physical Resources
- Biological Resources
- Cultural Resources
- Socioeconomic Resources
- Information Technologies

For each of the above resource areas, we address three criteria to define projects for FY 99. First, we review the FY 98 monitoring and research programs to determine which elements of those programs need to be continued. Second, we review objectives and information needs to assure that those critical needs specified are appropriately incorporated in the FY1999 Annual Plan. Third, we evaluate the Strategic Plan to assure that FY1999 monitoring and research proposed is in fact fully supportive of programs planned and time schedules proposed in the Strategic Plan.

CONCEPTUAL MODELING

As part of the overall synthesis to guide monitoring and research programs in each resource area, a conceptual model will be completed in FY 1999 to represent Colorado ecosystems, resources and resource attribute linkages. This systems model will be used to guide monitoring and research planning, define attribute linkages, characterize key attributes, and make qualitative assessments of resource change from alternative dam operations. All research and monitoring programs over will contribute to the conceptual modeling activities.

The conceptual model will be developed to represent the Colorado River ecosystem from the forebay of GCD to the western most boundary of Grand Canyon National Park. This conceptual model will be used to: (1) guide monitoring and research planning, (2) more clearly define critical attributes and linkages within and between resource categories, (3) promote improved understanding of key factors that drive change in the system, (4) make qualitative assessments of resource change resulting from alternative dam operations, and (5) provide information to stakeholders and managers regarding the potential impacts of alternative dam operations on the Colorado River ecosystem and associated resources. Completion of this conceptual model in FY 1999 will provide an important tool for organizing the GCMRC's understanding of the Colorado River ecosystem and the effects of dam operations.

GCMRC has selected a group of modelers through a competitive process to lead the development of the desired conceptual model. In FY 1998, the GCMRC, together with the modeling team, will convene a scoping meetings to define the scope of the problem, design the first of two subsequent modeling workshops, identify key people (scientists and stakeholders) to

participate in the modeling workshops, and to assemble the information that will be used in the first workshop.

Following the scoping meeting, an initial modeling workshop will be convened in FY 1998 to develop explicit relationships among attributes. This workshop will involve scientists and stakeholders knowledgeable about the Colorado River ecosystem. The GCMRC will work with the modeling team to develop the information bases including maps, databases, published reports, etc., that will be necessary for this workshop. Scientists and stakeholders together will define resource variables/attributes that serve as linkages between/among resources. This "looking outward matrix" specification of resources, their attributes and the attribute linkages to other resources are building blocks for the conceptual system (Fight et al. 1986). Figure 2 provides an example of this matrix for an anadromous fisheries submodel of a conceptual systems model. The goal for the first workshop is to produce a conceptual model of the Colorado River ecosystem based on critical relationships that structure the system, identify key information gaps, and suggest initial priorities for a long-term monitoring and research program.

A second modeling workshop will be held in FY 1999 to refine the conceptual model and develop a strategic simulation model with first approximation parameter estimates, that can be used to evaluate resource responses to different management strategies. Appropriate time will elapse between the first and second modeling workshops to validate and refine submodels, develop additional needed data and information, and where needed, specify necessary subcomponents of submodels.

During the second workshop the process of assigning more definitive co-efficient values to what are believed to be key model parameters will begin, as well as model validation and

sensitivity analysis to test key assumptions embedded in the model. Analysts will begin to explore the consequences of alternative dam operations based on the assumptions and hypothesis used to construct the model. This second workshop is intended to yield a first approximation strategic model that, in association with new synthesis information being developed in FY 1998 and 1999, will provide a sound basis for the development of a long-term monitoring and research plan.

The “working” strategic model will continue to be refined and developed over the course of the first five-year strategic plan. More detailed submodels for specific elements of the system (i.e., riparian vegetation, cultural resources, etc.) will be developed through prototypes to operational stages.

The project will, at a minimum, address the following objectives:

- 1) State of the science synthesis of data needed for development of the conceptual model and identification of key information gaps, as well as priorities for monitoring and research.
- 2) Scoping meeting to define the scope of the problem, design first modeling workshop, develop list of participants.
- 3) Develop, using a workshop approach, a working conceptual model of the Colorado River ecosystem that can be run on an appropriate software platform and which identifies critical relationships that structure the ecosystem.
- 4) Revision of the conceptual model, through a second workshop, to the level of a strategic model which assigns numeric values to key parameters in the model and which can be used to test alternative assumptions and hypotheses regarding changes to the ecosystem and associated resources from alternative dam operations.

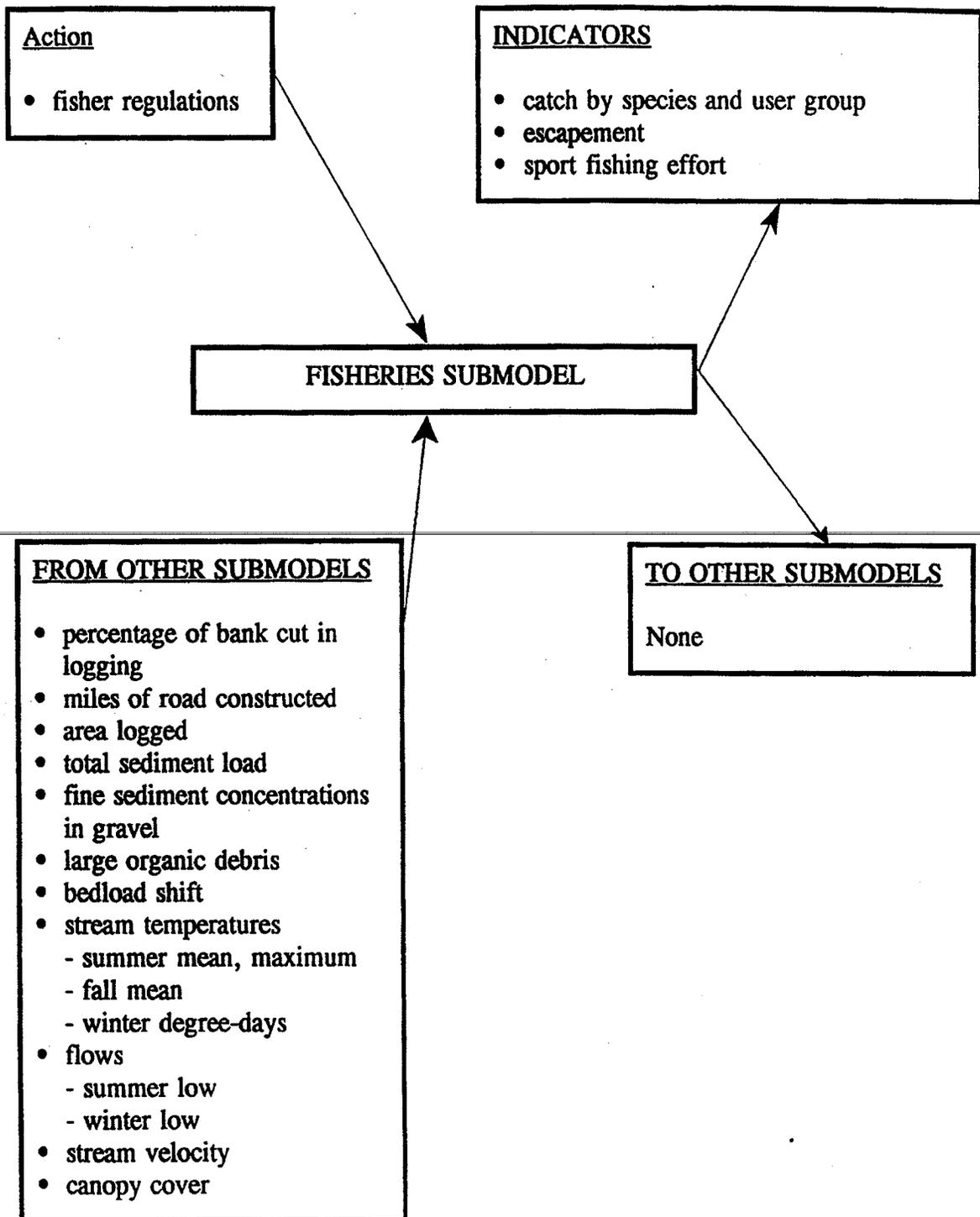


Figure 2. A "Looking Outward Matrix for Fisheries Resources in the Southeast Alaska Multi resource Model" (adapted from Fight et. al., 1986).

This project will take place over FY 1998 and 1999 with progress reports due following the scoping meeting and each workshop. The scoping meeting has been scheduled for January 1998, with the first workshop tentatively scheduled for June 1998 and the second workshop scheduled for October 1998. A draft final report is due in FY 1999 on 15 December 1998, and a final report due on March 31, 1999. The final report shall contain an executive summary, suitable for dissemination to management entities.

Upon completion of the project, the conceptual model will be delivered to the GCMRC in appropriate electronic format and with suitable documentation to allow GCMRC managers to operate and further develop the model.

THE PHYSICAL RESOURCES PROGRAM

Responding To Information Needs of Stakeholders

Vital information needs targeted for the FY1999 physical resources program are presented in the following synopsis:

Mainstem and Tributary Streamflow Resources

- 1) Monitor system-wide changes in the physical and chemical characteristics of mainstem streamflow through time,
- 2) Monitor mainstem concentrations of chemical constituents to standards which influence river ecosystem health,
- 3) Maintain annually updated GCMRC database of unit streamflow values derived from:
Paria River, Lees Ferry, Mainstem above the Little Colorado River (LCR) confluence,
LCR near Cameron, Grand Canyon near Phantom Ranch, Havasu Creek near Supai,

and Diamond Creek gages,

- 4) Monitor system-wide mainstem water temperature changes through time in ways that are useful to biotic investigations,
- 5) Monitor dam operations, mainstem and tributary flow/sediment contributions relative to mainstem sediment transport to Lake Mead [ongoing development of a system-wide sediment budget].

Sediment Resources

The most critical issue relating to the long-term health of the river ecosystem below Glen Canyon Dam is whether or not the system is in surplus or deficit with regard to sand and finer sediment. Future Beach/Habitat-Building Flows will only be effective in long-term preservation of sand bars if tributary supplies of sand and finer sediment are greater than the volume removed from the system to Lake Mead by dam operations. Based on previous studies, the most critical areas of the sediment budget question relate to sediment inputs from tributaries throughout Glen Canyon and the Paria River and the sediment budget of Marble Canyon.

The following, are areas that should be incorporated into the future monitoring program related to the question of overall sediment availability and conditions of sediment resources of interest to stakeholders:

- 1) Document planimetric changes in terrestrial sand bars, campsite areas and emergent backwaters in targeted GIS reaches and relate changes in these resources to changes in sediment availability and to dam operations between FY98 and FY99, as well as mainstem and tributary floods, if and when inflows from the Paria or LCR or releases
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from Glen Canyon Dam raise mainstem discharge above levels associated with normal operations at the dam,

- 2) Document annual changes in pre-dam flood terrace-based drainage areas containing cultural exist in selected GIS reaches related to factors described above,
- 3) Define annual changes in volume and particle-size distribution of channel-bed stored sand between Glen Canyon Dam and Phantom Ranch, with emphasis on sediment budgets for reaches above and below the Paria and LCR confluences,
- 4) Determine annual changes in system-wide sediment budget based on all tributary inputs of streamflow, and on sediment transport to Lake Mead driven by the combination of dam operations and tributary inflows.

General Components of the Fiscal Years 1998-99 Physical Resource Program

The FY1999 physical resources monitoring program is intended to be a continuation of the program implemented in FY 1998, and is designed to provide resource-status information to stakeholders, and support implementation of the strategic plan. The strategic plan, and this annual plan address information needs in three areas:

1. Dam releases and downstream discharge/stage relationships between Glen Canyon Dam and Lake Mead,
 2. The influence of dam operations on mainstem geomorphic processes associated with streamflow and sediment,
 3. Relations between dam operations and the mainstem sediment budget, including
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tributary inputs of streamflow and fine sediment, local-scale physical changes in the river channel caused by tributary debris flows, changes in mainstem storage of sand and finer sediment, and outputs of streamflow and sediment to Lake Mead.

Dam discharges and streamflow and sediment monitoring and research will continue in FY1999 with the following projects:

- 1) Capturing unit streamflow values for dam discharges and streamflow through Grand Canyon (Lees Ferry, mainstem above the LCR confluence, Grand Canyon near Phantom Ranch, Diamond Creek), as well as the following tributaries: LCR near Cameron, Paria River, and Havasu Creek,
- 2) Refine estimates of sediment deliveries from all tributaries with emphasis on the Paria and LCR (inputs), and transport in the mainstem to Lake Mead (output) associated with measured streamflows in a way that increases knowledge of overall sediment budget for the system.

Sediment monitoring, integration and research related to development of the sediment budget will focus on synthesis of past efforts, developing improved monitoring methodology and development of linkages to other resources. Individual projects may include:

- 1) A synthesis of selected past sediment transport research between Glen Canyon Dam and Lake Mead with the objectives of development of attribute associations between sediment flux and flow regimes,
- 2) A synthesis of historical information (pre and post dam) related to sandbar stability and erosion, with emphasis on developing reach-specific relations between dam

operations, sediment availability and sand bar deposition and erosion,

- 3) A synthesis of science and information (pre and post dam) related to sediment balance in the riverine system by geomorphic reach. Focus is on integrating information on bars, flux and storage to provide a method for determining sediment balance and evaluating headwall cutting impacts to upper terrace cultural resources,
- 4) Continue some level of sand-storage monitoring conducted previously (sandbar mapping, monumented cross sections, etc.). However, merge monitoring into a smaller number of projects, eliminate duplicated effort, and establish protocols that provide best time and space assessments of key parameters by geomorphic reach.

Also, merge efforts in research and mapping assessments into this new more comprehensive sediment monitoring approach that links camping areas to the socioeconomic program and cultural resource preservation and monitoring in the cultural resources program,

- 5) Develops a new sediment monitoring protocol by geomorphic reach that relates all mainstem channel dynamics related to sediment and flow to dam operations, as well as occasional natural floods from tributaries that impact mainstem resources. 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.

Tributary impacts and sediment interactions on mainstem resources is an area where considerable knowledge needs to be generated regarding water quality, sediment flux and nutrient levels.

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Following are some possible FY98-99 proposed projects.

- 1) Develop a new sediment monitoring protocol by reach from Glen Canyon Dam to upper Lake Mead that relates mainstem channel dynamics to physical processes in tributaries related to sediment and flow,
- 2) Synthesis of selected research and monitoring of marsh, back channel, backwater and mainstem streamflow and sediment characteristics below tributary confluences, documenting their relationships to tributary water and sediment characteristics at differing dam operations,
- 3) Synthesis of existing information relating sediment volume and particle size with nutrients below key tributaries and differing dam operations,
- 4) Maintenance of a GCMRC database for unit values of streamflow from all gaging stations listed above,
- 5) Develop new monitoring stations for streamflow and sediment at juncture between upper and lower Marble Canyon (temporary gaging station installed and operated at about river mile 38), and on the LCR near the confluence with the Colorado River.

Mainstem flow and sediment flux impacts to Lake Mead delta have not been determined for differing dam operations. Significant confounding results in the system owing to the distance between Glen Canyon Dam and the Lake Mead Delta, and Hoover Dam which impounds Lake Mead.

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

- 1) Resurvey of Lake Mead sediment delta through Reclamation cooperative agreement
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- with Lower Colorado River regional office, using a modern GPS-based protocol (possibly airborne LYDAR) that allows comparisons with results of 1962-63 upper Lake Mead delta survey. This work will compliment sediment budgeting as well as monitoring of habitat related to endangered species (southwestern willow flycatcher),
- 2) Synthesis of existing knowledge relating changes in sediments in Lake Mead delta to variable dam operations criteria and associated changes in flora and fauna, and sediment budget.

Physical Science Response to Information Needs During FY1999

The main focus of the FY1999 GCMRC physical science program is on hydrology and sediment transport, the physical processes related to those resources, and how they act independently and together upon other resources under Record of Decision (ROD) dam operations. Programmed monitoring and research, including synthesis of existing data, will continue to focus on documenting changes in these resources through time. These science efforts were initiated in FY1998 and were intended to be continued through FY1999. They are divided among seven areas that are distinguished by the following titles and general descriptions:

- 1) Monitoring and Research of Streamflow, Suspended Sediment Flux, and Changes in Mainstem Sediment, and Water Quality of the Colorado River Ecosystem - [U.S. Geological Survey (USGS)]. Special emphasis will continue to be placed on critical aspects of streamflow that influence biophysical processes, such as water temperature and other key water quality parameters as part of the U.S. Geological Survey monitoring and research program. Research Working Draft - 2.0 (10/24/97): For Review, Do Not Cite, Photocopy, or Distribute

and monitoring by the USGS will also continue to aim at refinement of the system-wide sediment budget through a combined approach of empirical and modeling approaches conducted by the USGS. This monitoring will focus on sediment inputs from gaged tributaries and mainstem sediment transport within and out of the river ecosystem. Monitoring efforts by the USGS will also track changes in volume and particle-size distribution of channel-stored sediment, and sandbar sedimentology relative to form, structure and distribution (see appendices). Monitoring of these physical resources may occur more frequently if special circumstances, such as a beach/habitat-building flood, occurs during the funding period, and if funds are available.

2) Monitoring Changes in Fine-Grained Sediment Deposits Throughout the Colorado

River Ecosystem - [Geology Department, Northern Arizona University (NAU)]. Changes in the planimetric size and volume of representative sandbars will continue to be monitored by NAU through FY1999, as well as changes in sand storage within eddies. Assessment of changes in sandbars, camping areas, backwater habitats, and pre-dam terraces associated with cultural resources will be conducted annually (see appendices). Monitoring of these physical resources may occur more frequently if special circumstances, such as a beach/habitat-building flood, occurs during the funding period, and if funds are available.

3) Estimating Sediment Flux From Ungaged Tributaries of the Colorado River
Ecosystem - [USGS]. The USGS will continue to develop long-term estimates of sediment yields from all ungaged tributaries between Glen Canyon Dam and Upper Lake Mead to provide a more robust system-wide sediment budget (see appendices). This work will follow-up on previous data developed by the USGS on ungaged tributary processes and inputs during the GCDEIS/GCES Phase II period from 1990-1995.

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4) Synthesis of Geomorphology and Historical Changes in Sediment Resources of the Colorado River Ecosystem - [Geography Department, Utah State University (USU)]. In addition, the physical program in FY1999 will continue to support efforts by USU intended to provide adaptive management stakeholders with a synthesis of existing hydrologic and geomorphologic data (see appendices). When completed at the end of FY1999, this work is intended to provide a better understanding of historic relations between river geomorphology, geomorphic processes of the river, sediment input/output and dam operations. Such information will support development of conceptual and simulation models being developed through the GCMRC.

5) Developing Predictive Capabilities for Estimating Fine-Sediment Inputs From the Little Colorado River to the Colorado River Ecosystem - [USGS]. The USGS will also continue development of a numerical flow and sediment model for the Little Colorado River (see appendices). When complete, this predictive tool will provide sediment volume and particle-size input data from streamflow hydrograph data that can be used in conjunction with the Paria River model for determining major fine-sediment budget components. This modeling effort will follow the general approach taken during an earlier modeling effort undertaken by the USGS for the Paria River between 1991 and 1997.

6) Evaluating monitoring protocols and Assessing New Technologies for Incorporation into the GCMRC Long-term Monitoring Program - During FY1999, the GCMRC physical science program will also continue efforts to incorporate information and findings from a series of monitoring-protocol evaluation and scoping workshops into the FY2000 long-term monitoring program. These efforts will be coordinated as part of a larger integrated effort that will also examine protocols and technologies used to monitor biotic and cultural resources. One of the

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main goals of this effort is to identify more effective means of monitoring sediment resources and flow that promote both cost efficiency and minimize intrusiveness to the river ecosystem (RFP to be released for this effort during the first quarter of FY1998, with workshops to be completed by September 30, 1998. FY1999 efforts will focus on integrating workshop/scoping results into the annual plan for FY2000, and design of the long-term monitoring program.

7) Conceptual Modeling - As described above (see appendices). New and existing information regarding physical resources and processes of the Colorado River ecosystem will be incorporated into the conceptual and numerical simulation models as they continue to be developed during FY1999.

The annual and strategic plans are intended to develop new information that builds on what was learned about the physical system between 1990 and 1997, while providing stakeholders with information on the changing state of sediment resources annually.

CULTURAL RESOURCES PROGRAM

The FY 99 cultural resources program is a continuation of activities initiated in the FY 98 program and it provides for a limited number of new activities. All activities, ongoing and new, respond to the stakeholder objectives and information needs that have been identified during the formation of the Adaptive Management Program (AMP) and the establishment of the Adaptive Management Work Group (AMWG). As the AMP proceeds, it is anticipated that the AMWG will revisit and reassess the objectives and information needs. Information provided by cultural program monitoring and research activities should assist in refining objectives and information needs.

The stakeholder objectives identified in the area of cultural resources reflect a general
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concern for in-situ preservation of resources to the maximum extent feasible. Preservation of resources stems from a recognition by the stakeholders of the finite value of these resources and their special concern to Native American stakeholders. If in-situ preservation is not possible, stakeholders are concerned that appropriate mitigative strategies be designed that integrate the full consideration of the values of all concerned tribes with scientific approaches. Protection and physical access to cultural resources for tribal religious purposes have also been identified by the stakeholders. Finally, stakeholders are concerned that appropriate research strategies are developed which maximize data collection from mitigation and monitoring efforts for understanding human use and occupation in the Canyon.

FY 1998 Program

The FY 98 program proposed four activity areas to address stakeholder objectives and the related information needs. A fifth activity area was also specified to accommodate projects that may be directed into the Grand Canyon Monitoring and Research Center (GCMRC) cultural program from the complementary Programmatic Agreement (PA) program by the PA signatories that are members of the AMWG. The FY 98 activity areas are: 1) synthesize existing data; 2) develop a risk assessment for cultural resources relative to varying flow regimes and the related sediment deposition; 3) develop tribal programs to assess resource impacts; 4) develop appropriate data systems and related technology; and 5) accommodate PA program activities as directed.

In order to respond to these activity areas, three Requests for Proposals (RFPs) were announced for the FY 98 cultural resource program. These RFPs called for a synthesis of the Working Draft - 2.0 (10/24/97): For Review, Do Not Cite, Photocopy, or Distribute

existing cultural resource data, mainstem modeling and sediment dynamics relative to cultural resources, and testing of a geomorphic model relative to cultural resource locations.

Data Synthesis.

The project objectives of the data synthesis effort include a synthesize of: 1) existing NPS and tribal data bases of all inventoried resources and their impacts resulting from dam operations that have been monitored and/or managed to date; 2) isolated occurrences; 3) NPS and Tribal resource management activities conducted to date at all sites; 4) results of ancillary studies such as geomorphic studies, ethnobotany, mapping; 5) public information and education efforts accomplished to date; and 6) results of data recovery conducted to date at river corridor sites.

This project will provide basic information for use in the GCMRC cultural resources program and to meet the requirements of the PA program. In addition, these data are needed to formulate other preservation and mitigative activities that address the identified stakeholder objectives for cultural resources. At present, a comprehensive proposal has been received to accomplish these tasks and is pending award. This project is scheduled to be completed in FY 98.

Mainstem modeling and sediment dynamics at selected cultural resource locations.

The project objectives of this effort include: 1) model stage-discharge relationships for varying flow regimes in selected reaches containing cultural resources up to the approximate elevation associated with the 100,000 cfs discharge; 2) model flow and sediment-transport dynamics at these resource locations up to the 100,000 cfs discharge elevation; 3) apply predictive flow and sediment modeling capabilities to specific river-terrace locations containing

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cultural resources to evaluate results of flow and sediment -transport model scenarios; and 4) provide recommendations on scenarios that optimize depositional rates along terraces or within arroyo confluences where cultural resources are located. This project will provide information on possible impacts to resources at specific stages-discharge elevations and the sediments that are predicted to be deposited in associated with those flows. Deposited sediments are believed to provide a buffer for pre-dam terraces that contain cultural materials. This information relates to stakeholder objectives that address in-situ preservation of cultural resources and mitigation strategies. At present, a comprehensive proposal has been received to accomplish these tasks and is pending award. This project is scheduled for FY 98 and FY 99.

Test and apply a geomorphic model related to erosion of pre-dam terraces containing cultural materials.

The project objectives of this effort include: 1) incorporation and evaluation of data from previous geomorphic work on river- and terrace-based arroyos, existing archaeological monitoring data, and relevant research from sedimentation and climatological studies; 2) testing and evaluating the validity of the geomorphic hypothesis, refining and revising model as needed to improve predictive utility in determining how, when and where terrace-based erosion is likely to impact cultural resources; 3) identifying most threatened resources, prioritizing remedial action needs, and making management recommendations based on findings. The results of this study will provide guidance for targeting resources that are most threatened and most likely to be lost through dam related erosional processes. As such, this project will provide basic information that addresses stakeholder objectives relative to preservation and mitigation strategies. At present, a

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comprehensive proposal has been received to accomplish these tasks and is pending award. This project is scheduled for FY 98 and FY 99.

FY 99 Cultural Resources Monitoring and Research Activities

Five activity areas are proposed for FY 99. These represent a continuation of FY 98 activities with some incremental changes in FY 99.

Activities Continued from FY 98

- 1) Mainstem modeling and sediment dynamics at selected cultural resource locations.

FY 99 activities for this project are a continuation of work initiated in FY 98. This project will be concluded at the end of FY 99. Deliverable schedules for the project are currently under negotiation and specific products and time frames are not available. The numeric, predictive model will be delivered at the end of FY 99.

- 2) Test and apply a geomorphic model related to erosion of pre-dam terraces containing cultural materials. FY 99 efforts in this project area are a continuation of FY 98 activities. This project is scheduled to conclude at the end of FY 99. Deliverable schedules for the project are currently under negotiation and specific products and time frames are not available. The study results will be available at the end of FY 99.

- 3) Funding for NPS and Tribal Programmatic Agreement proposals submitted to the AMWG and transmitted to the GCMRC. At the request of PA parties, that are members of the AMWG, PA activities may be included in the FY 99 program. At the present time, these activities have not been specified for FY 99, however, it is anticipated that some of these activities will be proposed and incorporated into the Plan.

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4) Tribal proposals submitted to the GCMRC. 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 and they span and integrate GCMRC program areas. Tribal programs also provide important technical information about a group's past and present resources. Although specific tribal proposals have not been developed for FY99 as yet, the GCMRC encourages proposals in areas related to technology, student education, and monitoring and research that utilize Native American perspectives. Activities proposed in this area relate to stakeholder objectives that incorporate Native American perspectives, concerns and participation in resource assessments and management.

5) Continuation of the development of tribal technology/procedures for dissemination and access to GCMRC data. The GCMRC continues to work with stakeholders to develop and implement appropriate technologies for data dissemination. On-going working groups of stakeholders continue to assist the GCMRC in defining protocols for scientific and/or sensitive data. Technological capabilities to receive and/or house appropriate data will be investigated in FY 99 as a continuation of efforts undertaken in FY 98. One specific concern in this area relates to the technological ability of tribal stakeholders to access data in a timely, cost efficient manner.

New Activities For FY 99

1) Provision for research projects resulting from conceptual modeling project.

Conceptual modeling will begin during FY 98 and continue into FY 99. Depending on the information generated during the modeling process, research projects may be proposed for the Working Draft - 2.0 (10/24/97): For Review, Do Not Cite, Photocopy, or Distribute

cultural resource program. Although it is not possible to define these activities at this time, implementation of projects will be contingent upon prioritization, funding, and compatibility with stakeholder objectives. It is anticipated that these activities, if proposed, would occur in the final portion of FY 99, based on the modeling effort schedule.

THE BIOLOGICAL RESOURCES PROGRAM

Introduction

The synthesis, inventory, monitoring and research activities proposed for biological resources is intended to develop and maintain critical data streams relating to the structure and function of the Colorado River ecosystem. The effort will improve 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 the prediction of ecosystem effects. It is key that relationships between the biotic and abiotic components of the ecosystem be addressed, for without an understanding of these relationships, no predictive capability exists to evaluate the "...effects of the Secretary's actions..." on critical biological resources and the Colorado River ecosystem in general.

Responding to Stakeholder Objectives and Information Needs

As described in Chapter 2, consultation with stakeholders led to the development of a set of stakeholder objectives and corresponding stakeholder information needs. Subsequent meetings with scientists stepped the stakeholder information needs down into a knowledge base (i.e., scientists' knowledge and scientists' need to know), and potential elements of a monitoring

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and research program (i.e., scientists' monitoring statements and scientists' research questions).

The FY 99 biological resources program is based on (1) the GCMRC 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, and (3) the FY 98 Biological Resources Program.

The FY 98 and FY 99 Biological Resources Program

The FY 98 Biological Resources Program awarded its FY 98 monitoring and research studies through a competitive request for proposals process, as discussed in the Strategic Plan.

The FY 98 and FY 99 program consists of synthesis, monitoring and research activities. These

include aspects associated with the aquatic food base, humpback chub and other native fish, trout and other non-native fish; riparian vegetation, selected threatened and endangered species (i.e., Kanab Ambersnail) and general avifauna and the southwestern willow flycatcher.

Aquatic Food Base

The aquatic food base in the Colorado River ecosystem is composed primarily of Cladophora and other macrophytes, chironomids, Gammarus, gastropods, oligochaetes, simuliids, lumbricids and other macroinvertebrates, diatoms and detritus. These organisms are a primary component of survival for many wildlife species, especially fish. Fluctuations in the amount and types of aquatic food available can trigger changes in the population dynamics of native and non-native fish species. Fluxes in the aquatic food base may be associated with water temperature, turbidity, and flow fluctuations, to name a few variables. Understanding the relationships between dam operations and productivity of the aquatic food base is an important link towards understanding the effects of dam operations on higher trophic levels, especially the

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population dynamics of native and non-native fish species in the Colorado River ecosystem.

Recognizing the primary role played by the aquatic food base in the Colorado River ecosystem, the stakeholders and managers have determined that an objective for the aquatic food base in the Colorado River ecosystem should be to maintain and enhance this resource. In addition, dam operations should be conducted in such a manner that areas should be inundated continuously for Cladophora and aquatic invertebrates at or above 8,000 cfs discharge.

Understanding the processes that enable the maintenance and/or enhancement of the aquatic food base requires monitoring, research and synthesis activities. In addition, management objectives for the Colorado River ecosystem are to manage the resources in an ecosystem approach. With

these overall objectives in mind, monitoring and research efforts will increasingly focus on developing and exploring interdisciplinary and trophic level linkages as they relate to the aquatic food base and dam operations.

Understanding the processes that enable the maintenance and/or enhancement of the aquatic food base requires synthesis and monitoring and research activities. Synthesis activities will utilize existing information, both published and unpublished, to address questions concerning trophic dynamics. Efforts will be made to understand the likely response of the aquatic food base to alternative dam operations. Special emphasis will be placed on the relationship of the aquatic food base to native and non-native fish.

Presently, FY 98 efforts associated with aquatic food base monitoring and research involve monitoring community structure, density, distribution and composition along the mainstem and tributaries, and making linkages and distinctions between dam operations, Lake Powell input, tributary influences, and inherent variation in the aquatic food base. Associated Working Draft - 2.0 (10/24/97): For Review, Do Not Cite, Photocopy, or Distribute

with these monitoring efforts are the identification of parameters (i.e., nutrient levels, water quality, community structure) that maintain and enhance the aquatic food base. Efforts are also being made to link the aquatic food base to fish diet and habitat preferences. Data collection associated with field monitoring and research will proceed in parallel with synthesis efforts in order to forge trophic level linkages and will continue in to FY 99.

Information needs for FY 99 that go toward meeting management objectives will address questions pertaining to: (1) lower level interactions such as nutrient cycling (phosphorous availability) in the mainstem and primary productivity, (2) the microbial contributions to organic processing in this system, and (3) recruitment mechanisms associated with *Cladophora* (i.e., zoospore vs fragmentation), a keystone species in the aquatic food base. The role temperature has on each of these subjects should be considered as management begins to consider alternative operating plans such as seasonally adjusted steady flows and selective withdrawal scenarios.

Monitoring programs associated with the aquatic food base will run concurrent with synthesis activities. Protocols associated with monitoring need to be defined for each parameter considered for monitoring. Data for both biotic and abiotic variables (e.g., species composition, productivity, temperature, pH) that are thought to be critical for food base monitoring will be collected and analyzed.

Fish

Native fish are an important part of the Colorado River ecosystem because of their intrinsic value and trophic role, and they are of concern because some are listed as threatened or endangered species. Changes in the structure or function of the Colorado River ecosystem resulting from dam operations could have either harmful or beneficial effects on native fish

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populations.

The Colorado River ecosystem and its tributaries currently support four species of native fish, namely humpback chub (*Gila cypha*), flannelmouth sucker (*Catostomus latipinnis*), bluehead sucker (*Catostomus discobolus*), and speckled dace (*Rhinichthys osculus*). These native fish populations are variously dispersed throughout the Colorado River ecosystem, and all four species seem to be experiencing difficulties with reproductive success and recruitment. Mainstem water temperatures continue to be below optimum ranges (16-22°C) for reproduction and survival of eggs and larvae of these warmwater species.

An overall goal GCMRC monitoring and research activities is to determine the effects of dam operations on native fish. Understanding the processes that enable the maintenance and/or enhancement of native fish, especially the endangered humpback chub, requires monitoring and research activities. Native fish populations depend on an appropriate habitat and an adequate food base for their continued survival. Both of these factors may change in response to dam operations. Changes in reproduction, recruitment, and growth in response to dam operations can also affect native fish population demographics. Data for both biotic and abiotic variables (e.g., species composition, productivity, temperature, turbidity, pH) that are determined to be critical for humpback chub monitoring will be collected and analyzed. Priority is being given to endangered fish monitoring and research activities.

For native fish populations to remain viable, successful recruitment must occur. Low temperature hypolimnetic releases from Glen Canyon Dam are thought to have negative effects on the population dynamics and recruitment of native fishes. The four major factors thought to influence successful fish recruitment are: hydrology and transport; food production and

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availability; larval fish abundance; and predation. 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 and predatory interactions can potentially increase risks at young life stages, resulting in increased mortality and reduced recruitment.

Native fish found in the Colorado River ecosystem represent a unique assemblage of species ecologically adapted to a fluvial riverine environment characterized by seasonally variable flows, temperature, and sediment loads. With the completion of Glen Canyon Dam abrupt environmental changes (e.g., altered sediment transport, flow patterns and thermal characteristics) were imposed on this system. This resulted in abiotic and biotic changes to habitat, channel morphology, predation pressures, parasitism and diseases, food base and trophic linkages. These changes are reflected in the present relative abundance, reproductive success, survivorship, distribution, and movement of native fish.

Humpback Chub. In the Colorado River ecosystem, the endangered humpback chub is found at eight mainstem aggregations comprising 3,500 - 4,000 adults. Another aggregation in the Little Colorado River (LCR) comprise approximately 4,500 adults. Spawning (March-May) and successful recruitment is documented only for the LCR aggregation. Adults in other mainstem aggregations peak in reproductive condition in May-June, but mainstem spawning remains undocumented.^{6/} Recent synthesis suggests that the LCR aggregation, may be experiencing a decline in numbers of adults, although causes for this decline are unknown. An

^{6/} About 100 post-larval chub were observed and captured in a warm spring in 1993 at RM 30, where an aggregation of about 50 adults resides.

extensive database on PIT tagged humpback chub in the vicinity of the LCR has been developed through GCES sponsored projects. The consolidation of this PIT tag data base will be an FY 99 activity.

Different age-classes of humpback chub utilize dissimilar habitats, adults typically use large recirculating eddies, whereas young of year are thought to use nearshore complex habitat and backwaters. The relative abundance of the aquatic food base (i.e., standing mass of benthic invertebrates and periphyton) has been suggested as a potential limiting factor for native fish populations. The diversity and abundance of the aquatic food base can be directly related to dam operations.

Recent dam operations, under interim flows (August 1991 - present) have reduced stage fluctuations, stabilized shoreline habitats and backwaters, and increased macroinvertebrate food production for fish. Benefits to humpback chub have not been documented and will require regular monitoring of adults and juveniles. Also, the Asian tapeworm (Bothriocephalus acheilognathi) has been reported in humpback chub from the Colorado River ecosystem since 1990, but the effect on the species remains unknown.

Flannemouth Sucker. Flannemouth sucker are dispersed throughout the Colorado River ecosystem, with highest numbers recorded during spring spawning aggregations at tributary mouths, such as the Paria and Little Colorado Rivers, Bright Angel Creek, Shinumo Creek, Kanab Creek, Havasu Creek, Spencer Creek, and Surprise Creek. Although reproductive success is reported from numerous tributaries, juvenile suckers in the mainstem are uncommon, and length-frequency distributions indicate low recruitment to adult-sized fish. It has been hypothesized that larval flannemouth suckers are succumbing to thermal shock as they drift from

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warm tributaries to the colder mainstem. Recently, about 500 adult flannemouth suckers have been observed annually at RM 4 (above Lees Ferry) in spawning aggregations; despite cold water temperatures of about 10°C. These fish are presumed to be producing viable eggs, but the fate of the larvae is unknown.

FY 98 - 99 Project Objectives:

- 1) Establish linkages among dam operations and the resulting flow regimes and related abiotic (e.g., temperature, turbidity) and biotic (e.g., food base) parameters on spawning, reproductive success, larval transport, recruitment, habitat use, food availability and diet.
- 2) Monitoring to annually evaluate the status and trends of native fish populations, especially humpback chub and flannemouth sucker, in the Colorado River ecosystem. Monitoring activities should consider parameters such as: abundance, age structure, growth rates, condition, year class strength, distribution (i.e., spatial patterns of abundance) reproductive success and overall recruitment in response to dam operations. Monitoring activities should utilize PIT tags to augment existing databases, as appropriate.
- 3) Competitive and predator-prey interactions with non-native fish and the influence of dam operations, including potentially increased water temperatures, on these competitive and predatory interactions, if any.
- 4) Assess the condition of adult humpback chub and other native fish. Utilize results of aquatic food base studies, as appropriate. Evaluate the effects of existing and potential parasites, diseases, and other factors on the condition of mature humpback chub and other native fish.

- 5) Examine the importance of the LCR, backwaters, and nearshore habitats to differing parts of the life cycles of native fish.
- 6) Temperature studies: Determine optimal, upper and lower water temperature limits on reproductive success, and growth and survival of larval, juvenile, and adult fish. Evaluate effects of increased water temperatures on various factors which may affect population survival (e.g., parasite distribution and abundance, swimming performance).

Trout and other non-native fish. Trout were first introduced into tributaries of the Colorado River in Glen and Grand Canyons in the 1920s. With the completion of GCD in 1963, and the stocking of rainbow trout (*Onchorynchus mykiss*) below the dam in 1964, rainbow trout have become an important recreational resource in the tailwaters below GCD. The Glen Canyon/Lees Ferry trout fishery (25 km reach) has developed in response to the constantly cold and clear hypolimnetic releases have promoted the high primary productivity of algae and aquatic macrophytes, and its secondary production of aquatic invertebrates. The presence of coarse substrates for natural spawning and reproduction, and the regular stocking and management of this recreational trout fishery has resulted in this fishery being of socio/economic importance and concern.

Currently, 70 percent of the rainbow trout in the tailwater are naturally produced, while 10 years ago, most fish were of hatchery origin. Although large trout in excess of 5 pounds were numerous before 1983, these large fish are now rare. Nevertheless, high numbers of well-conditioned fish are being sustained by a high biomass of amphipods (*Gammarus lacustris*), midges (Chironomidae), and blackflies (Simuliidae).

Understanding the processes that enable the maintenance and/or enhancement of the
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rainbow trout fishery requires monitoring and research activities. Special emphasis will be placed on the relationship of the rainbow trout fishery to the aquatic food base. Data for both biotic and abiotic variables (e.g., species composition, productivity, temperature, pH, turbidity) that are determined to be critical for rainbow trout monitoring should be collected and analyzed.

Numerous research studies have evaluated spawning, age class structure, reproductive success, survival and recruitment, in addition to movement and demographic patterns, adult, juvenile and larval rearing habitat, and condition/health factors. GCD operations and the resulting flows have been shown to affect many population characteristics, as well as energetic demands on fish, availability and use of food base, and to increase risks associated with stranding, dispersal, displacement, or loss to predation.

Sound management of the rainbow trout fishery to meet stakeholder objectives requires managers to be able to accurately predict the aquatic resource's response to ecological changes that are a (direct or indirect) result of alternative dam operations. Since, the Glen Canyon/Lees Ferry fishery has become an important social and economic resource to diverse publics; stakeholders have stated a management goal that natural reproduction comprise at least 50% of the total reproductive effort; that sufficient suitable spawning habitat be maintained to reach this objective; and that rainbow trout be maintained at a population level of approximately 100,000 fish.

Project Objectives:

- 1) Synthesize existing information (published and unpublished data) on the Glen Canyon/Lees Ferry trout fishery and determine the fishery's likely response (growth, reproduction, recruitment population structure, size and distribution) to dam operations.

- 2) Monitoring activities for determining population size, structure, growth, distribution, reproductive success and overall recruitment in response to dam operations.
 - 3) Develop methods for estimating the proportion of natural reproductive success in combination with stocking quantities and rates to determine desired levels of recruitment balanced against the carrying capacity for a range of dam operations.
 - 4) Develop evaluation criteria for, and measure and assess the health and condition of the rainbow trout population.
 - 5) Evaluate changing health and condition factors in relation to changes in the aquatic foodbase and nutrient levels as determined in the aquatic food base RFP.
-
- 6) Conduct symposia that emphasize science understanding of tailwater, cold water fisheries in the western United States.

Riparian Vegetation

Riparian vegetation is recognized as an important resource serving many roles in the Colorado River ecosystem. The vegetation stabilizes the river's banks, provides habitat for fish and wildlife, and has aesthetic and recreational value. The riparian vegetation communities within the Colorado River ecosystem were changed drastically by the construction and subsequent operations of GCD. Today the riparian vegetation is composed of three distinctive communities: (1) the upper riparian zone, (2) the lower riparian zone, and (3) the nearshore wetland community. The preservation or restoration of riparian communities affected by dam operations is an objective identified by the stakeholders.

FY 99 monitoring program for riparian vegetation represents a continuation of FY 98 funded projects. These combined year funding activities will focus on (1) the community response (i.e., Working Draft - 2.0 (10/24/97): For Review, Do Not Cite, Photocopy, or Distribute

community structure, diversity, density, distribution, and extent of riparian and marsh vegetation) to dam releases along the Colorado River ecosystem, (2) compare 1998 riparian and marsh vegetation data with historical monitoring data to evaluate change over time (i.e., the spread and contraction of communities, change in species composition, etc.), in relation to dam operations, (3) monitor non-native/invasive vegetation with respect to recruitment, spread and survivorship, and (4) examine habitat integrity and composition as it is related to threatened and endangered species (e.g., Southwestern Willow Flycatcher, Kanab Ambersnail), and linkages between vegetation, aquatic food base, fish habitat, and sediment-related resources.

These objectives involve collecting current data and synthesizing previous years data associated with riparian and marsh community productivity, composition, and distribution. Integrating and developing linkages between terrestrial and aquatic biota are efforts that are currently funded for FY 98 will be continued in FY 99. These research and monitoring efforts are directed towards understanding the effects of the Preferred Alternative on riparian vegetation.

In order to further the linkages and develop interdisciplinary efforts between vegetation and the river corridor, research efforts should be directed toward evaluating the current monitoring sites and determining if the present sites are sufficient to characterize the status riparian vegetation (i.e., do more sites that coincide with fish, aquatic food base and terrestrial vertebrate study need to be added?). Additionally, the interactions between decomposition, nutrient availability, and nutrient cycling between terrestrial and aquatic interfaces need to begin to be examined. Efforts such as these will strengthen ties between aquatic and terrestrial primary productivity.

Native Terrestrial Wildlife

Adaptive management of regulated river ecosystems requires inclusion of regularly and consistently collected monitoring data on indicator organisms, as well as special status species. In the Colorado River ecosystem, endangered Kanab Ambersnail studies have been conducted since 1994, and dam operations have been demonstrated to strongly affect the snail population at Vaseys Paradise. Avifaunal studies have been conducted since the early 1970's. Avifauna are trophically significant secondary consumers, integrating habitat structure, food resource production, and predator populations. Reduced flood frequency and sediment transport in this system has increased development of the aquatic foodbase, trout populations, and profuse stands of wetland and riparian vegetation. As a result, threatened or endangered Kanab Ambersnail (KAS), bald eagle, peregrine falcon, and southwestern willow flycatcher (SWWF) and other regionally significant Neotropical migrant and other breeding bird species populations may have increased in the post-dam river corridor. These species of special concern have become management concerns for some stakeholders in this system.

Stakeholders in the Colorado River influenced by Glen Canyon Dam identified several objectives regarding management of native terrestrial wildlife in 1997. These objectives pertain to: 1) protection, enhancement and survival of special status species and their habitat; 2) maintaining native fauna for the benefit of endangered species; 3) maintain natural age-classes across most of the natural range, emphasizing recruitment; 4) evaluate food chain integrity for endangered species; 5) mitigate impacts on opportunistic populations of listed species, to the extent that natural ecosystem components are not disrupted; 6) maintain present range of the Vaseys Paradise KAS population; and 7) maintain a diversity of wildlife (especially native)

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species.

These objectives focused monitoring activities in two areas in FY 98, including the endangered Vaseys Paradise KAS population, and aquatic and riparian avifauna throughout the river corridor, particularly listed species. The following discussion outlines the concerns and monitoring under consideration for FY 99.

Avifauna. Consistent with stakeholder objectives and information needs and building upon ongoing studies, limited and focused avifauna monitoring and research activities will be considered as part of the FY 99 program. These will focus on the southwestern willow flycatcher and general riparian avifauna.

Endangered bird species constitute a special research and monitoring focus downstream from Glen Canyon Dam, as a result of the Endangered Species Act and federal land management missions. The Colorado River ecosystem supports several avian species federally listed as threatened or endangered, including bald eagles, breeding peregrine falcons and Southwestern Willow Flycatchers. The Southwestern Willow Flycatcher (SWWF) has been the focus of intensive monitoring in upper Grand Canyon since 1983.

Nearly 320 species of birds have been observed downstream from GCD in the Colorado River ecosystem since the 1920's. The avian assemblage within the Colorado River ecosystem includes more than 25 obligate and facultative riparian species, and at least 59 species of waterbirds. Little is known of the pre-dam (pre-1963) avian assemblage within the Colorado River ecosystem. However, numerous post-dam riparian Neotropical migrant species nest in and use the lush native and non-native vegetation along the river, and habitat patches vary considerably in size and condition.

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Management of bird-related ecosystem variables requires consistent monitoring to determine if changes in bird populations and distribution are related to natural among-year variation, dam-related factors or other factors.

Endangered Southwestern Willow Flycatcher

In contrast to other willow flycatcher subspecies, the breeding habitat of SWWF appears to be more closely related to riparian environments. In the Colorado River ecosystem, SWWF population status, breeding season distribution, nesting habitat, and nest characteristics are documented in published papers and monitoring reports from 1976 to 1995. SWWF distribution, habitat use and diet data were summarized in the Bureau of Reclamation (Bureau) Biological Assessment. Collectively, these data indicate that SWWF in the Colorado River ecosystem nest in relatively wide stands of riparian vegetation along the wide reaches of the Colorado River, particularly in dense groves of tamarisk, occasionally with a scattered overstory of taller trees, and usually with nearby exposed sand bars or fluvial marshes. SWWF nests are typically 3.5 to 7 m above the ground and several meters below the canopy and nest sites have a high percentage of canopy from 0 to 4 m above the ground. SWWF usually nest over moist or wet soil, and all SWWF nests recorded during the high flow years of 1984-1986 occurred over water and nest trees were at the water's edge or stood in shallow water. However, all nests detected in the Colorado River ecosystem in the 1990's have been situated in tamarisk stands over dry ground on elevated terraces and at least several meters away from the river's edge.

Four areas have been consistently occupied by territorial SWWF in Colorado River ecosystem. These areas all lie in wide, low gradient reaches, with abundant riparian zone vegetation dominated by tamarisk and coyote willow (*Salix exigua*) on upper bar surfaces, and

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with associated fluvial marshes in reattachment bar settings. Fluvial marsh vegetation at those sites consisted of common reed (*Phragmites australis*), horsetail (*Equisetum* spp.) and other wetland species.

SWWF failed to breed successfully in upper Grand Canyon in 1997 as a result of brown-headed cowbird (*Molothrus ater*) brood parasitism. One SWWF nest produced two fledglings on upper Lake Mead on the Hualapai Indian Reservation in 1997, and at least one nest was successful on upper Lake Mead in 1997.

Project Objectives:

- 1) Collect and interpret data on the current and historic distribution and population densities of wintering and spring and summer avifauna, and their relation to habitat patches, within the Colorado River ecosystem (River Miles -15 to 278).
- 2) Relate habitat structure/composition of survey areas to dam discharges and river flows during the study period, to breeding bird distribution and density.
- 3) Collect detailed monitoring data of SWWF habitat condition, habitat use and nesting success, and nesting fidelity, including the dynamic nature of its colonizing behavior through the study period and in comparison with previous data and other SWWF monitoring programs.
- 4) Relate current SWWF distribution to past data to provide a comprehensive analysis of population change through time.
- 5) Evaluate the effect of brown-headed cowbird (*Molothrus ater*) on the abundance and/or distribution of SWWF and what management alternatives should be considered to counteract this effect, if it is negative, in a fashion that does not interfere with SWWF territory occupation or nesting success.

Kanab Ambersnail. The stakeholders have recognized in their objectives the importance of native and other special status plant and animal species. Specifically, they have called attention to the Humpback chub, Flannelmouth sucker, Kanab ambersnail, and the Southwestern willow flycatcher. They have called for information which will help protect, restore, or enhance the survival of special status species. In the case of the Kanab ambersnail, specific activities will be focused on addressing the requirements of the Biological Opinion, and Recovery Plan as appropriate. This includes a focus on appropriate age-class distributions, food availability, and habitat needed to ensure the sustainability of these populations.

The KAS is a federally endangered snail that is presently known to exist in the United States from the Three Lakes location near Kanab, Utah, and at Vaseys Paradise in Marble Canyon, Arizona. The remaining Utah population occurs on privately owned land at Three Lakes, a wetland habitat consisting of several, small spring-fed ponds at an elevation of 1900 m. Vaseys Paradise is a cool-water, dilute dolomitic spring that issues from the Mississippian Redwall Limestone in Grand Canyon National Park, 31.5 mi (51 km) downstream from Lees Ferry, Arizona. The spring issues at 3,200 ft (925 m) elevation and flows ca. 100 m to the Colorado River. Aspect protects the spring from hot, direct mid-afternoon sunlight during summer and may allow it to warm quickly after winter freezes. The site is dominated by diverse wetland vegetation, including: non-native water-cress (*Nasturtium officinale*), and by native crimson monkeyflower (*Mimulus cardinalis*), sedge (*Carex aquatalis*), horsetail (*Equisetum* spp.), helleborine orchid (*Epipactis gigantea*), and maiden-hair fern (*Adiantum capillis-veneris*). The site has a heavy overstory of poison ivy (*Toxicodendron rydbergii*).

Project Objectives:

- 1) Relate food availability, habitat patch composition, area of cover, and condition at Vaseys Paradise to the historic and recent condition of those patches, and population requirements for sustainability.
 - 2) Determine and statistically compare the historic (1995-98) and current population distribution, abundance, age-class/size distribution, population density, and condition (i.e., occurrence of Kanab Ambersnail trematode parasite) of *Oxyloma haydeni kanabensis* at Vaseys Paradise as it relates to natural variation and to the local stage-discharge relationship.
 - 3) Evaluate the abundance of *Peromyscus predator* at Vaseys Paradise.
-

Monitoring activities must be undertaken with limited impact to this fragile spring habitat, where researchers also will encounter dense stands of poison ivy and steep terrain. This project will require researchers to readily and reliably distinguish between *Oxyloma haydenikanabensis* and two morphologically similar *Catinella* species. In addition, data collection methods and analyses should be sufficiently robust to predict population effects of alternative dam operations and should distinguish natural population variation from dam impacts. Consideration of the KAWG contingency plan is recommended, and the monitoring should include consideration of 1995, 1996 and 1997 Biological Opinion issues.

Biological Opinion

The stakeholders also identified, as important, work related to the reasonable and prudent alternative and Biological Opinion. Specific activities related to the Biological Opinion that are being proposed for FY 99 include (1) design of experimental seasonally adjusted steady flows using the information resulting from the conceptual modeling activities, the fish data integration Working Draft - 2.0 (10/24/97): For Review, Do Not Cite, Photocopy, or Distribute

report and GCES Phase II biological data integration report being completed in FY 98, (2) review of the feasibility of, and the development of a plan for the establishment of a second population of humpback chub, (3) a study focused on quantifying and understanding the causes and significance of overwintering mortality of humpback chub, and (4) Kanab ambersnail genetics and taxonomy research to resolve issues regarding the status of the species.

Other studies

Given the limited amount of funds available for the FY 99 program and the uncertainty surrounding the budget until the FY 98 contracts are issued, limited additional work is being proposed. Based on the availability of funds, the following work will be considered: (1) review and development of monitoring and research protocols for all biological resources, (2) state-of-the-science assessments, and (3) limited scoping studies to better define appropriate monitoring and research activities.

The Contribution of the FY 99 Program to the Strategic Plan

The FY 99 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 significant contributions to understanding the key components and processes that structure the Colorado River ecosystem. 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 the development of a conceptual systems model, and associated synthesis and research activities, will result in the design of a sound long-term monitoring and research program that can be initiated in 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 storage and delivery. Further, due to the biological and geologic distinctiveness of the Colorado River corridor, the Grand Canyon National Park has acquired national and international recognition, and all of the resources in the canyon are considered to be significant to the public.

The FY96 and FY97 socio-economic resources program was reduced from the FY94 and FY95 program, where studies were undertaken to evaluate 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 riparian plant beach invasions and beach habitat building in Grand Canyon National Park.
- Beach campsite area changes resulting from the beach habitat building flow.

Both of these projects relate to changes in recreation benefits resulting from a modified flow regimes. Both projects were completed FY97/FY98, and will be terminated. However, after a synthesis effort in FY 98, the socio-economic program including campsite beach studies will be redesigned for FY 99.

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.

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

The FY 98 and FY 99 Programs emphasize several areas through monitoring and research projects as well as cooperative and volunteer programs as follows:

- Use past monitoring, research and cooperative studies to develop synthesis of campsite beach changes through time associated with differing flow regimes, i.e.; camping area, vegetation changes, etc.
- Research user preferences and attitudes assessing wilderness experience relative to differing flow regimes.
- Monitor trout anglers use and satisfaction through creel census and cooperative monitoring program with fishing guides and Trout Unlimited.
- Evaluate effectiveness of new monitoring protocols for long-term assessments of camping beach change from differing flow regimes.
- Monitor beach changes and user preferences through cooperative programs with boating guides.

INFORMATION TECHNOLOGIES

The function of the information technology program is to satisfy the information needs of stakeholders, scientists, and the public relative to the GCMRC study area. Extensive data and information currently exists in the GCMRC database relating to resource conditions and their relationship to other resources. This information represents a valuable resource to researchers, manager, and interested stakeholders, but some 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 systems under study, justify an aggressive program of information acquisition, management, and evaluation.

The information technology program embraces the principles and objectives of the National Information Infrastructure (NII), the National Biological Information Infrastructure (NBII), and the National Spatial Data Infrastructure (NSDI). Guidelines and protocols promulgated by these infrastructures will be incorporated into the overall database design and delivery systems whenever possible. Implicit in the plan is support of the objective to increase access, sharing, and application of data among public and private cooperators and partners. The program recognizes that guidelines and protocols have not been established for all aspects of biological and spatial data warehousing. When lacking, the plan allows establishment of its own guidelines and protocols that will adhere as closely as possible to the intent and spirit of the infrastructures.

The information technology program is committed to making public data freely available to stakeholders, researchers, and the public while at the same time protecting sensitive and confidential data provided by private entities for the purpose of evaluating the Colorado River resources. To ensure critical access to developed data, scientists will be expected to provide their

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data to GCMRC after a reasonable period of exclusive use, currently being addressed by the TWG working group on data protocols. However, in some cases, such as archaeological-site data the Indian Tribes define as sensitive, or information on localized endangered species, a level of confidentiality will be necessary.

Objective of the Information Technology Program

The objective of the information technology program is to satisfy the information needs of stakeholders, scientists, and the public relative to the GCMRC study area.

Dependencies of a successful information technology program

The information technology program at the GCMRC is dependent upon several key components for it to successfully execute its objective:

1. An information system infrastructure capable of a state-of-the-art centralized data storage and delivery systems incorporating a high degree of information technology integration.
2. Strict data standards and protocols which assures the validity of data contained in the information system and facilitates the integration of data collected by different researchers at different times.
3. Cooperation among contributing Tribes, institutions, and agencies concerning timely transmittal of data relating to the GCMRC study area.

Building an Information Technology Program

Building an information technology program at the GCMRC requires the three following steps that result primarily from the dependencies of a successful information technology program:

1. Build the infrastructure
2. Develop the data standards and protocols
3. Populate the database
4. Develop user interfaces

Each of these steps are; however, monumental in themselves when considering that they need to be built from the ground up incorporating legacy data collected over a 10 year period.

Build the infrastructure

The infrastructure of the information system consists primarily of the computer hardware and software needed to warehouse, access, report, and analyze the data. This requires careful selection of hardware and software to enable a tightly integrated system requiring minimal administration. The information infrastructure at the GCMRC depends upon the successful exploitation and integration of several key information technologies:

1. Database management system
2. Geographic information system
3. Computer hardware, software, and networking
4. World Wide Web.

Aside from application of information technology to the warehousing of data, but no less important, is the ability of the information users to easily access, query, and obtain data from the

information system. A process needs to be established by which the information user knows how to find and obtain the information he/she is looking for. Therefore, an additional key area of concern is adequate documentation and training in the use of the information system. Successful application of information technology, a well defined process for obtaining data, and thorough documentation and training culminates in an information system that is accessible and easy to use.

Although the objective of the information technology program is to provide a centralized DBMS, it is our policy not to duplicate data warehousing already provided by other entities. In these circumstances it would be preferable to interrogate the remote database through an ODBC link when possible. However, the GCMRC will act as a clearinghouse of data owned by other entities in the case where remote database interrogation is not possible. In both of these cases, a common interface can be developed which will facilitate dissemination of data to interested parties.

Warehoused data will conform to the National Information Infrastructure (NII), the National Biological Information Infrastructure (NBII), and the National Spatial Data Infrastructure (NSDI). Guidelines and protocols promulgated by these infrastructures will be incorporated into the overall database design and delivery systems whenever possible.

The infrastructure will provide for database connectivity to compatible data analysis packages such as graphics, statistics, and GIS software, and World Wide Web interfaces.

Develop the data standards and protocols

Development of data standards and protocols ensures that data contained in the information system is valid data and that the data can be integrated with data collected by different

researchers at different times. Data standards define field descriptors within the database such as definitions, formats, units, significant figures, decimal places, etc. Protocols define standard operating procedures for data collection, entry, and verification, which include quality control and quality assurance procedures, that guarantee the integrity of the warehoused data.

Populating the database

Data and document holdings of interest to GCMRC will be identified by conducting an assessment of data and document holdings of interest to the GCMRC. Once holdings have been identified, they will be classified as to type and format. Database structures will be developed and the database populated. Since electronic data provides the greatest degree of dissemination with the least impact on GCMRC resources, holdings not currently in digital format but which can be converted to digital format, will be converted to digital format. This will be accomplished using digitizers, scanners, optical character recognition, and other automated data input and software processing technologies.

Developing user interfaces

Indexing and retrieval of data, once in the database, will be accomplished by using existing DBMS, ftp, gopher, and WWW technology utilizing browser interfaces. The browser interface has the advantage of providing a consistent interface to the various technologies used by the infrastructure that will be intuitive to information users familiar with the Internet.

Outreach will be provided to stakeholders, partners, and the public in the form of training in the retrieval and utilization of electronic and paper data. Specifically, areas of training will include data and document retrieval interfaces to WWW enabled databases and GIS. Outreach will also be provide for public announcements, notifications, press releases, etc. and topics of

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interest via WWW pages and newsletters. The GCMRC will also aid stakeholders in acquiring and using technology needed to fully exploit information systems developed by the GCMRC.

Ancillary Information Technology Program Services

System administration of computers and networks

Computer hardware and operating systems at the GCMRC will largely be a combination of state-of-the-art Intel processors running Windows NT. Each workstation will have a core suite of software applications available that will include mainstream off-the-shelf integrated office products such as a word processor, spreadsheet, graphics, database, browser, etc. Additional software needed for specialized scientific data processing will also be available. To the extent possible, hardware and software will be standardized throughout the GCMRC. The information technology program anticipates standardization will facilitate inter-office exchange of information and reduce the administrative effort of hardware and software support to a level sustainable in-house.

A primary objective of the plan is to improve overall system performance, reliability and maintenance. The information technology program believes that this can best be achieved by having competent individuals in-house trained in the administration, maintenance, and troubleshooting of the computer system. However, computer administration comes at a high cost in terms of manpower and expertise. A brief analysis of the current GCMRC computer environment has identified that most problems occur at the application - operating system - local area network layer and that few problems occur at the wide area network, or Internet, layer.

Internet connectivity infrastructure can be very expensive. Therefore, it makes fiscal sense that

Internet connectivity and associated services such as DNS, mail, and news will continue to be administered by entities outside the GCMRC. Most notably the U.S. Geological Survey in the case of the Gemini office and U.S. Bureau of Reclamation in the case of the Bank of America office.

Geographic Information System (GIS) services and GIS library

Geographic Information System (GIS) services will be provided by the information technology program to stakeholders, researchers, and GCMRC staff. In addition to providing GIS services, the program will operate a clearinghouse of GIS coverages and metadata relevant to the GCMRC study area and populated by GCMRC studies and contributed data. A GIS specialist has been identified and is being trained for this assignment.

The GIS program is committed to the principles and objectives of the NII and NSDI. As such, guidelines and protocols promulgated by these infrastructures will be incorporated into the overall program design and development with specific consideration given to GIS metadata standards.

Library services

A library containing written reference material, aerial photos, maps, videography, etc. will be maintained by the Information Technology group. The library will be a formal undertaking appropriately staffed to facilitate the archiving and dissemination of information in hard copy form to interested entities in a logical and safe manner. A bibliography of library holdings will be made available in searchable form on the WWW.

World Wide Web Publishing Services

The information technology program will operate a WWW server dedicated to the
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dissemination of information about its program. Pages will be developed specific to the needs of the Technical Work Group and the Adaptive Management Work Group to facilitate the dissemination of reports, minutes, and other documents in an efficient and timely manner.

CHAPTER 4
PROGRAM ADMINISTRATION
ORGANIZATION STRUCTURE

The GCMRC is restructuring to accommodate the challenges of both the Strategic Plan and the FY1999 Annual Plan. Three program managers (physical, biological, and cultural) will manage the individual resource areas and together with the chief, continue to create greater 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.

Logistics Coordinator. The GCMRC has decided to conduct all logistics for its programs internally in FY 98 and FY 99, with direct coordination with appropriate NPS offices. This effort is projected to reduce logistics costs by 30% from FY 97 to FY 99. All river trip logistics and permitting, air photography, rescue, etc, will be programmed by the logistics coordinator in cooperation with the NPS. An annual logistics plan will be drafted, incorporating joint GCMRC/NPS workshops for principal investigators, and published guidelines,for permitting and reporting.

Review Coordinator. All competed proposals, PI reports, GCMRC reports, cooperative programs, etc. will be subjected to specific independent review protocols of the GCMRC.

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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 review coordinator. The review coordinator can be contacted by PIs and/or their organizations, managers and other stakeholders to access critical documents detailing GCMRC programs.

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

A Programmatic Agreement Task Group Is proposed to facilitate articulation between the Cultural Resource Program and the Programmatic Agreement program. The Task Group will consist of the GCMRC Cultural Program Manager, Bureau and NPS managers, and tribal representatives.

A Biological Opinion Task Group will be linked to the Biological Resources Program Managers office. It will assure GCMRC responds, as appropriate, to the monitoring and research needs of the Bureau and USFWS. The Task Group will consist of the GCMRC Biological Resources Program Manager and appropriate representatives of BOR and FWS. All proposed activities will be reviewed by the AMWG.

Coordinators are 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.

GCMRC intends to establish in cooperation with the AMWG, a Science Advisory Board
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(SAB), a group of ten to twelve scientists, selected on the basis of their record of scientific accomplishment, to provide guidance to GCMRC on long-term and annual plans, program structure and information technology. The SAB will meet annually with the AMWG and GCMRC staff to provide council on overall program direction.

PROGRAM SCHEDULE

The schedule for implementation of the FY 99 Annual Plan is as follows:

January 15-16, 1998	AMWG review of FY 99 Annual Plan and recommendations for implementation
January 30, 1998	Announcement of intent to issue RFPs
March 1, 1998	Review of FY 1996/97 program—Accomplishments and new monitoring and science protocols
April 1, 1998	Release of RFPs
April 1, 1998	First Progress Report due on FY 98 program activities
June 26, 1998	Receipt of Proposals for FY 1999 program
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July 1, 1998	Second Progress Report due on FY 98 program activities
August 3, 1998	Panel Review of FY 99 Proposals
August 21, 1998	Notification of Intent to Award FY 99 Contracts
September 1, 1998	Draft Final Report due on FY 98 program activities
October 1, 1998	Award Contracts Final Logistics Plan for FY 99 program
October 15, 1998	Draft FY 2000 Annual Plan and draft FY 99 “State of Colorado Riverine Corridor Resources” for review by TWG/AMWG
November 15, 1998	Approval of NPS permits on FY 1999 monitoring and research program
December 1, 1998	Final Report dues on FY 98 program activities with all contract deliverables
December 15, 1998	Final “State of Colorado Riverine Corridor Resources” report to AMWG
January 1999	AMWG approval of FY 2000 Annual Plan and recommendations for implementation

BUDGET

The FY 99 budget for the Adaptive Management Program was proposed in the 1997 Bureau budget process at approximately \$7.1 million. The GCMRC anticipates the budget level will accommodate the FY 99 Annual Plan, if the plan is approved without significant changes.

Following are the tentative budget allocations toward the FY 99 Adaptive Management Program.

	<u>000 of \$</u>
• Bureau Administration of AMP/TWG	211
• Overhead Services Bureau	229
• Operations, Personnel, Contract Services	2,100
• Information Technologies	488
• Biological Resources Science, including Logistics	1,390
• Physical Resources Science, including Logistics	1,175
• Cultural Resources Science, including Logistics	1,188
• Socioeconomic Resource Science, including Lake Powell program	<u>313</u>
	<u>\$7,094,000</u>